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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

PROJECT DOCUMENT

Project of the Government of the Peoples Republic of China

Title:	**Photovoltaic Power Utilization** (Project 4-5A, Part 1, in the Priority Program of China's Agenda 21)
Budget Estimate:	US$ 2,946,860
Starting Date:	September 1995 (estimate)
Project Site:	Beijing and Hangzhou
Host Country Implementing Agency:	China National Photovoltaic Technology Development Center, Hangzhou
Backstopping Officer:	R. Kaulfersch
Division/Section:	ISED/EM

Brief description:

The project seeks to promote the development of the photovoltaic industry in China by strengthening research and development of silicon solar cell technologies, by lowering the production cost of solar cells and modules, by upgrading the reliability/lifetime of photovoltaic systems, and by initiatives to enlarge the market for these technologies. In particular, the following actions are envisaged:

- Develop, procure and set up a production facility for poly-crystalline silicon wafers of 10x10cm size, aiming at a production cost of < 2$/wafer at an output equivalent to 1 MWp/a of solar cells, in order to privide an indigenous source of poly-silicon wafers for the Chinese PV solar cell/module industry;
- Set up a solar cell pilot production line with 0.5 MWp/a capacity for identifying suitable processes by which current PV solar cell and module manufacturing facilities in China can be upgraded, thus strengthening the know-how base in the field of higher-efficiency (>13%) mono-crystalline silicon solar cell production technologies;
- Establish a facility for the performance testing of balance-of-system components of PV systems in order to assist development of high-quality and reliable/long-life components for low- and medium-power PV systems which are suitable for deployment in remote and/or rural areas;
- Demonstrate the viability, user-satisfying performance and cost-effectiveness of low- and medium-power PV systems operating in remote areas, and test financing instruments to enable private users to acquire PV systems, in order to show how living conditions in remote areas can be improved;
- Set up a high-quality laboratory to perform research and development for crystalline silicon thin films and other novel solar cell technologies with promising cost reduction potential, in order to strengthen the solar cell R&D know-how base in China;
- Establish a qualification and test laboratory for certifying, on national level, the quality and performance of photovoltaic modules;
- Carry out an assessment study about the long-term operating/performance history of PV systems in China, in order to identify technological developments needed to improve PV system technology, and to develop strategies by which these improvements can be effected on national level

A. Context

1 Description of the subsector

Although the electric power industry in China developes rapidly, the growth rate of this industry did not keep pace in past years with that of the national economy. Electricity supply does not match demand, resulting in a significant underutilization (by 20-30%) of industrial capacities, particularly in the South and Southeast regions of the country. In recent years, electricity consumption grew by 7.9%/a to about 500 TWh in 1989 and the share of electricity in energy end-use increased significantly[1]

By 1989, also various measures of energy conservation were adopted and implemented, the amount of primary (fossil) energy allotted for electricity generation was increased, energy consumption per unit output value (energy intensity) decreased and the share of electricity in energy end-use rose from 18.6% to 22.8%

The demand for electricity expected by the year 2000 demands further expansion of electricity generation by about 6%/a. Considering that coal is the main (and abundant) indigenous primary energy source in China, this generation expansion will, in all likelihood, be based on coal. Considering further that the expanding demand for industrial and domestic heat will probably remain based on coal as well, the resulting environmental danger from CO_2 and toxic emissions is obvious. The Government of China is highly concerned about the potential threat to the very base on which economic and social development depend, it seeks to develop and to implement methods and technologies by which this threat can be counteracted and the Country's development in the future sustained

Expansion of energy generation also calls for an extension of the electricity supply lines. Such electricity supply network extension is highly capital intensive as well, also in the low to medium voltage levels. In general, investments in low-voltage electricity supply lines are justified if electricity demand is reasonably large (or is expected to increase in the foreseeable future) and the aggregate demand is not too distant from low- or (at most) medium-voltage power lines. Such situation is not at all characteristic for the large and only thinly populated Western regions of China. For cost reasons it is unlikely that these areas, where demand for electric services is and most probably will remain small, will become extensively connected to the national power grid in the foreseeable future.

Improving living conditions in remote areas of China remains a national task of immediate and high priority nonetheless. Exploiting local solar and wind resources to satisfy at least minimal needs for electric services such as home lighting, communications (radio telephone), entertainment (radio and TV reception) or the supply of small quantities of water supply for human and animal consumption can be a viable, environmentally benign and in many cases cost-effective solution in comparison to conventional alternatives -- provided that an appropriate and reliable technology is available

2 Host Country Strategy

Aiming, inter alia, at applications such as these, the Government of China since the late 1970's initiated a number of measures to encourage the exploitation of renewable sources of energy in general and the development, application and dissemination of appropriate solar technologies in particular. In this regard, a number of R&D projects and manufacturing initiatives in the photovoltaic sector have been incorporated in the last two Five-Year Plans. As a result, several R&D institutions were supported to address issues of basic and applied research in photovoltaics, independent from these research activities, the Government of China supported the build-up of a limited industrial base using the then standard production technology for photovoltaic cells and modules. Annex C-1 provides an idea about the expected expansion of the market for PV systems in China

It turned out not to be possible, however, to expand and steadily upgrade the production capacity of the photovoltaic industry, as well as the infrastructure in R&D institutions for doing advanced photovoltaic research. Today, the product delivery capability of the domestic photovoltaic industry is significantly lower than its production capacity, with product quality and performance lower, and production cost higher, than possible. If China's photovoltaic industry is to remain competitive and the capacity to carry out meaningful advanced photovoltaic research and advance development is to be retained, (1) industry must be enabled to improve its manufacturing capability to fully exploit its production capacity and to expand its market by better and more

[1] The distribution of electricity consumption in 1989 by sector was: 71.8% for industry (63.7% for heavy and 11.8% for light industries), 10.4% for agriculture, 9.9% for municipalities and households, and 1.9% for transportation

cost-effective products, and (ii) equipment and infrastructure for conducting photovoltaic research of (at least some) R&D institutions must be brought up to the state-of-the-art level

The policy of the Government of China is therefore to assist the modernization of the R&D and industrial base in the photovoltaic sector and to render it, in comparison to international standards, competitive for the future. The overall policy objective remains the diversification and dissemination of photovoltaic application technologies in China, aiming in particular to provide cost-effective electric services in rural China for the betterment of local living conditions.

3. Prior and Ongoing Assistance

Having recognized the importance of photovoltaics as a key technology suitable for improving living conditions of population segments which cannot be served by conventional means, the Government of China promoted the terrestrial application of photovoltaics since about 1980 and supported photovoltaic technology development in a number of institutions (university laboratories; university-independent R&D institutes) and by the establishemen of an indigenous PV cell and module production capability (over 20 institutions in total). Starting around 1980, several collaborations were entered with UNDP and foreign Governments for the demonstration of PV systems[2] Ongoing collaborations with assistance character are not known

4. Institutional Framework

Beginning in the late 70ies, R&D in semiconductor materials suited for photovoltaic solar cells was undertaken by several universities and research institutions, supported by direct or indirect public funds. Also, on prototype basis, solar cells and photovoltaic modules were fabricated and tested

In September of 1983, the Chinese Government established the China Photovoltaic Technology Development Center (CPVC) in Hangzhou and charged it to set up a program and to formulate an annual plan for PV R,D&D, manufacture and application in China, to oversee the flow and use of public funds to research institutes and industry (provided by the State Science and Technology Commission (SSTC)), and to promote the application in and dissemination of PV systems to different parts of the country. Presumably, a coordinated national program for the promotion of R&D in photovoltaics and related fields in China, requiring the support of a coordinating agency, will not be an element in the Ninth Five-Year plan (1996-2000).

In the course of this program and beginning in 1987, production equipment of limited capacity (~ 1 Mwp) for crystalline silicon solar cells and PV modules was installed in four industrial entities (equipment imported from the US), while equipment for the production of amorphous silicon PV modules was installed in two factories (equipment also imported from the US).

This fledgling PV industry was not supported beyond the equipment purchase and has been obliged to earn operating expenses (and financial gains, if any) on the market. After initial sucess, the industry suffers today from inadequate supplies of mono- and/or poly-crystalline silicon wafers and the lack for upgrading production technology and improving product quality.

B. Project Justification

1. Problem to be Adressed / The Present Situation

Today, about 900 million people in China live in rural areas, of these, about 120 million people in 28 counties and thousands of small villages and islands still are without electricity (and, by end of 1994, 80 million subsist with incomes below the poverty limit of 100 RMB/month and family). Disregarding that an electric power shortage presently exists (and probably will prevail under conditions of rapid economic expansion) in the Southern highly industrialized provinces of China, the cost of about US-$ 15-30,000/km to extend medium-voltage utility power lines will render it most unlikely that this scattered population segment will become utility connected in the foreseeable future

For improving the living conditions in areas where conventional supplies are logistically unavailable or not viable for other reasons, the Chinese Government adopted a policy of integrated development and efficient

[2] Examples: (i) China-German Cooperation on Renewable Energy Applications in Rural Areas, located in Daxin County, Beijing (completed), (ii) UNDP CPR/88/002 Project "Development of Photovoltaic Systems in Western China" executed by the Gansu Natural Energy Research Institute (completed)

utilization of the various forms of locally available renewable energy sources towards complementary use with conventional (fossil) energy supplies. Furthermore it stipulated pooling of resources from different Government departments for the support of R&D and D of renewable energy technologies, while simultaneously encouraging the cooperation with of other partners to supplement the national efforts. With similar intent and as a direct follow-up of its commitment at the June 1992 UN Conference on Environment and Development, the Government of China has drawn up a program of practical actions to guide China's overall development into the 21st century. This *Agenda 21 White Paper* concentrates on ameliorating the pressing problems of population growth, sustainable exploitation of natural resources, preservation of the environment and continued development.

China's Agenda 21 gives priority to the introduction of modern science and technology for improving productivity and stimulating economic growth, while at the same time ensuring that natural resources are used efficiently and that the national and global environment is preserved, thus ensuring a livable environment for the 1.3 Billion inhabitants expected by the year 2000. These goals will be embodied in the medium- and long-term plans for national economic and social development, particularly in the formulation of the Ninth Five-Year Plan (1996-2000) and the plans up to 2010 at various levels, based on domestic resources and international support.

In the course of elaborating the implementation of China's Agenda 21, sixty-two executable project proposals were identified which address urgent priority issues and which were selected for review during a „High-level Round-table Conference - Agenda 21" (Beijing, July 7-9, 1994) with the objective to secure external financial as well as technical assistance for their implementation. In this conference, UN agencies including UNDP and UNIDO participated, together with representatives of foreign governments, international financial institutions NGO's, private-sector companies and more than 200 Chinese government officials attended.

This project on „Photovoltaic Power Utilization" is amongst the priority projects selected for cooperation between China and UNIDO and is based on program areas 12B, 12C and 13D of China's Agenda 21.

From 1983 to 1987, seven larger PV standard production lines were imported and installed, of which five presently are operational with significant output and sales (see Annex C-2). Four industrial lines produce monocrystalline silicon wafers, cells and modules, all companies together have a combined annual production capacity of 2.2 MWp/a for modules and, by the end of 1994, only about 1.0 Mwp/a (mono-)silicon wafer production capacity; a pilot line in a National R&D laboratory (GRINM) has a capacity of about 100 kWp/a of 10x10cm polycrystalline silicon wafers. The industrial amorphous silicon production lines of 2.0 MWp/a capacity deliver about 700 kWp /a. Annex C-3 provides an overview over cell efficiencies obtained experimentally as well as in production.

By 1994, about 5,2 MWp cumulative capacity of PV system has became installed in China (see Annex C-4). While early applications addressed commercial applications such as cathodic protection or power supplies for repeater stations, the scope of application gradually expanded into fields such as agriculture (home lighting systems), animal husbandry (electric fences), forestry (insect traps), culture and education (remote TV reception), medicine and health care (vaccine cold store). Subsequently, supplying electric power in remote areas and offshore islands by photovoltaics proved attractive and viable to play a key role in providing decentralized power. However, further market expansion is presently hampered by limited domestic production capability (induced in part by a shortage of crystal pulling/casting and wafering capability, by a shortage of low-cost off-grade silicon for mono- and polysilicon material), by very low module efficiency (of amorphous silicon modules), and by the insufficient quality of PV modules, balance-of-system components and PV system technology in general. In the application and dissemination sector, PV systems frequently do not provide the expected service due to system design deficiencies, inadequate perfomance and/or low reliability and lifetime of balance-of-system components.

Similarly, advanced experimental facilities for preparing samples of mono- and poly-crystalline silicon cells of high efficiency (>13% for poly-silicon and >15% for mono-silicon cells) are limited in China; advanced facilities do not exist for conducting research in the novel field of crystalline (rather than amorphous) thin-film silicon solar cells.

It is essential that new tools are introduced and new methods are adopted which are necessary to conduct state-of-the-art photovoltaic research or which are needed to upgrade the domestic manufacturing capability. In this context, experience with the production aspects of high efficiency solar cells (and modules) is particularly relevant. For alleviating the shortage of lower cost crystalline silicon wafers for solar cell production, the expansion of the polysilicon casting and ingot slicing capability will be of considerable strategic significance.

To accelerate market penetration and market expansion into areas important for sustainable development specifically in rural/remote regions of the country several measures must be undertaken

- the quality of PV system components needs to be improved and (in a subsequent phase) be assured and certified by an independent National test/certification laboratory,
- the capability for PV system design and for the development of PV system technologies (other than PV modules) which are adapted to application circumstances needs to be established,
- the viability, cost-effectiveness and (non-institutional) user acceptance of PV systems in remote areas and in a number of non-standard applications and configurations needs to be tested, demonstrated and publicized to spur replication and technology diffusion,
- the financial instruments need to be developed by which the purchase, lease, repayment in installments of PV systems by the population in rural or remote regions or by third-party ownership can be facilitated

It finally is of strategic value to derive parameters for policy formulation, intervention and/or action from the (substantial) experience in operating small- and medium-size PV systems in urban and rural/remote areas of China. For this purpose, the operating history and operational status of the about 5 MWp of installed capacity of PV system greater than about 100 Wp shall be surveyed on a selected basis, user reactions be solicited, results be assessed and conclusions and recommendations for future action be drawn.

For addressing these issues, this project aims to broaden the industrial supply base of polycrystalline silicon wafers, to develop high-quality long-life balance-of-system components, to demonstrate the technical viability, maintainability and performance of stand-alone small- to medium-size PV systems in remote areas, to test financing instruments which enable the acquisition of small PV systems by low-income rural population, as well as to enhance the R&D base for solar cell research (by establishing a thin-film crystalline silicon research laboratory) and to further the advance of more cost-effective manufacturing technology (by establishing a pilot production line for monocrystalline silicon cells with efficiencies >15% cell efficiency)

2. Expected End-of-Project Situation

Upon completion of the project it is expected to have achieved the following

1. a facility for the commercial manufacture of 10x10cm poly-crystalline silicon wafers with a capacity equivalent to 1 MWp/a of solar cells will be established, fully operational and selling more than 850,000 wafers/a at a unit price < 2 US-$.

2. a pilot facility with a capacity of 0.5 MWp/a for the production of crystalline silicon solar cells with an efficiency higher than 13% at standard test conditions will have been set up, will have become operational, and methodologies will have been identified by which the photovoltaic cell- and module production facility of at least one commercial entity in China has been upgraded (higher efficiency, reliability and production yield, lower cost).

3. a test facility has been set up and is operational for the purpose of developing and performance testing of high-reliability and cost-effective balance-of-system PV system components which are optimally adapted for the specific application, as well as for the design, optimization and performance testing of low- to medium-power stand-alone PV systems suitable to render essential services requiring electricity for the population in off-grid regions of China;

4. a number of stand-alone or hybrid small- to medium-power PV systems have been designed, system components developed and/or adapted, the PV systems installed in remote areas of China, the PV system users trained, and the operation of these PV systems performance-monitored for at least one year

5. a high-quality research laboratory has become established and operational which permits to conduct state-of-the-art research in crystalline thick- and thin-film silicon materials, structures, devices and cells which hold the promise of cost-reduction in the manufacture of high-quality photovoltaic cells

6. a survey and assessment study has been carried out about the performance and operational history of the multitude of stand-alone PV systems which have been installed already in China, lessons learned have been derived and recommendations for courses of action and Government intervention have been elaborated

7 the specification and financial requirements for the establishment of a National Photovoltaic Qualification Test and Certification Facility have been identified and the decisions and required courses of action decided upon.

These seven two end-of-project results may be grouped according to common objectives

(i) item one and two adress the enlargement of the supply base for PV wafers and the improvement of PV cell/module production technologies and capabilities.

(ii) items three, four, six and seven address issues of improving the technology and quality of PV system and PV system component, i.e. optimization of component/system design, performance assessment of existing and optimized PV systems, and the quality assurance and certification of PV components.

(iii) item 5 addresses the issue of improving the capability to carry out advanced state-of-the-art R&D in the field of crystalline silicon solar cell technology

While the overall objective of the project addresses major issues on national level, each of the seven end-of-project results can only make a limited contribution towards these national goals, their aggregate indirect and direct effect towards the sustainable development in rural regions of China can be significant, however. Each end-of- project result is related to a specific technological issue or presently existing deficiency in the PV sector which need to be addressed or resolved in order to derive the social and economic benefits from PV technology on the macro level

To achieve the end-of-project results in a focused manner, execution of the project will be structured into distinct parts In these parts, technologically quite specialized activities need to be carried out which requires to to formulate individual objectives for each part; such structure not only is useful for the execution of the project but also because the project parts are carried out by four different organizations which are, or are to become, specialized in their respective fields. While the short-term significance (in view of macro-level goals) of the results of the individual project pars varies, the success or even partial failure of any of the project parts does not impair the (then partial) success of the overall project

3 Target beneficiaries:

The organizations/institutions responsible for the execution of the seven distinct parts of the project („Tasks") and their code names are

for Task 1 (POLY) the General Research Institute for Non-ferrous Metals (GRINM), operating under the ministerial-level China National Non-Ferrous Metals Industry Corporation (CNNC).

for Task 2 (PVLAB): the SUNPU Corporation, operated as manufacturing entity of BSERI, in collaboration with the Qinhuangdae HUAMEI Photovoltaic Electronic Co., Ltd (alternatively with the KAIFENG Solar Cell Co. Ltd., and/or the YUNNAN Semiconductor Devices Plant).

for Task 3 (SYSLAB): the New Energy Department (NED) of the Beijing HUASUN Hi-Tec Co., Ltd., operating as a manufacturing entity of The Sixth Research Institute which in turn operates under the Ministry of Electronic Industry (MEI).

for Task 4 (DEMO) the New Energy Department (NED) of the Beijing HUASUN Hi-Tec Co., Ltd.

for Task 5 (HIGH-η) the Beijing Solar Energy Research Institute (BSERI) operating under the Academy of Science of the ministerial-level Government of the City of Beijing

for Task 6 (STUDY) the China Photovoltaic Technology Development Center (CPVC) Hangzhou operating on contract basis under the State Science and Technology Commission (SSTC) and the State Planning Commission (SPC) in collaboration with BSERI and NED

for Task 7 (QAL AB) the China Photovoltaic Technology Development Center (CPVC) Hangzhou in collaboration with NED

The direct and indirect beneficiaries of the Task outputs are

	Primary Beneficiary	*Secondary Beneficiary*	*Tertiary Beneficiary*
Task 1 (POLY)	GRINM	PV industry	ACCA 21
Task 2 (PVLAB)	BSERI	PV industry	ACCA 21[1]
Task 3 (SYSLAB)	NED	PV system component industry; PV user community	ACCA 21
Task 4 (DEMO)	NED	PV user community	ACCA 21
Part 5 (HIGH-η)	SUNPU/BSERI	PV industry	ACCA 21
Task 6 (STUDY)	CPVC	SSTC; SPC	ACCA 21
Task 7 (QALAB)	CPVC	PV industry	ACCA 21

The ultimate beneficiaries will be the population of China at large, but especially the population in rural and remote areas such as islands.

4 Project Strategy and Institutional Arrangements

The overall project („Project") is structured in parts/Tasks and can therefore be flexibly executed. The Tasks are listed in their approximate importance relative to the overall Project objective. Tasks 1-4 are viewed as the more important Tasks, while Tasks 5-7 may be delayed and executed contingent on the availability of funds. With possible exception of Tasks 6 and 7, the *close cooperation between primary and secondary beneficiaries in each Task will be crucial*. The responsibility to effect this cooperation rests with the primary beneficiary institution, specifically with the individual which is assigned overall responsibility for the respective Task („Task Director").

The project further aims to contribute to Project success by specifying specific goals to be achieved in each Task, defined by *quantifiable measures of success* defined by the Task Director. This will allow to better assess the measure of succes in each Task at the end of the Project. Hence, acting on behalf of their institutions, Task Directors become personally and identifiably responsible.

The China National Photovoltaic Technology Development Center (CPVC), by contract from ACCA21 or SSTC, shall monitor the progress of Tasks 1-5, alert ACCA21 or SSTC of impending or existing difficulties in project execution, and shall check the validity of expenditures of funds in each Task. For Tasks 6-7, a different national organization will have to be charged to monitor status and progress on behalf of ACCA21 or SSTC. CPVC shall be assisted by a Project Technical Advisor, being engaged on a part-time basis (see Annex A-1).

National contributions wich are expected to be made available by SSTC and/or SPC, respectively, are channeled directly to the primary beneficiary institutions, based on the counsel of CPVC. Assistance provided for the Project by or via UNDP/UNIDO (or other international bodies or foreign government entities) in terms of funds for equipment, provision of experts or of opportunities for training will be channeled to the Tasks via ACCA21.

5 Reasons for Assistance from UNIDO

UNIDO through ist international arrangements, has the ability to provide a package of goods and services without national restrictions and to provide technical assistance quickly through ist links with industry in developed countries. This Project will provide increased capacity building in the form of upgraded PV manufacturing and R&D capabilities within China, along with fostering of long-term relationships between China and foreign industry. UNIDO's lack of commercial bias or interest permits the quickest possible transfer of the most appropriate technology and process know-how to China. UNIDO not only will be able to support the Project by the provision of a Project Technical Advisor by international consultants and by fellowship/training of Chinese

[1] Administrative Center for China's Agenda 21

scientists/engineers in PV technologies, but also is able to solicit the funding support for major equipment items from the international communities

6. Special Considerations

For reasons of cost and need for energy storage, solar energy utilization by photovoltaic means will not be a competitor to bulk electricity generation from fossil or nuclear sources. However, PV power utilization will not only be one of the environmentally most benign forms of electric energy generation, but it also will be the most economical form of providing limited amounts of electrical energy in (frequently ecologically fragile) remote regions of China

PV power utilization improves the living conditions in off-grid regions of China without adding to CO_2 emissions (after the energy pay-back time of ~ 6 months for amorphous silicon and 2-3 years for crystalline silicon solar cell modules) or disrupting the ecological balance

7. Coordination Arrangements - Links/Coordination with other Projects in Subsector

(i) Coordination Arrangements

Close cooperation with industry in Tasks 1-4, and of Task 1 and 2, will be very essential to achieve an overall Project success. Also, the collaboration with users of PV systems and the accounting of user needs in the PV system design will be a very important element in Task 4

Overall Project coordination on a continuous basis will be carried out by the National Project Coordinator

(ii) Links/Coordination with other Projects in Subsector

None required, as there are no other major R&D activities in the photovoltaic field at present in China

8. Capability and Commitment of the Host Country

China has committed to safeguarding it's future by adopting the Agenda 21 White Paper and establishing an administrative center at the highes level for carrying out the initiatives defined. It is to be expected that funds adequate to carry out the initatives will be made available by China (national funds). The ultimate success of this Project in terms of improving living conditions in remote areas depends, however, also to a significant degree on the enthusiasm and willingness of regional and local authorities to accept PV systems as alternatives to provide local needs. The availability of funds or financing mechanisms for the purchase of PV systems by private users is another factor which will be decisive for Project succes on the level of objectives pursued with China's Agenda 21.

Upgrading of the PV R&D capability towards state-of-the-art level of research will require investments in infrastructure which have not been accounted for in budget calculations of the Priority Program. The clean room facilities which will have to be created for Task 2 (PVLAB), and particularly for Task 5 (HIGH-η), are a case in point; this infrastrucure is a prerequisite for meeting the Task success criteria.

C. Development Objective

The priority program China's Agenda 21 stipulates the long-term objective of this Project „to promote the progress of the photovoltaic industry, to strengthen research and development of solar cell technologies, make production costs competitive and to expand the market for the industry's products"

The Project, therefore, aims foremost (i) to broaden the base for, and to reduce the cost of, the domestic manufacture of PV solar cells and modules, (ii) to identify methods how to upgrade the Chinese PV industry towards larger output, production yield and quality, and (iii) to diversify the application of autonomously operating PV and PV hybrid systems to reliably render essential services in rural regions of China. The objectives of strengthening the R&D base for solar cell technologies, on the other hand, is an investment for the future of high cost and risk, and can be pursued when the funding provisions are adequate

D. Immediate (Task) Objectives, Outputs and Activities

Task 1 (POLY):

Objective: To broaden the supply base for high-quality and lower-cost (poly-)crystalline silicon wafers to make fuller use of existing production capacity of domestic PV manufacturing industry.

Output: Establishment of a full production line for the casting of poly-crystalline silicon ingots and the cutting of 10x10cm poly-crystalline silicon wafers with a minority carrier lifetime equal to or greater than 2 µm (sufficient to manufacture single-diffusion solar cells with >=12% efficiency), at a production rate of >800,000 wafers/a and at a cost permitting the sale of these wafers at < 2.0 $/wafer.

Activities:

- 1-1 Design and specify polysilicon wafer production facility and infrastructure{completed}
- 1-2 Assemble production (counterpart) team {completed}
- 1-3 Procure funding for investment in equipment
- 1-4 Tender and procure equipment (from foreign or domestic suppliers)
- 1-5 Fellowship of up to 4 persons for 1 m/m each to receive training abroad on how to operate a poly-crystalline casting and wire-cutting machine
- 1-6 Install, commission and test-run equipment and production line
- 1-7 Fielding of 2 international experts on poly-crystalline silicon ingot casting, for 1 m/m each
- 1-8 Fielding of 2 international experts on the adaptation of poly-silicon solar cell processing, for 1 m/m each
- 1-9 Fielding of 1 international expert to advise on wire-cutting techniques and on ways to improve cutting skills, for 0.5 m/m
- 1-10 Improve output quality and quantity in full-production mode
- 1-11 Assume full production mode

Task Director: Dr. An-Zhong Lin, Photovoltaics Group, Beijing General Research Institute for Non-ferrous Metals (GRINM)

New equipment required (costs estimated, not including transportation and import taxes)

Type of Equipment/-Activity	*Cost of Equipment/-Activity (in US-$)*	*Remarks*
Silicon Ingot Casting Furnace	$ 890,000 (imported), or $ 150,000 (domestically procured)	for 145 kg ingots
Wire-cutting Machine	$ 450,000 (imported)	3,000 wafers/d (10x10 cm)
Ingot Cutter	$ 100,000 (imported), or $ 30,000 (domestically procured)	700 mm diameter saw blade
Spin Dryer	$ 40,000 (domestically procured)	250 pieces/charge
Square Graphite Crucible Production Machine	$ 40,000 (domestically procured)	550x550x220 mm crucible
Infrastructure	None	room, power line connections, etc available at GRINM
Training abroad: Fellowships	$ 28,000	4 x 1 m/m
Experts: Consultants	$ 102,500	2 x 2 m/m + 1 x 0.5 m/m
Total:	*$ 1,650,500 (imported)* *$ 840,500 (domestically procured)*	

Existing equipment (serves research purposes, yet suitable for use)

Type of Equipment	*Year of Acquisition*	*Remarks*
Silicon Ingot Casting Furnace	1994	for 20 kg ingots
Ingot Cutter	1986	for 15 kg ingots
ID Saw	1988	domestic make

Schedule			
	Design and specify equipment	{completed}	
	Assemble production (counterpart) team	{completed}	
	Procure funds for equipment	Sep 95 - Dec 95	
		if imported	if domestically procured
	Tender and procure equipment	Jan - Jun 96	Jan - Dec 96
	Fellowships	Jan - Jun 96	Jan - Jun 96
	Install equipment	Jul - Sep 96	Jul - Sep 96
	Start-up and test runs	Oct - Dec 96	Jan - Mar 97
	Fielding of first three international experts	Oct - Dec 96	Jan - Mar 97
	Fielding of last two international experts	Jan - Sep 97	Apr - Dec 97
	Improve output quality/quantity	Jan - Sep 97	Apr - Dec 97
	Attain full production	Oct 97 - Sep 98	Jan - Dec 98
	Subactivity duration	~ 37 M	~ 40 M

Suggested Activity Funding:

Equipment/ Activity	*Cost (in US-$)*	*Government Grants (SPC/SSTC)*	*Comm. Loans (domestic currency)*	*Grants from Intl. Organizations (UNDP, UNIDO)*	*Foreign Government Grants*
Tech. Assitance; Training	$ 130,500			100%	
Ingot Casting Furnace	$ 890,000 (imp) $ 150,000 (dom)	25% 50%	25%	25% 50%	25%
Wire Saw	$ 450,000 (dom)	25%	25%	25%	25%
Ingot Cutter	$ 100,000 (imp) $ 30,000 (dom)	40% 60%	25%	35% 40%	
Spin Dryer	$ 40,000	60%		40%	
Crucible Maker	$ 40,000 (dom)	60%		40%	

Collaborations: GRINM intends to closely cooperate with all four major PV manufacturers in China in the evaluation of wafer characteristics and suitability for cell production, especially close relations exist with the NIMBO and KAIFENG factories which use GRINM technology to produce limited quantities of polysilicon solar cells

Success Criteria: -- 100% success if after 2.5 years, respectively 3 years (in case of domestic furnace procurement), the following is achieved:
  - -- full production at a volume of 83,000 wafers/M
  - -- minority carrier lifetime of 90% of wafers produced is > 2 µs
  - -- the wafers can be processed to solar cells by industry
  - -- all wafers are profitably sold;

-- 50% success if after 2.5, respectively 3 years, the following is achieved
  - -- production at a volume of 40,000 wafers/M
  - -- minority carrier lifetime of 90% of wafers produced is only < 1 µs;
  - -- the production is sold at cost

Other Remarks: -- the production line will be set up at GRINM
- -- the design of an ingot casting furnace has been discussed with three potential domestic suppliers
- -- consideration is given to establish a joint venture company on the premises of and with GRINM in case substantial foreign grants are offered
- -- GRINM is the only R&D entity in the field of poly-crystalline silicon technology (since 15 years) and sole producer of polysilicon solar modules in China
- -- a production capacity from ingot casting up to module production equivalent to 100 kWp/a equivalent exists at GRINM using ingots of 17 kg weight and yielding cell efficiencies of 9-12%
- -- a limited capability to produce square quartz and reusable crucibles and to produce single-junction solar cells exists at GRINM

- -- a silicon block of 145 kg will yield 100 kg of blocks suitable for wafering, at three growth runs/week, more than 15 to of Si-blocks can be produced. From these, 70 wafers/kg Si of 10x10cm with a thickness of 350 µm can be cut, resulting in a wafer production volume of 997,000 wafers/a at 95% yield (disregarding electronic quality)
- -- GRINM produces currently about 10% of monocrystalline Si ingots (Czochralski process) in the country (CNNC produces about 50% of poly-Si base material in the coutry using the „Siemens" process)
- -- about 20% of off-grade silicon will be obtained from GRINM while the rest of silicon stock must be procured from outside sources (at about 50 RMB/kg presently)

Task 2 (PVLAB):

Objective: To strengthen the know-how base in the field of higher-efficiency mono-crystalline silicon solar cell production technology and to identify methods and methodologies by which currently existing PV manufacturing capabilities in China can be upgraded.

Output: Establishment of a pilot production line

(a) for higher-η mono-crystalline silicon solar cells from 5"Ø CZ-wafer material with an efficiency >15% at standard test conditions and at a capacity of 400,000 cells/a and an actual production rate of >26,000 cells/m (95% yield), at a cost < 3.75 $/cell or 38 yuan RMB/cell (<2.5 $/Wp or 26 yuan RMB/Wp), and

(b) by which the process characteristics can be elaborated to obtain higher-η poly-crystalline silicon solar cells from 10x10cm wafers with an efficiency >13% at standard test conditions

Activities:

2-1	Fellowship of 4 persons for 1 m/m each to receive training in the fields of production processes and other technologies needed for a higher-efficiency mono- and poly-silicon solar cell pilot production line
2-2	Fielding of 2 international experts of 1.0 m/m each to advise on manufacturing techniques for higher-efficiency mono-silicon solar cells, on production equipment use, operational principles, quality assurance and other key issues
2-3	Consult industrial PV producers and conclude a cooperation agreements with at least one of them
2-4	Specify clean-room facilities and infrastructure
2-5	Make final specification for equipment
2-6	Assemble counterpart team
2-7	Procure funding for all intended investments
2-8	Tender and procure equipment
2-9	Procure and install clean-room and infrastructure
2-10	Fielding of 1 international expert for 4 m/m to supervise and coordinate the installation of the equipment procured, as required, and to advise on commissioning, start-up and optimization of operations
2-11	Install production equipment
2-12	Perform commissioning and start-up procedures
2-13	Modify production processes to improve output quality
2-14	Perform economic analyses of the entire production process based on pilot line experience
2-15	Identify production processes transferable into existing PV production lines
2-16	Specify and design a complete production line for high-η solar cell production of 5 MWp/a output capacity

Task Director: Prof. Zhao Yuwen, Photovoltaics Technology Department, Beijing Solar Energy Research Institute (BSERI)

New equipment required (costs estimated, not including transportation and import taxes)

Type of Equipment - Activity	*Cost of Equipment - Activity (in US-$)*	*Remarks*
Solar Simulator	$ 140,000 (imported)	1 unit, SPI-SUN Simulator
Screen Printing Machine	$ 120,000 (imported)	2 units

Laminator	$ 120,000 (imported)	1 unit, SPI-Laminator 550
Diffusion Furnace	$ 1,000,000 (imported)	2 units, 6"Ø tubes, four tubes each
Spraying Machine	$ 50,000 (imported)	1 unit
Classifier and Sorter	$ 50,000 (imported)	1 unit, SPI-Cell QC6
Sintering Furnace	$ 300,000 (imported)	2 units
Dicing Saw	$ 50,000 (imported)	1 unit
LPVCD Equipment	$ 300,000 (imported)	1 unit
Software	$ 250,000	
Consumables	$ 100,000	for project duration
Infrastructure	$ 100,000	clean room Class 10,000, 100 m²
Training abroad, Fellowships	$ 56,000	6 x 1 m/m
Experts, Consultants	$ 111,000	1 x 4 m/m + 2 x 0.5 m/m
Total:	*$ 2,649,000*	

Equipment existing (yet suitable for use):

Type of Equipment	*Year of Acquisition*	*Useful Lifetime; Remarks*
alpha-step 200	1993	15 years; new
LPCVD	1985	10 years; restricted operability

Schedule:

Fellowships	Aug 95 - Apr 96
Field first two International Experts	Jan - Jun 96
Consult with user	Sep 95 - Jun 96
Specify infrastructure and equipment	Nov 95 - Jun 96
Assemble counterpart team	Aug 95 - Apr 96
Procure funding	Nov 95 - Jun 96
Tender and procure equipment	Jul- Dec 96
Tender and procure infrastructure	Jul - Dec 96
Install infrastructure	Jan - Jun 97
Field third International Expert	Jan - Jun 97 period
Install production equipment	Jan - Jun 97
Perform start-up procedures	Jul - Dec 97
Modify/improve production process	Jan - Dec 98
Assess cost-effectiveness	Jan - Mar 99
Transfer process to industry	Apr - Dec 99
5 MWp/a Plant Design	Jan - Dec 2000
Subactivity Duration	64 M

Suggested Activity Funding:

Equipment/ Activity	*Cost (in US-$)*	*Government Grants (SPC SSTC)*	*Comm. Loans (domestic currency)*	*Grants from Intl Organizations (UNDP, UNIDO)*	*Foreign Government Grants*
Techn. Assistance;Training	$ 167,000			100%	
Simulator	$ 140,000	16%	60%	14%	10%
Screen Printer	$ 120,000	16%	60%	14%	10%
Laminator	$ 120,000	16%	60%	14%	10%
Diff. Furnace	$ 1,000,000	16%	60%	14%	10%
Sprayer	$ 50,000	16%	60%	14%	10%
Sorter	$ 50,000	16%	60%	14%	10%
Sinter Furnace	$ 300,000	16%	60%	14%	10%
Dicing Saw	$ 50,000	16%	60%	14%	10%
LPCVD	$ 300,000	16%	60%	14%	10%
Software	$ 250,000	16%	60%	14%	10%
Consumables	$ 100,000	40%	60%		
Infrastructure	$ 100,000	40%	60%		

outdoor test facilities for balance-of system components and PV systems
3-9 Tender and procure indoor and outdoor laboratory infrastructure
3-10 Tender and procure laboratory equipment
3-11 Establish indoor and outdoor facility infrastructure
3-12 Install indoor laboratory equipment
3-13 Install outdoor monitoring instrumentation
3-14 Fielding of 1 international expert for 2x1m/m to advise on commissioning and start-up of indoor test equipment
3-15 Perform commissioning and start-up procedures
3-16 Carry out component development program

Task Director: Wang Si Cheng, New Energy Department (NEF), Beijing HUASUN Hi-Tech Co., Ltd. (HUASUN)

New equipment required (costs estimated, not including transportation and import taxes)

Type of Equipment/-Activity	*Cost of Equipment - Acivity (in US-$)*	*Remarks*
PV Solar Array Simulator, incl. Control Software	$ 150,000 (import)	25 kW (Priority 1)
PV Pump Test System, incl. Control Software	$ 120,000 (import)	10 kW (Priority 2)
PV Power & Battery Test Unit, incl. Control Software	$ 150,000 (import)	5kW/10kW (Priority 2)
Electric Machines Simulator, incl. Control Software	$ 180,000 (import)	15kW/25kW (Priority 2)
Electric Load Simulator, incl. Control Software	$ 65,000 (import)	25 kW (Priority 3)
D/A & Evaluation Software	$ 25,000 (import)	(Priority 1)
PV Module Tester	$ 40,000	portable (Priority 1)
PV Module Flasher	$ 140,000 (import)	(Priority 1)
Power Analyzer for DC/AC Inverters	$ 30,000 (import)	(Priority 1)
PV System Simulation Software	$ 7,000	TRNSYS
PV Systems for Outdoor Performance Testing	$ 100,000	Several home lighting systems; two PV pump systems < 1 kWp; one PV-Diesel hybrid system
Indoor Laboratory	$ 300,000	300 m²;
Indoor Lab Basic Equipment	$ 80,000	100 kWh batteries; DC power sources; oscilloscopes; multimeters; computers, printers, telephone; copier; fax; furniture
Outdoor Test Field Preparation	$ 150,000	500 m²
Outdoor Instrumentation	$ 30,000	data loggers, radiometer, anemometer, wind vane, temp sensors
Project Preparation	$ 50,000	
Training abroad	$ 56,000	4 x 1 m/m
Fellowships	$ 44,000	2 x 1 m/m
Total:	*$ 1,717,000*	

Equipment existing: None

Schedule:

Assemble counterpart team	Sep - Nov 95
Fellowship # 1	Sep - Nov 95
Field first international expert	Oct - Nov 95
Design and specify laboratory	Sep - Nov 95
Equipment design & specification	1 M
Procure funding for all investments	Sep - Nov 95
Tender facility infrastructure	Dec 95 - Feb 96
Tender and procure lab equipment	Dec 95 - Jul 96

Establish lab infrastructure	Mar - Jul 96
Install indoor equipment	Aug - Dec 96
Install outdoor instrumentation	Aug - Dec 96
Field second international expert	Feb - Mar 97
Commission and start-up facility	Jan - Jun 97
Carry out development program (indoor)	Jul 97 - Jan 99
Carry out outdoor measurements	Jul 97 - Jun 99
Subactivity duration	45 M

Suggested Activity Funding

Equipment/ Activity	*Cost (in US-$)*	*Government Grants (SPC/SSTC)*	*Comm. Loans (domestic currency)*	*Grants from Intl. Organizations (UNDP,UNIDO)*	*Foreign Government Grants*
Tech. Assistance: Training	$ 100,000			100%	
Indoor Test Equipment	$ 900,000			50%	50%
Simulation Software	$ 7,000				
Outdoor Performance Test Systems.	$ 100,000	50%	50%		
Indoor Laboratory	$ 300,000	33%	66 %		
Indoor Basic Equipment	$ 80,000	37.5%	62.5%		
Outdoor Test Field Preparation and Instrumentation	$ 150,000		1000%		
Outdoor Test Instrumentation	$ 30,000	50%	50%		
Project Preparation	$ 50,000	100%			

Collaborations: HUASUN will collaborate with CPVC and will conclude collaboration/cooperation agreements with different PV system and balance-of-system component developers/-manufacturers for the performance validation of components/systems

Success Criteria: - 100% success if after 28 months
  -- indoor and outdoor facilities are fully operational and all manpower is trained to perform all required tests
  -- cooperation agreements with >5 outside entities have been signed

- 80% success if after 28 months
  -- indoor and outdoor facilities are fully operational and all manpower is trained to perform all requiered tests
  -- cooperation with < 3 outside entities have been signed

- 50% success if after 28 months
  -- indoor facilities are operational

Other Remarks - the PV component and system development and test laboratory will be established on the premises of HUASUN Co . Beijing
- NEP/HUASUN Co will establish appropriate provisions to safeguard the confidentiality of test results of third-party equipment, if requested
- at the present time, no indoor PV system component test and development laboratory exists at NEP nor at other institutions in China

- consideration is given to enter into a joint venture with domestic or foreign partners in case that the project is successfully concluded
- consideration is given to transfer major indoor test equipment to CPVC at the end of the project to enlarge the capabilities of Qualification Test Center established in Hangzhou

Task 4 (DEMO):

Objective: Demonstrate the viability, cost-effectiveness and user-satisfying performance of low- and medium-power PV systems which operate in remote areas, and test financing and maintenance instruments which enable users to acquire and to maintain PV systems, particularly in non-urban regions

Output: Performance demonstration and monitoring of (i) sixty PV Home Systems (50 Wp each), (ii) one PV-Wind-Genset Village Power Supply System (20 kWp), (iii) three 2.5 kWp PV Pump Systems for Greenhouse Irrigation, (iv) four 500 W PV Pump Systems for Potable Water Supply, and (v) one PV RO-Water desalination System (30 kWp) (see Annex 5 for further specifications)

Activities:

4-1 Fellowship of 2 persons for 3 m/m each to receive training in the fields of designing high-quality PV balance-of-system components[4] and PV system design[5]
4-2 Identify demonstration sites/or regions
4-3 Fielding of international expert for 1 m/m each to advise on site selection and pre-survey activities
4-4 Relate with users and/or user communities to determine user needs and operational requirements/constraints
4-5 Design demonstration systems
4-6 Fielding of international experts for 1-2 m/m each to advise on the design of the demonstration systems
4-7 Procure funding for equipment and project activities
4-8 Procure and acquire components, build and pre-test the demo systems
4-9 Prepare infrastructure at demo sites where necessary (e.g. well drilling, housing)
4-10 Transport, and install, PV systems and D/A equipment
4-11 Instruct and/or train users in PV system use and maintenance
4-12 Elaborate options and possibilities how users and/or user communities could finance future PV installations or be enabled to pay for services rendered by PV systems
4-13 Accumulate and evaluate performance data
4-14 Report on performance and operational results and on lessons learned, recommend further actions how replications could be effected

Task Director: Wang Si Cheng, New Energy Department (NEP), Beijing HUASUN Hi-Tech Co. Ltd (HUASUN)

New equipment required (costs estimated, not including transportation and import taxes)

Demonstration, Location, Duration	*Type of Equipment - Activity*	*Cost of Equipment - Activity (in US-$)*	*Remarks*
Remote PV Home Systems Qinghai Province, 12 M	- Equipment	$ 68,000	60 units, 50 Wp each
	- Data Acquisition	$ 12,000	6 sets
	- Transport, Installation	$ 10,000	
	- Local Training	$ 4,500	3 m/m
	- Expert	$ 22,000	1 x 1 m/m[6]
Hybrid PV-Wind Village Supply Inner	- Equipment	$ 360,000	1 unit, 20 kWp/10 kWe,
	- Data Acquisition	$ 10,000	1 set
	- Local Construction (housing)	$ 70,000	200 m², 1 km local LV-line

[4] DC/AC inverters, MPP-trackers, battery charge controllers, electronic ballasts for DC powered lights, etc
[5] PV pump systems, PV/Wind or other hybrid systems, PV Village power supplies, etc
[6] for system design

Mongolia.	- Transport. Installation	$ 30,000	
36 M	- Local Training	$ 4,500	3 m/m
	- Experts	$ 44,000	2 x 1 m/m[7]
PV Green-house	- Equipment	$ 75,000	3 units. 2.5 kWp each. 20 m head
Irrigation.	- Data Acquisition	$ 6,000	3 sets
Tibet.	- Transport; Installation	$ 15,000	
30 M	- Local Training	$ 4,500	3 m/m
	- Experts	$ 22,000	1 x 1 m/m[5]
PV Potable	- Equipment	$ 25,000	4 units. 500 Wp each
Water Pumps:	- Data Acquisition	$ 12,000	4 sets
Inner	- Local Construction (wells)	$ 20,000	4 wells. 20 m head
Mongolia.	- Transport; Installation	$ 15,000	
30 M	- Local Training	$ 6,000	of four people
	- Experts	$ 44,000	2 x 1 m/m[6]
PV Desalination	- Equipment	$ 265,000	1 unit: 20 kWp
System:	- Data Acquisition	$ 10,000	1 set
Chang Island.	- Local Construction (housing)	$ 50,000	100 m²;
Shandong Prov:	- Tranport; Installation	$ 20,000	
36 M	- Local Training	$ 3,000	2 m/m
	- Experts	$ 66,000	1 x 1 m/m[8]; 1 x 2 m/m[5]
	Site Identification & Selection	$ 50,000	
	Project Management	$ 30,000	for 3 years
	Training abroad; Fellowships	$ 84,000	4 x 2 m/m
Total:		*$ 1,457,500*	

Equipment existing: None

Schedule

Assemble counterpart (project) team	Aug - Sep 95
Fellowships	Sep - Dec 95
Identify sites and users	Sep - Dec 95
Fielding of international experts (pre-survey)	Sep - Dec 95
Establish relationship with users	Jan - Mar 96
Design systems	Jan - Mar 96
Fielding of international experts (system design)	Jan - Mar 96
Procure funding for all investments/activities	Jan - Mar 96
Procure components and pre-test systems	Apr - Dec 96
Prepare site(s) infrastructure	Apr - Dec 96
Transport and install systems	Jan - Jun 97
Instruct users	Jun - Sep 97
Accumulate data; evaluate performance	Jul 97 - Jun 98
Subactivity duration.	48 M

Suggested Activity Funding:

Equipment Activity	*Cost (in US-$)*	*Government Grants (SPC/SSTC)*	*Commercial Loans (domestic currency)*	*Grants from Intl. Organizations (UNDP,UNIDO)*	*Foreign Govern ment Grants*
Tech. Assistance. Training	$ 191,000			100%	
Project Manage-ment	$ 30,000	100%			
Site identification & Selection	$ 50,000	100%			
Local Training	$ 22,500	100%			
Demonstration System Hardware	$ 793,000	13%	48%	13%	27%

[7] for pre-survey and system design
[8] for pre-survey

D/A Equipment & Software	$ 50,000	13%	48%	13%	27%
Local Construction	$ 140,000	30%	70%		
Transport & Installation	$ 90,000	56%		44%	

Collaborations: NED of HUASUN High-Tech Co. will closely collaborate with the the users of the PV demonstration systems; it will also inform the suppliers about the performance of the equipment supplied by or procured from them, together with recommendations about possible technical improvements.

Concerning the demonstration of home lighting systems, NED will furthermore collaborate with the Gansu National Energy Research Institute (GNERI) in Lanzshou.

Success Criteria:

- 100% success if after 48 months
  - -- all demonstration and D/A systems have been installed
  - -- all demonstration and D/A systems have been nominally operating for at least 12 months (system operation and useful data collection for >95% of the time with > 100 W/m² of global radiation)
  - -- all user accept systems, have successfully been trained to maintain the systems, and are satisfied with the services rendered
  - -- financing mechnisms for replicate systems have been devised in collaboration with the respective user communities, and the viability of some of these schemes have been tested
- 80% success if after 48 months
  - -- only four types of demonstrations could be realized
  - -- demonstration and D/A systems operated nominally for at least 12 months
  - -- users are trained, accept systems and are satisfied
  - -- financing mechanisms have been elaborated
- 50% success if after 48 months
  - -- only three demonstration systems have been installed
  - -- the demonstration and D/A systems have accumulated less than 12 months nominal performance history

Other remarks:

- Although demonstrated already elsewhere in China, PV home lighting systems are included as important demonstrators how living conditions in remote areas can be improved
- NED recognizes that financing mechanism for the purchase of PV systems, or of the services provided by them, is equally important as the demonstration of the technical viability, life-time and performance of the PV systems

Task 5 (HIGH-η):

Objective: To strengthen R&D capability in the field of high-efficiency mono-crystalline silicon solar cells and high-efficiency poly-crystalline thin-film solar cells, to improve conversion efficiency and to reduce the cost to (to be completed) cells

Output: Establishment of a high-quality R&D laboratory to perform development work in the field of (i) high-efficiency crystalline silicon solar cells to exceed conversion efficiencies >21%, (ii) poly-crystalline silicon thin-film solar cells to achieve conversion efficiencies >10%, and (iii) to develop large-volume production processes suitable for transfer to the PV industry

Activities:

5-1 Fellowship of 3 persons for 2 m/m each to receive training in the technologies of crystalline thin-film solar cells and the production processes associated with high-efficiency mono-crystalline silicon solar cells

technologies

5-2 Fellowship of 2 persons for 2 m/m each to receive training in measurement to characterize crystalline silicon solar cells
5-3 Fielding of 2 international experts of 1 m/m each to advise on production processes of high-efficiency solar cells and on their measurement/characterization
5-4 Assemble production (counterpart) team
5-5 Specify and design laboratory infrastructure
5-6 Procure funding for laboratory infrastructure and equipment
5-7 Establish collaboration with advanced PV R&D teams in China working in the same field
5-8 Tender and procure laboratory equipment
5-9 Tender and procure cleanroom and other laboratory infrastructure
5-10 Install cleanroom and other laboratory infrastructure
5-11 Fielding of 1 international expert for 1 m/m to advise on installing and commissioning of laboratory equipment
5-13 Install laboratory equipment
5-14 Conduct acceptance tests of laboratory equipment
5-15 Carry out R&D work and identify pilot-line processses transferable to industry
5-16 Identify processes transferable into pilot production line

Task Director: Prof. Zhao Yuwen, Photovoltaics Technology Department, Beijing Solar Energy Research Institute (BSERI)

New equipment required (costs estimated, not including transportation and import taxes)

Type of Equipment - Activity	*Cost of Equipment - Activity (in US-$)*	*Remarks*
Automated Photolithography Machine	$ 150,000 (imported)	1 unit
LPCVD Facility	$ 300,000 (imported)	1 unit
I-V Measuring Instrument	$ 50,000 (imported)	1 unit
Laser scriber	$ 150,000 (imported)	1 unit; Quatronix 603
Minority Carrier Lifetime Tester	$ 30,000 (imported)	1 unit
Diffusion Furnace	$ 500,000 (imported)	1 unit; 6"∅, 4 tubes
PECVD	$ 300,000 (imported)	1 unit
Super Clean Room	$ 310,000 (domestic)	150 m^2; Class 100 or better
PECVD Equipment	$ 300,000 (imported)	1 unit
Consumables	$ 100,000	
Infrastructure	$ 300,000	new building; UPS; gas supplies
Training abroad; Fellowships	$ 105,000	6 x 2 m/m
Experts; Consultants	$ 66,000	3 x 1 m/m
Total:	*$ 2,561,000*	

Equipment existing (needed for and yet suitable for use)

None

Schedule:

Fellowship #1	Aug 95 - Apr 96
Fellowship #2	Aug 95 - Apr 96
Field first two international consultants	Jan - June 96
Establish collaboration	Sep 95 - Jun 96
Design and specify	Nov 95 - Jun 96
Assemble research (counterpart) team	Aug 95 - Apr 96
Procure funding for all investments	Nov 95 - June 96
Tender and procure lab equipment	Jun 96 - Dec 96
Tender and procure infrastructure	Jun 96 - Dec 96
Install facility infrastructure	Jan 97 - Jun 97
Field third international consultant	Jan 97 - Jun 97
Install laboratory equipment	Jan 97 - Jun 97
Perform commissioning and start-up	Jul 97 - Dec 97
Conduct R D&D work	Jan - Dec 98

Identify processes suitable for transfer	Jan - Dec 99	
Subactivity Duration	52 M	

Suggested Activity Funding

Equipment: Activity	*Cost (in US-$)*	*Government Grants (SPC/SSTC)*	*Comm. Loans (domestic currency)*	*Grants from Intl Organizations (UNDP/UNIDO)*	*Foreign Government Grants*
Experts; Fellowships; Training	$ 171,000			100%	
Photolithography Machine	$ 150,000	16%	60%	14%	10%
LPCVD Facility	$ 300,000	16%	60%	14%	10%
I-V Performance Tester	$ 50,000	16%	60%	14%	10%
Laser Scriber	$ 150,000	16%	60%	14%	10%
Minority Lifetime Tester	$ 30 000	16%	60%	14%	10%
Diffusion Furnace	$ 500,000	16%	60%	14%	10%
PECVE	$ 300,000	16%	60%	14%	10%
Cleanroom	$ 310,000	16%	60%	14%	10%
Infrastructure	$ 300,000	16%	60%	16%	10%
Consumables	$ 100,000	60%	40%		

Collaborations: BSERI will (i) collaborate with P&D groups in China investigating issues of high-efficiency of solar cells, (ii) will closely consult with all four major PV manufacturers in China in the design and specification of high-efficiency solar cell production lines, and (iii) will collaborate closely with the Qinhuangdao Huamei PV factory concerning the transfer of production technology

Success Criteria: - 100% success if after 5 years the following is achieved

-- an efficiency >21% for 50 cm² mono-crystalline silicon solar cells
-- the technology for a high-μ pilot production line is transferred to industry

- 80% success if after 5 years the following is achieved

-- an efficiency >20% for 50 cm² mono-crystalline silicon solar cells
-- the technology for a high-μ pilot production line is transferred to industry

- 50% success if after 5 years the following is achieved

-- an efficiency >19% for 50 cm² mono-crystalline silicon solar cells

Other Remarks: - the advanced photovoltaic R&D Laboratory will be set up at BSERI

Task 6 (STUDY):

Objective: To carry out an assessment about the long-term operating and performance history of large-, medium- and large-capacity PV systems in China, both grid-connected and stand-alone in PV-only or hybrid configurations, in order (i) to identify the technological issues needed to be addressed for improving PV system technology, and (ii) to develop strategies by which these improvements can be effected on national level

Output: A study about the long-term operating performance of a statistically relevant number of PV

systems in China, as well as about the measures needed to be undertaken to improve or to better adapt PV system technology for deployment conditions in China

Activities

6-1 Assemble Chinese counterpart team
6-2 Establish collaboration with other institutions to support the assessment/survey
6-3 Survey PV systems installed in China and select a statistically representative number of differing PV system size, configuration and application
6-4 Fellowship of 2 persons for 1 m/m each to obtain information about the operating history of PV systems in countries outside China
6-5 Survey selected PV system application sites, collect/obtain performance data and interrogate PV system users
6-6 Fielding of 1 international expert for 1 m/m to advise on PV system performance measurement and recording technology
6-7 Select PV systems for coarse and detailed performance monitoring over ~ 15 M
6-8 Procure funding for measurement and recording equipment
6-9 Tender and procure measurement/recording equipment
6-10 Install measurement/recording equipment
6-11 Collect an analyze performance data
6-12 Prepare section on system performance of the report
6-13 Develop strategies for technological and/or regulatory initiatives which would be helpful to improve quality and performance of PV systems manufactured in China
6-14 Issue report

Task Director: N. N., the China Photovoltaic Technology Development Center (CPVC), Hangzhou

New equipment required (costs estimated, not including transportation and import taxes)

Type of Equipment - Activity	*Cost of Equipment - Activity (in US-$)*	*Remarks*
Radiometers	$ 60,000 (imported)	60 units
Data Loggers	$ 200,000 (imported)	60 units
Temperature Sensors	$ 15,000 (imported)	180 unit
Incidental Measurement Instrumentation	$ 100,000	
Modems	$ 60,000	75 units
Server	$ 15,000	1 unit
Computers and Printers	$ 50,000 (domestic)	10 units
Consumables	$ 30,000	
Domestic Travel	$ 200,000	200 missions
Training abroad, Fellowships	$ 28,000	2 x 1 m/m
Experts, Consultants	$ 22,000	1 x 1 m/m
Total	$ *780,000*	

Equipment existing (needed for and yet suitable for use)

None

Schedule

Assemble research (counterpart) team	Aug - Oct 95
Establish collaboration	Aug - Oct 95
Survey and select systems	Nov 95 - Feb 96
Study missions	Nov 95 - Feb 96
Site surveys and history collection	Feb - Jun 96
Select sites to be measured	Jul - Aug 96
Field international consultant	Jul - Aug 96
Procure funding for all investments	Feb - Aug 96
Tender and procure meas/record equipment	Sep - Dec 96
Install measurement/recording equipment	Jan - Mar 96
Collect/analyze data	Mar 97 - Jun 98
Develop strategies; recommend initiatives	Jan - Jun 98
Issue report	Jun 98
Subactivity Duration	35 M

Suggested Activity Funding

Equipment Activity	*Cost (in US-$)*	*Government Grants (SPC/SSTC)*	*Comm. Loans (domestic currency)*	*Grants from Intl Organizations (UNDP,UNIDO)*	*Foreign Government Grants*
Experts, Fellowships, Training	$ 50,000			100%	
Radiometers	$ 60,000	60%	16%	14%	10%
Data Loggers	$ 200,000	60%	16%	14%	10%
Temp Sensors	$ 15,000	60%	16%	14%	10%
Other Instrumentation	$ 100,000	60%	16%	14%	10%
Modems	$ 60,000	60%	16%	14%	10%
Server	$ 15,000	60%	16%	14%	10%
Computers, Printers	$ 50,000	60%	40%		
Domestic Travel	$ 200,000	60%	40%		
Consumables	$ 100,000	60%	40%		

Collaborations: CPVC will (i) collaborate with institutions in China active in the field of PV system technology for identifying systems suitable to be assessed and monitored, (ii) engage the support of regional authorities in the observation of monitored PV systems, and (iii) will consult with SSCT/SPC and ACCA 21 on the proposed regulatory and technology-push initiatives

Success Criteria: -

100% success if after 3 years

-- the performance assessments and measurements are sucessfully completed
-- viable recommendations for improving the situation in the PV application sector have been formulated
-- the study has been issued
-- Chinese government endorses the recommendations

- 80% success if after 3 years

-- the performance assessments are completed
-- viable recommendations for improving the situation in the PV application sector have been formulated
-- the study has been issued

- 50% success if after 3 years the following is achieved

-- the study has been issued

Other Remarks: None

Task 7 (QALAB):

Objective: To establish a qualification and test laboratory, for certifying, on national level, the quality and performance of of photovoltaic modules

Output: Establishment of a high-quality laboratory to certify performance and quality of PV modules which are manufactured in or outside of China, according to IEC Specifications 1215 (or EU Specifications 503)

Activities:

7-1 Fellowship of 2 persons for 2 mm each to receive training in the establishment and operation of PV module qualification test laboratories and in the qualification testing of PV modules using crystalline-silicon solar cells

7-2 Assemble counterpart (test laboratory) team
7-3 Specify and design qualification test laboratory
7-4 Fielding of 1 international expert for 1 m/m to advise on the specification and design of a PV module qualification test laboratory
7-5 Specify and design test laboratory infrastructure
7-6 Procure funding for laboratory infrastructure and test equipment
7-7 Tender and procure test laboratory equipment
7-8 Conclude collaboration agreements with international qualification centers for jointly carrying out round-robbin test
7-9 Tender and procure test laboratory infrastructure
7-10 Establish test laboratory and infrastructure
7-11 install test laboratory equipment
7-12 Conduct acceptance tests of laboratory equipment
7-13 Acquire multiple PV module specimen from Chinese and other manufacturers
7-14 Carry out qualification tests
7-15 Verify test results by carrying out round-robbin tests

Task Director: N. N., China Photovoltaic Technology Development Center (CPVC), Hangzhou

New equipment required (costs estimated, not including transportation and import taxes)

Type of Equipment/-Activity	*Cost of Equipment/-Activity (in US-$)*	*Remarks*
Solar Simulator, incl. Control Equipment	$ 700,000 (imported)	1 unit (4 m²; continuous light source 1,000 W/m²; 100 kVA)
UV Simulator	$ 120,000 (imported)	1 unit (2x2m light source)
Mechanical Tester	$ 40,000 (imported)	1 unit (stiffness; loading; impact)
Environmental Chamber, incl Control Equipment	$ 350,000 (imported)	1 unit (2x2m; -40 - 95°C; 100% humidity; salt spray; 50 kVA, Brabender or Weiß)
A/D converters	$ 15,000 (imported)	3 unit
Data Loggers	$ 10,000 (imported)	2 units
Computers; Printers	$ 15,000	3 units
Spares	$ 200,000	lamp units
Incidental Equipment	$ 150,000	
Infrastructure	$ 300,000	building, UPS
Training abroad; Fellowships	$ 65,000	2 x 2 m/m
Experts; Consultants	$ 23,000	1 x 1 m/m
Total:	*$ 1,988,000*	

Equipment existing (needed for and yet suitable for use):

None

Schedule

Fellowship	Oct - Dec 95
Assemble counterpart team	Sep - Oct 95
Specify and design laboratory	Nov 95 - Feb 96
Establish collaboration with intl. test labs	Jan - Sep 96
Specify and design lab infrastructure	Jan - Jun 96
Field international expert	Feb - Apr 96
Procure funding for all investments	Jan - June 96
Tender and procure test equipment	Jul 96 - Mar 97
Tender and procure laboratory infrastructure	Jun - Sep 96
Install laboratory infrastructure	Oct 96 - Mar 97
Install test equipment	Apr - Sep 97
Perform commissioning and start-up	Oct - Dec 97
Conduct qualification tests	Jan - Sep 98
Conduct round-robbin tests	Apr - Dec 98
Subactivity Duration	30 M

Suggested Activity Funding

Equipment Activity	*Cost (in US-$)*	*Government Grants (SPC/SSTC)*	*Comm. Loans (domestic currency)*	*Grants from Intl Organizations (UNDP/UNIDO)*	*Foreign Government Grants*
Experts; Fellowships; Training	$ 88,000			100%	
Solar Simulator	$ 700,000	60%	16%	14%	10%
UV Simulator	$ 120,000	60%	16%	14%	10%
Mech. Tester	$ 40,000	60%	16%	14%	10%
Env. Chamber	$ 350,000	60%	16%	14%	10%
A/D Converters	$ 15,000	60%	16%	14%	10%
Data Loggers	$ 10,000	60%	16%	14%	10%
Computers; Printers	$ 15,000	60%	16%	14%	10%
Incidental Equipment	$ 150,000	60%	16%	14%	10%
Spares	$ 200,000	60%	16%	14%	10%
Infrastructure	$ 300,000	60%	16%	16%	10%

Collaborations: The CPVC will collaborate with the EU Test Facility, Ispra/Italy, the JQI Japanese Quality Institute, Tokyo/Japan and NREL, Golden/CO in the execution of round-robbin-tests of PV modules

Success Criteria: - 100% success if after 3.5 years the

-- qualification test laboratory has been established and is fully operational
-- round-robbin tests have verified the accuracy of the measurements performed

- 80% success if after 3.5 years the

-- qualification test laboratory has been established and is operational
-- some tests performed are off by >5% compared to measurements taken at collaborating institutions

- 50% success if after 3.5 years

-- qualification test laboratory has been established and only partially operational

Other Remarks: - the CPVC as previous PV program management agency (on behalf of SPC/SSTC is an institution without commercial interest and hence capable of safeguarding confidentiality of test results

E. Inputs

Chinese Inputs

(i) Each Chinese institution carrying out a Task of the Project will assign a Task Director who, on behalf of the institution, is personally responsible for the scientific results and managerial execution of the respective Task. The Chinese institution will consult with the National Project Coordinator when intending (or asked) to replace this individual

(ii) All Chinese institutions responsible for the execution of a Task of the Project will make, as far as existing and required, facilities and equipment available and will assign an adequate number of qualified staff to carry out the Task

(iii) The Chinese Government will assign a National Project Coordinator who on behalf of ACCA 21, SPC and SSTC will monitor the progress of the respective Tasks of the Project. The Project Coordinator will alert ACCA 21 in case corrective measures will have to be undertaken to safeguard the success of a Task or the Project. The Project Coordinator will furthermore monitor that national and international funds made available to the Tasks are spent appropriately. The Project Coordinator will also write and issue a English-language final Project report

(iv) It is expected that the Chinese Government (SPC, SSTC, ACCA 21) will contribute about US-$ xxx Mio (in the form of direct grants and/or loans) to the institutions executing the Tasks of the Project.

(v) The Chinese Government will, after the end of the Project, continue support of the PV Qualification Test Center in Hangzhou (Task 7) to an appropriate level to assure its continued functioning as a National PV Qualification Center. The Chinese Government also commits to encourage the continued utilization of the Qualification Test Center by Chinese PV industry

UNDP/UNIDO Inputs.

11 International Experts

11-01	Project Technical Advisor (PTA): this person to be recruited for making visits to the Project 5 times (for 1 month) over the Project's duration. The CTA will provide overall guidance in the implementation of the various Project Tasks and will closely interact with the Project Coordinator and the Task Directors. The CTA will be an expert in PV material- and system technologies.	5 m/m
11-02	Consultant on Poly-crystalline Silicon Ingot Casting (for Task 1): the experts will make one visit to assist during commissioning and test-runs of equipment installed (2 persons; 1 m/m each)	2 m/m
11-03	Consultant on Crystalline Silicon Solar Cell Processing (for Task 1). the experts will make one visit to assist in the optimization of the poly-silicon casting process by identifying modifications to the processes of solar cell production (2 persons; 1 m/m each)	2 m/m
11-04	Consultant on Silicon Material Wire Cutting (for Task 1). the expert will make one visit to assist in the training in wire-saw techniques and in improving cutting skills (1 persons; 0.5 m/m)	0.5 m/m
11-05	Consultant on Crystalline Silicon Solar Cell Processing (for Task 2). the experts will make one visit to advise in manufacturing techniques of higher-efficiency mono- and poly-silicon solar cells, in production equipment use, operational principles, quality assurance and other key issues (2 persons, 1 m/m each)	2 m/m
11-06	Consultant on Silicon Solar Cell Production Equipment (for Task 2). the expert will make one visit and will, as required, supervise and coordinate the installation of the solar cell production equipment and will advise on commissioning, start-up and process optimization (1 persons; 4 m/m)	4 m/m
11-07	Consultant on PV System Test Laboratories (for Task 3). the expert will make one visit to advise on the specification and design of a development and test laboratory for PV balance-of-system components and PV systems (1person, 1 m/m)	1 m/m
11-08	Consultant on PV System Test Equipment (for Task 3) the expert will make one visit to advise on commissioning and start-up of an indoor development and test laboratory for PV balance-of-system components and PV systems (1person, 1 m/m)	1 m/m
11-09	Consultant on PV System Test Equipment (for Task 3). the expert will make one visit to advise on commissioning and start-up of an indoor development and test laboratory for PV balance-of-system components and PV systems	1 m/m

	(1person. 1 m/m)	
11-10	Consultant on PV Demonstraton Project Planning (for Task 4). the expert will make one visit to advise on the demonstration project pre-survey activities and site selection (1 person. 1 m/m)	1 m/m
11-11	Consultant on PV System Design and Performance Monitoring (for Task 4). the expert will make one visit to advise on the design of stand-alone and particularly hybrid PV demonstration systems and the data acquisition for performance monitoring (1 person. 2 m/m)	2 m/m
11-12	Consultant on High-Efficiency Solar Cell Technology (for Task 5). the experts will make one visit each to advise on technologies of crystalline silicon high-efficiency solar cell technology, measurement and characterisation, and production (2 persons. 1 m/m each)	2 m/m
11-13	Consultant on High-Efficiency Crystalline Silicon Solar Cell Production (for Task 5). the expert will make one visit to advise in the process of installing and commissioning of laboratory and production equipment for high-efficiency crystalline silicon solar cells (1 person. 1 m/m)	1 m/m
11-14	Consultant on PV System Performance Monitoring (for Task 6). the expert will make one visit to advise on the design of data acquisition systems for the performance monitoring of stand-alone and hybrid PV systems (1 person. 1 m/m)	1 m/m
11-15	Consultant on PV Module Qualification Tests (for Task 7): the expert will make one visit to advise on the specification and design of a PV module qualification test laboratory (1 person. 1 m/m)	1 m/m
16	UNIDO Staff Travel	
	Total of three missions: for progress reviews and/or resolution of obstacles in the execution of the Project (1 person: 3x1 m/m)	3 m/m
31	Individual Fellowships	
31-1	Training in the process of operating poly-crystalline casting, ingot cutting and wire-cutting of silicon wafers (for Task 1: four persons. 1 m/m each)	4 m/m
31-2	Training in the fields of crystalline solar cell production processes and other technologies needed for higher-efficiency mono- and poly-silicon solar cells (for Task 2. four persons. 1 m/m each)	4 m/m
31-3	Training in specifying and operating indoor/outdoor performance and life-time testing of balance-of-system components and PV systems (for Task 3. two persons. 1 m/m each)	2 m/m
31-4	Training in the field of designing high-quality PV balance of PV balance-of-system components (DC/AC inverters. MPP-trackers. battery charge controllers electronic ballasts for DC-powered lights. etc) and application-specific PV systems (PV pumps. PV/wind hybrid systems. etc) (for Task 4. two persons. 3 m/m each)	6 m/m
31-5	Training in the field of crystalline silicon high-efficiency solar cell technologies and production (for Task 5. three persons. 2 m/m each)	6 m/m
31-6	Training in the field of crystalline silicon high-efficiency solar cell measurement and characterisation (for Task 5. two persons. 2 m/m each)	4 m/m
31-7	Training in the establishment of a PV module qualification test laboratories and in	

the qualification testing of PV Modules (for Task 5, two persons, 2 m/m each) 4m/m

32 Study Tours

None; visits to relevant institutions are to be organized within the training missions

41 Expendable Equipment

None

42 Non-expendable Equipment

See Task description for itemization of required non-expendable equipment and associated cost estimates.

F. Risks

	Potential Risks	*Estimated Likelihood*
1	Know-How Transfer to Industry: The ultimate objectives of Task 1 and Task 2 are reached only after materials resp. processes are sucessfully transfered to the domestic PV industry and have resulted in PV-modules of performance and quality better. – and production cost lower -. than todays products. Sucess therefore hinges on the willingness, ability and capability of the PV industry to absorb the know-how which was generated in these two Tasks. As this know-how is made available to industry for free but know-how implementation may require manpower training and investments, the risk is considered	Low/Medium
2	End-of-Project Equipment Utilization: Considerable investment in pilot production and test equipment will be made in participating institutions (in Task 2/BSERI and Task 3/HUASUN) in order to upgrade existing industry as a whole. As participating institutions like other R&D entitites are asked to earn operating and investment cost increasingly by contract R&D or commercial activities, BSERI and HUASUN may use this equipment for commercial purposes at the end of the Project, thus competing directly in a field which they were asked to help upgrade As it is proposed to decide on the final ownership of equipment in Task 3 at the end of the Project, and since BSERI is to become a center of excellence for advanced R,D&D in c-Si technologies, this risk is considered	Medium
3	Qualification Test Center Operation: In Task 7, the establishment of an accredited PV Module Qualifaction Test Center is proposed, to be augmented later by the capability to also test PV systems and balance-of-system components. Income from carrying out qualification tests will be inadequate to pay for a continued operation and maintenance of such a Center. Government authorities must commit to maintain operation of the Center on a continuing basis to justify the investment in the Center's infrastructure. As it is proposed that Government supports Task 7 beyond the end of the Project, this risk is considered	Low
4	Replication of PV System Demonstrations: While larger stand-alone systems such as PV village supplies or water purification/desalination facilities will require funding decisions by regional or local Government authorities, smaller systems such as PV home lighting systems will have to be acquired by private individuals. The ability to defray such expenses (in case of public funding) or to pay for such investment in installments (in the private sector) will be crucial for replication of PV systems beyond demonstrations and for the intended betterment of living conditions in remote off-grid regions of China.	

As it is intended to demonstrate not only high-quality well-functioning systems in important applications (building on the experience in precursor demonstrations) but also to experiment with financing instruments for private individuals, the risk that the demonstrations will trigger only few replications is considered — Low/Medium

5 Competitive Stance in PV High-End R&D The investments and activities in Task 5 aim to facilitate R&D in PV semiconductor fields which are highly competitive and fast moving internationally (thick- and thin-film k-Si solar cells with highest efficiency) To succeed in this field needs not only a high-class laboratory and infrastructure but also the skills and motivation of adequately trained scientific and technical personnel, as well as the ability to defray the operating cost of such activity over an extended period of time.

As BSERI is envisaged to become a center of excellence for k-Si PV R&D, and since income from BSERI's subsidiary SUNPU is available which can be used to support advanced PV R&D activities, the risk that China will not attain a competitive position in high-efficiency photovoltaics as a result of activities in Task 5 is considered — Medium

G. Prior Obligations and Pre-Requisites

Successful execution of this Project depends on the availability of National cost share funds in a timely manner

The Chinese Government (ACCA 21; SPC; SSTC) and the participating institutions (BSERI/SUNPU; GRINM; HUASUN; CPVC) will provide funds for all the counterpart activities as envisaged in this Project Document for the implementation of this Project. This includes provisions of counterpart funds for staff salaries, transport, travel costs, domestic training costs, procurement of indigenously manufactured equipment, capital costs and other related cost items. The Chinese Government will also provide the required staff for the national coordination of the entire Project

The Chinese Government shall also

(i) provide immediate English language training to those persons proposed to be sent to foreign locations for training in the form of fellowships.

(ii) ensure the release of these persons from their duties on the dates of the commencement of their fellowships.

(iii) provide local and field transport for the international consultants

(iv) defray all ground and air travel expenses in the country for the international consultants.

(v) provide suitable office accommodations, interpreters and other support requirements, as necessary, for the international consultants.

The Project Document will be signed by UNIDO, and UNIDO assistance to the Project will be provided, subject to UNIDO receiving satisfaction that the prerequisites and prior obligations listed above have been fulfilled or are likely to be fulfilled When anticipated fulfillment of one or more prerequisites fails to materialize, UNIDO may, at its discretion, either suspend or terminate it's assistance

H. Project Reviews, Reporting and Evaluation

(i) The Project will be subject to an annual review as part of the annual program reviews chaired by ACCA21 and attended by the National Project Coordinator (NPC), the Project Technical Advisor (PTA), the Task implementing entities (represented by the Task Directors/TD) and by representatives of the funding authorities Task status to date will be reported by the respective TD and and overall Project assessment will be provided by the NPC (written reports to be submitted by TD and NPC to the UNDP field office at least six weeks before these reviews) For each Task, the annual review will encompass, inter alia, schedule, funding, costs, personnel training, technical results, collaboration with

industry and users, technology/know-how transfer to industry, and the likelihood of attaining the Criteria of Success

The NPC shall further prepare and submit to each Project review meeting a Project Perfomance Evaluation Report (PPER), additional PPERs may be requested from the NPC, if necessary, during the Project

(ii) A Project Terminal report will be prepared by the NPC and TD for consideration at the Project Performance Review Meeting immediately following completion of the Project. It shall be made available in draft at least four months prior to the final review meeting to allow review and technical clearance by UNIDO and involved parties.

(iii) The Project shall be subject to the first review twelve months after the start of full implementation. The organization, terms of reference and timing of this review will be decided after consultation between the parties involved in the Project.

I. Legal Context

This Project Document shall be the instrument referred to as such in Art. 1 of the Standard Basic Assistance Agreement between the Government of the People's Republic of China and the United Nations Development Program, signed by the parties on June 29, 1979. The host country implementing agency shall, for the purpose of the Standard Basic Assistance Agreement, refer to the Government cooperating agency described in that Agreement.

The following types of revidisons may be made to this Project Document with the signature of the UNIDO represantative only, provided he/she is assured that the other signatories of the Project Document have no objections to the proposed changes:

(i) Revisions which do not involve significant changes in the immediate objectives, outputs or activities of the Tasks of the Project but are caused by the rearrangement of inputs already agreed to or by cost increases due to inflation, and

(ii) Mandadory annual revisions which rephase the delivery of agreed Project/Task inputs or increased expert or other costs due to inflation or take into account agency expenditure flexibility

The contractual agreements entered into by and between the Chinese Government and foreign suppliers/manufacturers of equipment shall contain all necessary terms, conditions and restrictions to provide full protection and shall be in accordance with applicable international standards (including, but not limited to patents and copyrights, if any) for the components and designs of the foreign supplier/manufacturer

The Chinese organizations/entities involved in this Project shall fully abide by all design and patent restrictions imposed by said contract.

The Chinese Government shall, on a continuing basis, indemnify and shall hold UNIDO harmless from all claims of any nature in connection with patent or intellectual property infringements that may arise from the activities of this Project

J. Budgets

Summary estimate of total costs by major budget category

Category	*Total Cost (in U.S.$)*	*National Grants in RMB yuan (in US$ equivalent)*	*Comm. Loans in RMB yuan (in US$ equivalent)*	*Grants from Intl Organizations (UNDP/UNIDO) (in U.S.$)*	*Other External Inputs (in U.S.$)*
Personnel	$	$	$	$ 566,500	$
Fellowships/ Training	$	$	$	$ 322,000	$

Study Tours	$ 0	$ 0	$ 0	$ 0	$ 0
Equipment	$	$	$	$ 1,958,360	$
Miscellaneous	$	$	$	$ 100,000	$
Totals	*$*	*$*	*$*	*$ 2,946,860*	*$*

K. Annexes

Annex A: Job Descriptions

A-1 Project Technical Advisor (PTA)

JOB DESCRIPTION
OF THE PTA - Project Technical Advisor

Post Number: XX/XXX/95/XXX

Post title: Project Technical Advisor (PTA)

Duration: One man/month per year over a period of five years, starting October 1995, with the possiblity of up to two additional man/month over the duration of the Project

Duty station: Beijing, with possible visits to Hangzhou and travels in the country and abroad (UNIDO, Vienna), plus work at home base

Purpose of Job: To reinforce the Chinese technical capabilities in manufacturing high-quality and high-perfomance photovoltaic components, to expand the utilization of photovoltaic systems and the market for PV applications in general, and to upgrade the possibilities to carry out advanced R,D&D in the field of crystalline silicon solar cells photovoltaic system components and photovoltaic systems..

Duties: The PTA will closely collaborate with the National Project Coordinator and the Task Directors in the elaboration, coordination, implementation and follow-up of the programs of work established for the defined Tasks. Specifically, the PTA will have the following duties:

(i) To participate in the annual Project/Task review meeting and to assess independently the progress of work in the respective Tasks, based on inputs received from the Task Directors and by on-site inspections of the Task sites.

(ii) To assist the National Project Coordinator and the Task Directors, if requested, in the resolution of technical issues which arise in the execution of the individual Tasks.

(iii) To assist UNIDO in the identification of individuals who could serve as international Technical Consultants for the Project, and in the writing of the terms of reference and job descriptions for these consultants;

(iv) To assist UNIDO in the identification of research institutions or industrial entities which could support the specialized technical training of individuals envisaged in the Project.

(v) To advise/assist the National Project Coordinator in the preparation of the Project Terminal Report at the end of the Project

Qualifications: University degree in Physics or Electrical Engineering, with a minimum of 15 years professional experience related to photovoltaics (cells, modules, components, systems, system applications) and in the management of scientific/-technological programs and projects

Experience in the collaboration with foreign partners will be an asset

Languages: English

A-2 Consultant on Poly-crystalline Silicon Ingot Casting

A-3 Consultant on Crystalline Silicon Solar Cell Processing

A-4 Consultant on Silicon Material Wire Cutting

A-5 Consultant on Crystalline Silicon Solar Cell Processing

A-6 Consultant on Crystalline Silicon Solar Cell Production Equipment

A-7 Consultant on PV System Test Laboratories

A-8 Consultant on PV System Test Equipment

A-9 Consultant on PV System Test Equipment

A-10 Consultant on PV Demonstration Project Planning

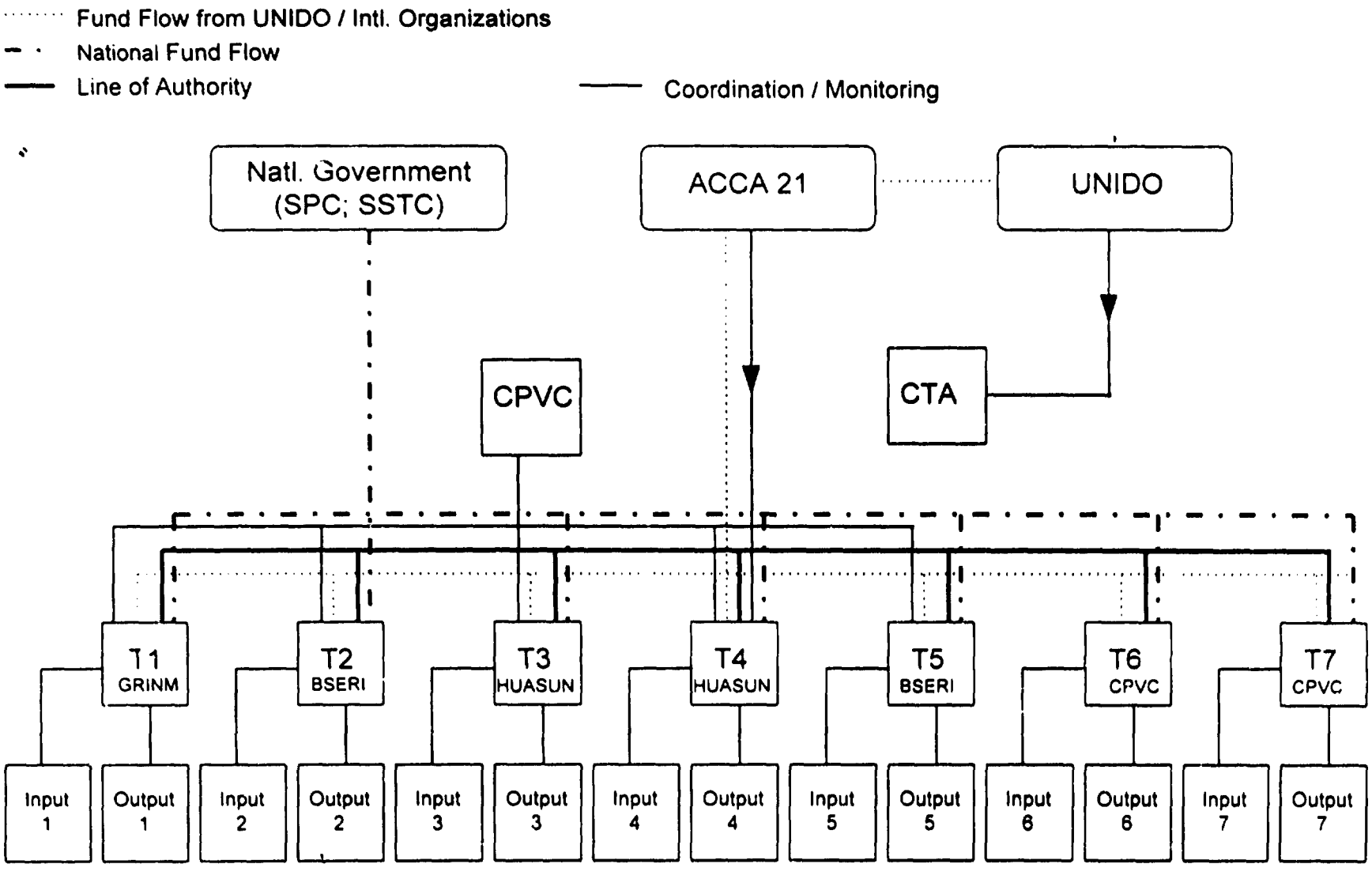
A-11 Consultant on PV System Design and Performance Monitoring

A-12 Consultant on High-Efficiency Crystalline Solar Cell Technology

A-13 Consultant on High-Efficiency Crystalline Solar Cell Production

A-14 Consultant on PV System Performance Monitoring

A-15 Consultant on PV Module Qualification Tests



PROJECT ORGANIZATION

Input: Equipment, Experts, Training
Output:

(UNIDO\chinapv1\projorg ppt)

Annex C:

C-1 Expected Market Expansion for PV Systems in China

Year	Annual Installed Capacity [Mwp/a]	Assumed Module Price [RMB/Wp][*]	Assumed System Cost [RMB/Wp]	Application Sectors
1989-1990	0.5-1.0	c-Si: 30-40 a-Si: 18-20	c-Si: 60-100 a-Si: 50-90	Decentralized Systems, Communications Systems, Small Pumping Systems (up to a few kWp)
1991-1995	5.0-10.0	c-Si: <20 a-Si: <12	c-Si: 40-50 a-Si: 30-50	Medium-size Power Station, Large Pumping Systems, Desalination Systems, etc (10-100 kWp)
1996-2000	10.0-50.0	c-Si: <15 a-Si: <8	c-Si: 30-50 a-Si: 25-45	Large-scale Stand-alone Systems for Commercial, Industrial and Residential Uses (0.1-1.0 MWp)
beyond 2100	> 100.0	5-10	20	Central Utility Applications (> 1.0 MWp)

[*] At the time of preparation of the table (1991), the exchange rate was 1 US-$ = 5.2 RMB, the exchange rate as of the end of 1994 was 1 US-$ = 8.36 RMB

C-2 Main Silicon Solar Cell and Module Manufacturers in China (as of End of 1994)

Manufacturer	***Huamei*** *Photovoltaic Electronics Ltd. (Qinhuangdao -Hong Guang Joint Venture)*	***Yunnan*** *Semiconductor Devices Factory*	***Kaifeng*** *Solar Cell Factory*	***Ningbo*** *Solar Cell Factory*	***GRINM*** *General Research Institute for Non-Ferrous Metals*	***Harbin*** ***Chronar***	***Sokun*** *Company*
Addresses			No. 38 Xinhuadong Rd., Kaifeng, Henan Prov. ZIP 475000 +86/?/ 557722	No 6, Jiangguo Rd.,Qinhuangdao, Hebei Prov., ZIP 066000 +86/551/ 331234 or 335394		Har-Ar Highway 1.5 km, Harbin Prov.	
Production Start	1992		1985		1987		
Technology	mono-crystalline	mono-crystalline	mono- and polycrystalline	mono-crystalline	poly-crystalline[10]	amorphous silicon	amorphous silicon
Production Capacity of Wafer Line	300 kWp/a	300 kWp/a	100 kWp/a	100 kWp/a	100 kWp/a	N/A	N/A
Production Capacity of Cell & Module Lines	1,000 kWp/a	500 kWp/a	300 kWp/a	300 kWp/a	100 kWp/a	1,000 kWp/a	1,000 kWp/a
Equipment Origin	whole line imported	whole line imported	key equipment import	key equipment import	Laminator imported	whole line imported	whole line imported
Production resp. Sales in 1994	300 kWp	200 kWp	250 kWp	220 kWp	?	?	?
Upgrading Needs	puller and saws	entire line	puller and saw	puller, saws and laminator	entire line		

C-3 Efficiencies of Solar Cells developed/manufactured in China (as of 1988)

Cell Type	*Efficiency (Cell Area)*		*Test Conditions*
	Laboratory	*Production*	
PESC c-Si	20.27% (1 cm²)		AM 1.5
c-Si	15.6% (1 cm²)	10-13 (5" Diam)	AM 1.5
BSFR c-Si	13-14% (1 cm²)		AM 0
polycrystalline c-Si	13% (100 cm²)	8-10 (100 cm²)	AM 1.5
GaAlAs/GaAs	18-19% (1 cm²)		AM 1.0
CuS/Cd	8-9% (10 cm²)		AM 1.5
a-Si	9.8% (100 cm²)	5 (30x30 cm²)	AM 1.5

[10] Crystall puller and wafer ID-saw not in operation at the present time

C-4 Installed PV System Capacity in China by the end of 1990

Application Sector	*Application*	*Installed Power [kWp]*
Communication	μ-Wave Relay Stations; TV Transmitters, Terrestrial Satellite Stations; Carrier Telephone Systems; etc	400
Remote Areas & Rural Use	PV Power Stations; Lighting and TV Systems; Insect Trap Lights; Electric Fences; Water Pumping Systems, etc.	500
Transportation	Beacons; Light Houses; Highway and Railway Signaling Systems, etc.	100
Cathodic Protection	Sluice Gates; Oil Pipelines; Bridges; etc	25
Monitoring Stations	Meteorological Stations; Fire Warning Systems; Earthquake Stations; High Water Warning Systems; etc	25
Others	Tour Boats; Street Lights; Toys; etc.	200
Total		*1,250*

C-5 Proposed PV Demonstrations

The following demonstrations are proposed:

- Remote PV Home Systems
- Hybrid PV/Wind Power Supply System
- Solar Pumping Systems for Small Irrigation
- Solar Pumping Systems for Potable Water
- Demostration for islands (include desalination system)

PROPOSED PROJECTS

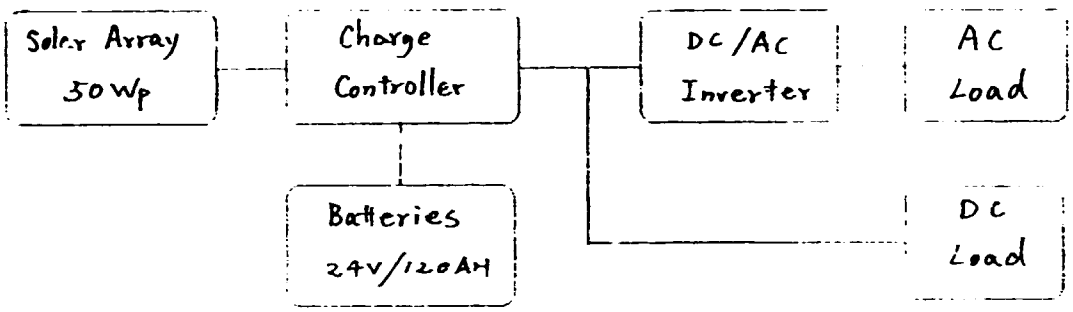
1. Remote PV Home Systems

Unit Power: 50 Wp
Number of the systems: 60 sets in 3 regions
Total Power: 50 Wp X 60 = 3 KW
Location: Qinghai Province
Local Cooperator: Qinghai Energy Research Institute
Load Specifications for One Set.

Load	Unit Power (W)	Number of Load	Daily Working Time (hours)	Daily consumption (WH)
Fluorescent Lights	14	2	5	140
Colour TV Set	60	1	5	300
Washing Mach.	120	1	0.5	60
Others	40	1	1	40
Total				540

Weather and Geographical Conditions:
Latitude: 36.5 N
Longitude: 98.6 E
Elevation: 2800.0 M
Annual Sunshine: 3000 Hours
Annual Global Radiation: 170.0 Kcal/cm2

System Diagram:



Project Duration: 2 Years (include 1 year test running and D/A)

Input:

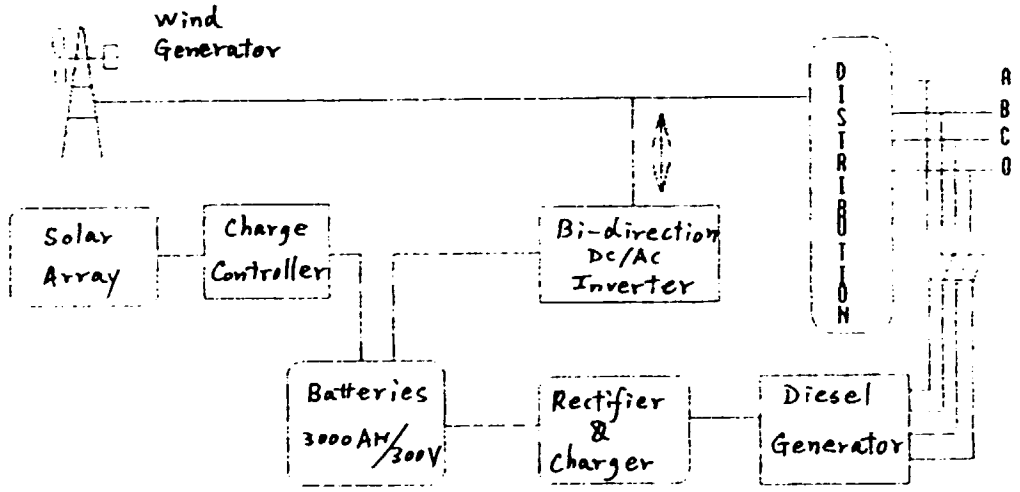
Item	Contents	Input (USD$)
Site Identification & Selection	3 places in Qinghai Province	see common issue
Solar Array	50Wp × 60sets = 3KWp	21,000
Batteries	24V · 120AH × 60sets	16,000
Controllers	60 sets	4,000
Data Acquisition System	6 sets	12,000
DC/AC Inverter	150W × 60 sets	5,000
Transportation & Installation		10,000
Experts	1 m/m	10,000
Training for Local People	3 m/m	4,500
Training Abroad	see common issue	see common issue
Project Management	2 years	see common issue
Total		82,500

2. Hybrid PV/Wind Power Supply System

Capacity: 30 KW (10KWp from PV and 20KW from wind)
Location: One village in Inner-Mongolia
Local Cooperator: New Energy Office of Inner-Mogolia
Operating Mode: Both wind generator and PV array charge the battery through charging controller. DC/AC stand-along inverter supply the power to the local grid and another inverter is backing up. Diesel Generator can be used as charger when battery is low or can supply the power directly to the local grid when inverter gets into troubles.
Daily Working Time: 8 Hours
Back Up Power Source: 55 KVA Three Phase Diesel Generator

System Feature

PV Power	10 KW
Wind Power	20 KW
Back Up Diesel Generator	55 KVA
Batteries	3000 AH/300V
Controlling & Data Acquisition System	2 set
30KVA DC/AC Inverter	2 set
Distribution System	1 set
Rectifier and Charging Controller for Diesel	1 set



Weather and Geographical Conditions:
Latitude: 41.2 N
Longitude: 112.0 E
Elevation: 1000.0 M
Annual Sunshine: 2800 Hours
Annual Global Radiation: 158.0 Kcal/cm2

Project Duration: 3 Years (include 1 year test running and D/A)

Input:

Item	Contents	Input (USD$)
Site Identification & Selection	1 place in Inner-Mongolia	see common issue
Local Construction	200 M^2	50,000
Local transmission line	1 KM	20,000
Solar Array	10 KWp	70,000
Wind Generator	20 KW	80,000
Diesel Generator	55 KVA	30,000
Batteries	3000 AH/300V	80,000
Charge Controller	1 set	20,000
Data Acquisition System	1 set	10,000
30KVA DC/AC Inverter	1 set	60,000
Distribution System	1 set	10,000
Rectifier and Charging Controller for Diesel	1 set	10,000
Transportation & Installation		30,000
Experts	1 m/m for pre-survey 1 m/m for system design	20,000
Training for Local People	3 m/m	4,500
Training Abroad	see common issue	see common issue
Project Management	3 years	see common issue
Total		494,500

3. PV Pumping for Small Irrigation

Unit Power: 2.5 KW

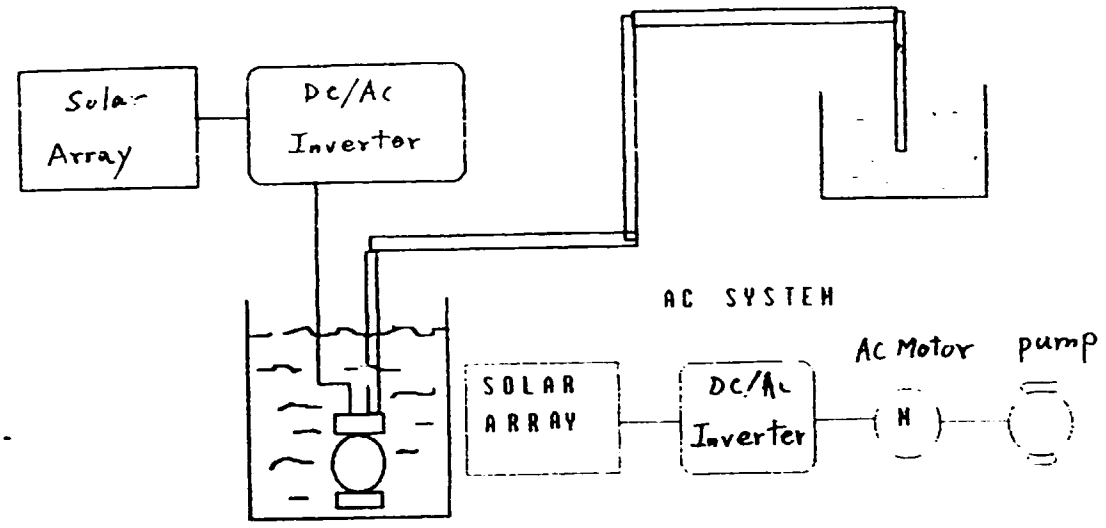
Numbers of The System: 3 sets

Location: 3 places in Tibet

Water Table: 20 M

Water Needs: 20 M^3 in each place

Objectives: In the north-west part of Tibet, vegetables can only be planted in green house. Irrigation for the green house is always a problem since electricity is only available in the evening when diesel generator start up for 3 hours lighting. PV pumps are the excellent solution for the green house irrigation.



Weather and Geographical Conditions:

Latitude: 30.0 - 34.0 N
Longitude: 81.0 - 93.2 E
Elevation: 3500 - 4500 M
Annual Sunshine: 3000 - 3300 Hours
Annual Global Radiation: 180.0 - 200.0 Kcal/cm2

Project Duration: 2.5 Years (include 1 year test running and D/A)

Input:

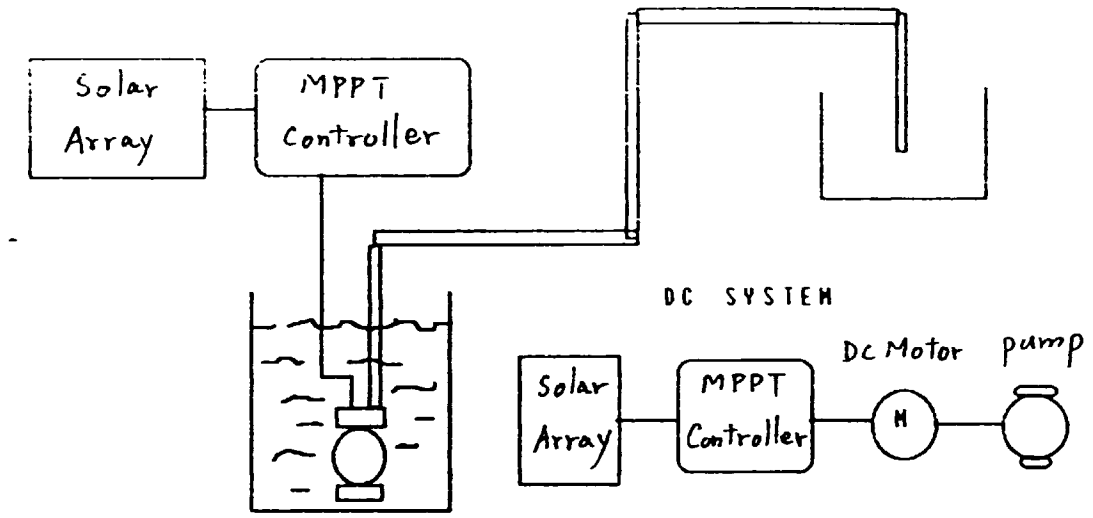
Item	Contents	Input (USD$)
Site Identification & Selection	3 places in Tibet	see common issue
Solar Array	2.5KW × 3	54,000
Inverter & Controller	3 sets	18,000
Pumps	3 sets	3,000
Data Acquisition System	3 sets	6,000
Transportation & Installation		15,000
Experts	1 m/m for system design	10,000
Training for Local People	3 m/m	4,500
Training Abroad	see common issue	see common issue
Project Management	2.5 year	see common issue
Total		110,500

4. PV Pumping for Potable Water

Unit Power: 500 W
Numbers of The System: 4 sets
Location: 4 places in Inner-Mongolia
Water Table: 20 M

Water needs [illegible]

Objective: [illegible] sets of PV pump [illegible] to supply portable water for irrigation and domestic animal.



Weather and Geographical Conditions:

Latitude: 40.0 - 42.0 N
Longitude: 87.0 - 120.0 E
Elevation: 800 -1200 M
Annual Sunshine: 2600- 2900 Hours
Annual Global Radiation: 150.0 - 170.0 Kcal/cm2

Project Duration: 2.5 Years (include 1 year test running and D/A)

Input:

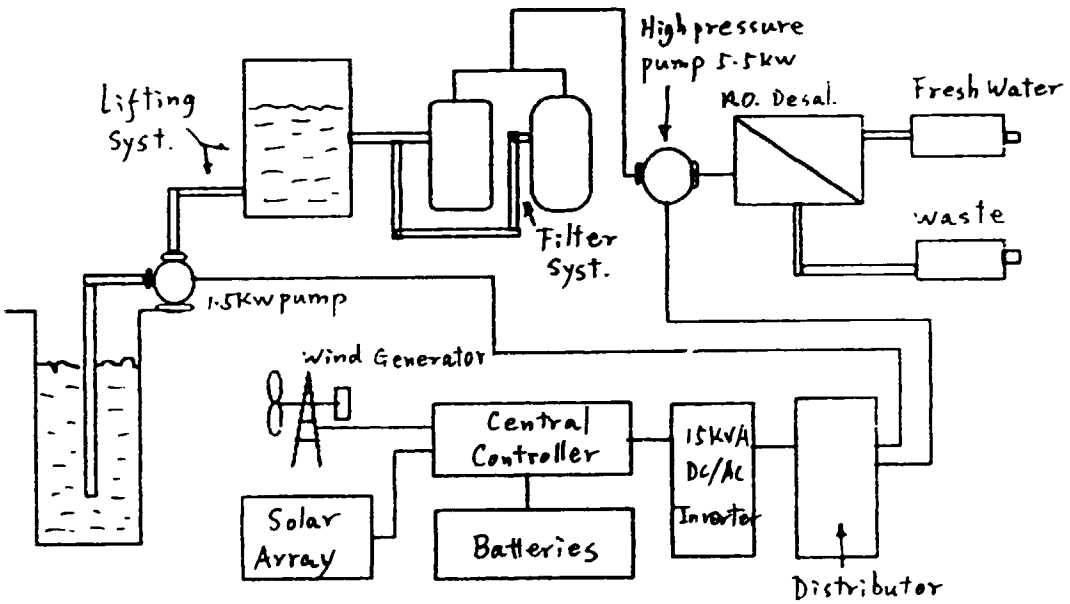
Item	Contents	Input (USD$)
Site Identification & Selection	4 places in Inner-Mongolia	see common issue
Local Construction	Well Digging · 4	20,000
Solar Array	500Wp · 4	15,000
Controller	4 sets	6,000
Pumps	4 sets	4,000
Transportation & Installation	4 places	15,000
Experts	1 m/m for pre-survey 1 m/m for system design	20,000
Training for local people	4 people	6,000
Training Abroad	see common issue	see common issue
Project Management	2.5 years	see common issue
Total		86,000

5. PV Desalination System for Island

Capacity: 15 KW (5KW from wind-generator, 10 KW from PV)
Location: Chang Island, Shandong Province
Cooperator: State Oceanic Bureau of China
Operational Mode: Power supply for a desalination system

System Feature

PV Power	10 KW
Wing Power	5 KW
Batteries	1000 AH/300V
Controlling System	1 set
15KVA Inverter	1 set
Distribution System	1 set
Water Lifting System (with 1.5KW Pump)	1 set
Reverse Osmosis Desalination Syst. (with 5.5KW high pressure pump)	1 set
Fresh Water Output:	15 M^3/Day



Weather and Geographical Conditions:
Latitude: 37.5 N
Longitude: 121.4 E
Elevation: 16.0 M
Annual Sunshine: 2400 Hours
Annual Global Radiation: 120.0 Kcal/cm2
Annual Average Wind Speed: 6-9 M/S

Project Duration: 3 Years (include 1 year test running and D/A)

Input:

Item	Contents	Input (USD$)
Site Identification & Selection	Chang Island in Shandong Province	see common issue
Infrastructure & Housing	100 M²	50,000
Solar Module	10 KWp	70,000
Wind Generator	5 KW	20,000
15KVA Inverter	15 KVA	30,000
Batteries	1000 AH/300V	30,000
Distribution System	1 set	5,000
Water Lifting System	with 1.5KW pump	10,000
RO Desalination Equipment	with 5.5KW high pressure pump	20,000
Charging Controller	1 set	10,000
Data Acquisition	1 set	10,000
Transportation & Installation		20,000
Experts	1 m/m for pre-survey 2 m/m for system design	30,000
Training for local people	2 m/m	3,000
Training Abroad	see common issue	see common issue
Project Management	3 years	see common issue
Total		308,000

Budget for Common Issue:

Items	Contents	Input (USD$)
Site Identification & Selection	For 5 demostrations	50,000
Project Management	3 years	30,000
Training Abroad	8 m/m	40,000 -
Total		120,000

Project Budget:

Items	China Input (USD$)		Donor Input (USD$)		Total (USD$)
	Grant	Loans	Grant	Soft Loans	
Experts			90,000		90,000
Training for Local People	22,500				22,500
Training Abroad			40,000		40,000
Project survey & pre-conditioning	50,000				50,000
Constructions	40,000	100,000			140,000
Equipment	100,000	359,000	100,000	200,000	759,000
Transportation & Installation	50,000		40,000		90,000
Project Management	30,000				30,000
Total	280,000	564,000	345,000	300,000	1,221,500

Time Schedule:

Demo Project	Remote PV Home Systems			
Activities	1st Year		2nd Year	
	M 1-6	M 7-12	M 1-6	M 7-12
Proj. Survey				
Contract Date				
Local Construction				
Equipments Manufacturing				
Tech Training				
Shipment				
Installation				
Training for Local People				
Test Running & D/A				

Demo Project	Hybrid PV/Wind Power Supply System					
Activities	1st Year		2nd Year		3rd Year	
	M 1-6	M 7-12	M 1-6	M 7-12	M 1-6	M 7-12
Proj. Survey						
Contract Date						
Local Construction						
Equipments Manufacturing						
Tech Training						
Shipment						
Installation						
Training for Local People						
Test Running & D/A						

Demo Project	PV Pumping for Small Irrigation				
Activities	1st Year		2nd Year		3rd Year
	M 1-6	M 7-12	M 1-6	M 7-12	M 1-6
Proj. Survey					
Contract Date					
Local Construction					
Equipments Manufacturing					
Tech Training					
Shipment					
Installation					
Training for Local People					
Test Running & D/A					

Demo Project	PV Pumping for Potable Water				
Activities	1st Year		2nd Year		3rd Year
	M 1-6	M 7-12	M 1-6	M 7-12	M 1-6
Proj. Survey					
Contract Date					
Local Construction					
Equipments Manufacturing					
Tech Training					
Shipment					
Installation					
Training for Local People					
Test Running & D/A					

Demo Project	PV Desalination System for Island					
Activities	1st Year		2nd Year		3rd Year	
	M 1-6	M 7-12	M 1-6	M 7-12	M 1-6	M 7-12
Proj. Survey						
Contract Date						
Local Construction						
Equipments Manufacturing						
Tech Training						
Shipment						
Installation						
Training for Local People						
Test Running & D/A						