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**UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION**

# PROJECT DOCUMENT

***Project of the Government of the People's Republic of China***

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| **Title:** | **Research, Development and Diffusion of New Types of High-Performance Solarthermal Collectors** (Project 4.5A. Part 2. in the Priority Program of China's Agenda 21) | |
| **Budget Estimate:** | UNIDO | US-$ |
| | Chinese Government Contributions | US-$ |
| | Total Project Cost | US-$ |
| **Starting Date:** | September 1995<br>Planned Duration: 36 months | |
| **Project Site:** | Beijing, China | |
| **Host Country Implementing Agency:** | Beijing Solar Energy Research Institute (BSERI). Beijing | |
| **Backstopping Officer:** | R. Kaulfersch | |
| **Division/Section:** | ISED/EM | |

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**Project description:**

This project seeks to facilitate in China the research, development of new types of high-performance, vacuum-insulated tubular solar-thermal collectors and their diffusion and market penetration on a large scale by (i) carrying out system-level performance demonstrations in intermediate-temperature (up to 200°C) applications such as industrial process heat and solar-assisted space cooling, and (ii) designing and implementing a production facility for these new designs of solar collectors. in particular. the following activities are envisaged:

- Setting-up of an R&D laboratory with the capability (i) to produce flanges on glass tubes up to 200 cm length and 15 cm diameter. (ii) to produce and (iii) to experiment with glass-metal end seals on glass tubes up to 15 cm diameter. (iv) to evacuate and outgas glass tubes with metal end seals. and (v) to produce highly selective coatings on aluminum surfaces by magnetron sputtering;

- Training of technical staff to perform advanced R.D&D work in glass-metal technology;

- Development and performance-testing of advanced designs of evacuated-tube-collectors (ETC) of higher efficiency of the (i) concentric tube (tube-in-tube) type. (ii) the storage (cylindrical absorber) type, and (iii) the bent-absorber type (with heat pipes or concentric tubes)

- Demonstration of the suitability and performance of advanced ETCs in several intermediate-temperature applications of high relevance for China (e.g. solar-assisted space-conditioning, industrial process heat generation); and

- Carrying out (i) a full engineering design of a production line for advanced ETCs with a production capacity of 30-40,000 m2/a and 80-100,000 m2/a, respectively, and (ii) the construction of such production facility

## A. Context

### 1 Description of the Subsector

Coal currently provides 75% of China's primary energy needs and is used primarily in the chemical and electricity generating industries and for the production of space and industrial process heat. Recent projections envisage ~1,420 million tons of coal consumption by the year 2000, 38% of which (540 Mtc/a) destined to be burned for producing electricity. By 2010, consumption is expected to rise to ~2,100 million tons of coal of which 60% (1,260 Mtc/a) are to serve electricity generation purposes.

The efficiency of present coal firing technologies is low by international standards and specific coal consumption correspondingly high. In large coal-burning installations, environmentally harmful and health-hazardous emission of $CO_2$, $SO_2$ and particulates can, in principle, be minimized (e.g. fluidized bed combustion and combined-cycles). Emission control in small coal burning units (<20kW$_t$), on the other hand, is technologically demanding and difficult to implement, considering the large number and mostly private ownership of these units.

Environmentally benign utilization of (renewable) solar energy for the generation of low-temperature thermal heat has the potential of significantly alleviating this problem on local level. Solar-generated heat can be used to produce domestic warm water (solar water heating), warm air for the drying of produce (solar drying), heat for the preparation of meals (solar cooking), process heat for commercial and industrial purposes (solar industrial process heat) and thermal energy for the control of comfort in living spaces (solar-assisted space conditioning; passive solar houses).

The specialized technologies for providing these services are under development over 15 years in China and elsewhere. Technologies which became mature and encountered receptive marketing conditions are commercial. In China, solar water heaters have been produced for more than 15 years in different varieties and are, disregarding hydropower, the most successful example to date of renewable energy utilization. Production of collectors for solar water heating systems reportedly has reached ~600,000 m²/a, well the largest production in one country worldwide. Of this volume, 1/3 is produced by one manufacturer (of this, 20% for export) and the rest by more than 100 small-to-medium-size enterprises (SMEs). The variety of collector types (mostly flat-plate) and the span in quality of components and systems produced is large (mostly marginal).

Given the favorable insolation conditions and the potential for services beyond the provision of domestic warm water, there is the urgent need in China to upgrade solar-thermal technologies towards higher efficiency, performance, quality and cost-effectiveness; all-glass evacuated-tube solar collectors are a prime candidate technology for reaching these goals. The solar evacuated-tube-collectors already developed provide a good basis and chance for such undertaking.

### 2. Host Country Strategy

The Government of China recognizes the value of renewable sources of energy (in terms of safeguarding the environment and for improving living conditions) for the augmentation of present and future energy supplies. In 1992, the State Council defined 10 measures/steps concerning environmental protection and national development. It declared that "the technologies for the utilization of the clean solar, wind, geothermal, tidal and biomass energies shall be developed and their use disseminated commensurate with local conditions". Also, a number of renewable energy R,D&D and dissemination projects were carried out within the "8th Five-Year Plan".

The Government of China recognizes the significant contribution which solar-thermal utilization can in principle, make to reduce coal consumption (for low-temperature heat production), environmental degradation and health hazards. It desires to upgrade the present technological level by strengthened R,D&D, to transfer new technology into production, and to stimulate commercialization and application dissemination.

### 3 Prior and Ongoing Assistance

In the past, the solar-thermal industry enjoyed considerable support by the Government of China (financial; manpower), by R&D institutes and universities (technological know-how) and through the scientific-technological cooperation with foreign countries (equipment, expertise). Guidelines for technology development were provided by national standards for flat-plate solar collector performance rating (GB 4271-84) and for the quality assessment of solar collector products (GB 6424--86). These activities gave considerable impetus to technological development and lead to product improvement and diversity.

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* focuses on the pressing problems of population growth, sustainable exploitation of natural resources, environmental preservation and continued development. In this context, 62 executable project proposal were identified. This Project on „Research, Development and Diffusion of New Types of High-Performance Solarthermal Collectors", being based on program areas 12B, 12C and 13D of China's Agenda 21, is one amongst the projects selected for cooperation between China, UNDP/UNIDO and other countries (belonging to Priority Area 3 „Clean Energy and Transportation"). It is envisaged that ~2.5 Mio$ from the Government of China and (and ~ 2.4 Mio$ from external sources) will be invested in this Project.

4. Institutional Framework

National R&D centers were established to coordinate and advance the development of technologies for wind, biomass/biogas, geothermal, small hydropower and solar-electric (PV) energy utilization, such institution does not exist for solar-thermal technologies. Solar-thermal technological advance depends to a large degree on the initiative of individuals and institutions.

BSERI has been at the forefront of solar-thermal technical advances since its establishment in 1979 (flat-plate collectors; Sunstrip® absorbers, heat-pipe evacuated-tube-collectors). BSERI is the responsible executing agency in this Project for R,D&D on component and system level, while its wholly-owned manufacturing subsidiary SUNPU Co. will be responsible for commercial production of evacuated-tube-collectors and marketing of products and systems.

## B. Project Justification

1. Problem to be Addressed / The Present Situation

In China, a variety of solar collectors for water heating has been developed and solar warm water systems been produced for over 15 years, ranging from very simple designs to more complex configurations. Over these years, the market for solar warm water systems developed gradually but steadily, with domestic warm water (DHW) systems attaining considerable popularity to date. Most of the solar water collectors produced today are of the flat-plate type with single glazing and black-paint/low-grade absorptive coating of absorbers. Only few collectors produced are of the higher efficiency, vacuum insulated type.

The solar water heating industry is characterized by a large number (about 180) of predominantly small or medium-size enterprises (and even University institutes) which produce domestic hot water systems in often small quantities (1,000-2,000 $m^2/a$) and with quality standards customary for such industry in China. One company produces about 1/3 of the annual national output in absorbers, however, for domestic industry as well as for export (anodized aluminum strips roll-bonded onto Cu-tubing), using a Swedish license and imported machinery. China is said to be the largest producer of solar absorbers, solarthermal collectors and DHW systems in the World, with an annual production equivalent to about 600,000 $m^2$.

DHW systems produced are installed mainly in rural but also urban areas. Around 85% of the DHW systems produced are of the one-loop thermosyphon (natural circulation) type with storage tank separate from the collectors (two-loop systems are more costly and need assured line electricity for pumped circulation and electronic controls).

While quality, lifetime and production cost of flat-plate collector DHW systems produced would need upgrading in general, there also is the need (and ample application opportunity) in China for more efficient solarthermal collectors which provide DHW over longer periods of time of the year, or which produce intermediate- to high-temperature heat for industrial/commercial processes (e.g. in the food processing and textile industries or in hospitals) or for space cooling (e.g. air-conditioning of hotels or offices or cold storage of food). While the demand for process heat is particularly large in the North of the country, space-conditioning is particularly important for regions of South China.

As an outcome of a Sino-German technical cooperation project and after considerable indigenous development work for adaptation, a novel technology for a high-efficiency heat-pipe all-glass evacuated tube collector (ETC) was successfully transferred and a pilot production line established by the end of 1994 (for about 30,000 tubes/a equivalent to ~ 6,000 m²/a) The production relies completely on domestically produced materials and half-products. The ETCs have been used in high-quality DHW systems, samples of which were marketed domestically at competitive prices and favorable cost/benefit ratios (compared to standard flat-plate collectors).

Using different absorber- and heat-transfer designs and larger glass-tube diameters, the heat-pipe ETC technology can be replaced and upgraded for higher efficiency, operating temperatures up to 250°C, higher annual performance, adaptation for specific applications and/or for lower production cost, provided that a domestic R&D capability can be established to pursue advanced glass-metal materials vacuum-tightness issues.

The Project, therefore, aims to establish modern methods and R&D capacities for advance development of highly efficient solar ETCs, for transfer of this technology into pilot production, and for the technological and economic demonstration of ETC technology in intermediate-temperature solar applications in China. The Project will upgrade the knowledge about advanced solarthermal systems, about the ability to produce them, and about the capability of these systems to assist in alleviating an increasing National demand for thermal energy.

2. Expected End-of-Project Situation

Upon completion of the Project, it is expected to have achieved the following:

1. an R&D laboratory will have been set up with the capability (i) to produce flanges on glass tubes up to 200 cm length and 15 cm diameter, (ii) to produce and (iii) to experiment with glass-metal end seals on glass tubes up to 15 cm diameter, (iv) to evacuate and outgas glass tubes with metal end seals, and (v) to produce highly selective coatings on aluminum surfaces by magnetron sputtering;

2. technical staff will have been trained to perform advanced R,D&D work in glass-metal technology;

3. alternate designs of ETCs of the (i) concentric tube type, (ii) the storage type, and (iii) the parabolic absorber type will have been developed and performance tested;

4. the performance of advanced ETCs will have been demonstrated in several intermediate-temperature applications of high relevance for China; and

5. an engineering design for a large-volume production line of advanced ETCs will have been carried out and such production line will have been installed and commissioned.

3. Target Beneficiaries

The immediate beneficiary of the Project will be the Beijing Solar Energy Research Institute (BSERI) and the BSERI manufacturing subsidiary, SUNPU Co.. The secondary beneficiary will be the Chinese society as a whole which will get access to a technology of the future which, under the climatic and insolation conditions of the country, can significantly contribute to stem the demand for fossil-based energies. The tertiary beneficiaries will be the agencies and organizations participating in the Project and the institutions and societies (e.g. ISES) encouraging the utilization of renewable energies in China.

4. Project Strategy and Institutional Arrangements

The Project builds on the expertise, know-how and competence on solar evacuated-tube-collector (ETC) technology which has been developed by BSERI over the past two years (1993-1994). BSERI will be the sole responsible counterpart executing institution in this Project but will collaborate during Project execution with other R&D entities domestically and internationally in the field of glass-metal and evacuated-glass-tube technology (one R&D institution in China pursues a very different ETC design, however only for domestic hot water supply).

The execution of the Project will be assisted by a National Project Coordinator (NPC) and by Chief Technical Advisor (CTA), both individuals being engaged on a part-time basis. Chinese national financial contributions which are expected from SSTC and/or SPC for the Project shall be channeled directly to BSERI based on the advice of the NPC, while financial assistance to the Project (for equipment and in-country expenditures, if any) from international organizations or foreign national bodies shall be channeled to BSERI via ACCA 21 (based on the advice of the NPC and CTA, if UNDP/UNIDO so desires).

5. Reasons for Assistance from UNIDO

UNIDO through its international arrangements, has the ability to provide a package of goods and services without national restrictions and to provide technical assistance quickly through its links with industry in developed countries. This Project will provide increased capacity building in the form of upgraded solar-thermal 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 Chief Technical Advisor, by International Experts and by Training of Chinese scientists/engineers in solar-thermal technologies and related issues, but also is able to solicit the funding support for major equipment items from the international communities.

6. Special Considerations

The Project is specifically designed to address environmental issues, e.g. alleviating energy shortages, reducing atmospheric emissions from fossil fuel combustion and, in general, preserving the environment.

It is predicted that demand for low-temperature thermal heat in China (for heating, warm water, process heat) will rise significantly in the coming years in parallel with overall economic development. If the pattern in industrialized countries is any guide, it can be expected that about 40-50% of primary energy input will be utilized in this sector. Given China's favorable climatic and insolation conditions and still large percentage of population living in rural areas, intelligent solar-thermal utilization will be one of the most promising option to stem the tide of rapidly increasing demand for fossil energy, inevitably influencing negatively the environment on local, regional and even national level. Disregarding electricity generation with large machines (>300 $kW_e$) at favorable sites ($v_{wind}$>5m/s annual average), solar-thermal heat generation to satisfy low-temperature needs will also be very promising in terms of cost-effectiveness compared to supply alternatives.

Vigorously developing and implementing this renewable energy technology in China immediately, will therefore be an important activity safeguarding the national future well-being.

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

(i) Coordination Arrangements

Overall Project coordination will be carried out by the National Project Coordinator (NPC).

(ii) Links/Coordination with other Projects in Subsector

None, as there are no other major R.D&D activities in the solar-thermal field in China at present.

8. Capability and Commitment of Host Country

China has committed to safeguarding it's future by adopting the Agenda 21 White Paper and establishing an administrative center at the highest level for carrying out the initiatives defined. It is to be expected that funds adequate to carry out the initiatives will be made available by China (national funds).

The ultimate success of the Project towards providing energy by environmentally benign means depends to a significant degree on the success to develop suitable technologies and to produce them at quality and cost commensurate with purchasing powers (of equipment users) and energy supply alternatives (which impact the environment). The success of the Project executing counterpart organization in adopting foreign-developed technologies for solar-thermal systems (Sunstrip' absorbers, heat-pipe ETC prototype production line) attests to the capability to execute this ambitious Project.

**F. Development Objective**

The priority program for China's Agenda 21, in priority area 4-5A, seeks to facilitate the research, development and diffusion of new types of high-performance collectors.

The Project therefore aims to promote solar-thermal utilization in China by

(i) establishing the capability to conduct R&D in and to develop evacuated tube collector (ETC) technology.
(ii) conducting technical investigations and R&D work to develop new types of ETCs which are of larger diameter, more efficient, more adapted to specific applications and/or more cost-effective.
(iii) designing, building, operating and performance-monitoring several solar-thermal systems, using the new types of ETCs developed.
(iv) by preparing for the large-scale production of such new types of ETCs via the engineering design of a production line for 30~40,000 $m^2$/a and 80~100,000 $m^2$/a capacity, respectively

## D. Immediate (Task) Objectives, Outputs and Activities

***Part 1*** *(ETCLAB)*

**Output**: Re-establishment of a laboratory for the development, assembly and test of new types of solar-thermal evacuated tube collectors (ETC), comprising, inter alia, (i) a magnetron sputtering facility to produce highly selective absorptive coatings on Al- and Cu-substrates, (ii) a facility to make and to experiment with vacuum-tight glass-metal seals, (iii) a lathe for fabricating glass-flanges on glass-tubes of varying diameter, (iv) a facility for the outgassing of tubular assemblies, and (v) a test facility for the performance testing of ETCs

**Activities**:

1-1 Assembly of a Chinese counterpart team (consisting of eight engineers specialized in the technology of solar-thermal collectors, and four engineers specialized in the field of solarthermal system design)
1-2 Establishment of links with between the counterpart team and universities or R&D institutions (nationally and internationally)
1-3 Fellowship of one person for 2 m/m to receive training abroad on solar-thermal system simulation and space conditioning technology
1-4 Procure funding for the intended investment
1-5 Specify, tender and procure laboratory equipment and facilities
1-6 Install, test-operate and commission procured equipment
1-7 Fielding of one international expert in the field of solar-thermal performance measurement and measurement equipment for 1 m/m

**Responsible**: Dr He Zinian, Solarthermal 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* |
|---|---|---|
| Glass flange forming machines | $ 130,000 (import) | D = Ø100 ~ 150 mm (2 units) |
| Photo glass-stress detector | $ 10,000 (import) | D = Ø250mm |
| Molecular pump | $ 30,000 (domestic) | v = 450 l/s, p < $10^{-9}$ |
| Temperature controller | $ 25,000 (domestic) | t = 0~500°C, ±0.5 °C @ 500°C |
| Supersonic cleaning equipment | $ 10,000 (domestic) | P = 500W, 50 l capacity |
| Vacuum annealing apparatus | $ 50,000 (domestic) | V = Ø300x1,000mm, $10^{-6}$ @ 500°C |
| Air compressor | $ 5,000 (domestic) | v = 0.15 l/s |
| TIG Welding machine | $ 30,000 (import) | I = 200A (2 units) |
| Multi-metal cutting machine | $ 25,000 (domestic) | D = Ø100mm |
| High-frequency heating facility | $ 30,000 (domestic) | P = 15kW |
| Sputtering facility | $ 250,000 (import) | Ø500 – 1,000mm |
| Solar simulator system | $ 20,000 (import) | A = 2,000x400mm |
| High-temperature thermostat | $ 20,000 (import) | t = 0 – 500°C |
| Measuring and D/A equipment | $ 20,000 (import) | temp., heat flow, flow rate |
| IR spectrophotometer | $ 65,000 (import) | λ = 2.5 – 50μm |
| Absorptivity measuring apparatus | $ 20,000 (import) | α = 0.01 – 1.00 |
| Emissivity measuring apparatus | $ 40,000 (import) | t = 0 – 350°C |

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|---|---|---|
| Infrastructure | None | room, power line connections, etc available at BSERI |
| Training abroad; Fellowships | $ 21,000 | 1 x 2 m/m |
| Experts; Consultants | $ 22,000 | 1 x 1 m/m |
| *Totals: (i) equipment* | *$ 580,000 (imported)* | |
| | *$ 208,000 (domestically procured)* | |
| *(ii) training, experts* | *$ 43,000* | |

Existing laboratory facilities and measuring equipment (dedicated to pilot-prduction-line use)

| *Facility; Equipment* | *Year of Acquisition* | *Type* | *Remarks* |
|---|---|---|---|
| Magnetron Sputtering Facility | 1990 | Domestic | Ø500x1,000 mm |
| Residual Gas Analyzer | 1993 | Leybold (D) QX 2000 | 1 ~ 100 AMU, < 1 AMU |
| Thin Film Controller | 1992 | Leybold (D) IC/4-plus | 0.5 % |
| Surface Profiler | 1993 | α-step 200 | 160 Å ~ 160 μm |
| Thermocompression sealing facility | 1991 | Prinz (D) | 400°C; 10 bar |
| Leak detector | 1991 | Leybold (D) UL 100 Plus | $2*10^{-10}$ mbar/s |
| Glass lathe | 1993 | Shengyang BJ 150 W | Ø 100mm ~ Ø 130mm |
| Outgassing facility | 1990 | | $1*10^{-4}$ Pa, 400 °C |
| Flat-plate solar collector test facility | 1987 | Dornier (D) | 4 collectors, 150 °C |
| Pyranometer | 1980 | Eppley (US) PSP | 0 ~ 1,300 W/m², ±1% |
| Pyranometer | 1980 | Eppley (US) 848 | 0 ~ 1,300 W/m², ±1.5% |
| Pyrheliometer | 1980 | Eppley (US) NIP | 0 ~ 1,300 W/m², ±1% |
| Radiation Accumulator | 1980 | Eppley (US) 411-6140 | 0 ~ 9,999 W h/m², ±1% |
| Anemometer | 1987 | Thies (D) CLIMA | 0.3 ~ 60 m/s, ±0.5 m/s |
| Temperature data acquisition system | 1982 | Yokogawa (J) YEW 3873 | 0 ~ 20 mV, 1 μV |
| Spectrophotometer | 1981 | Hitachi (J) 330 | 0.25 ~ 2.5 μm |
| Alphatometer | 1983 | D&S (US) 1A | 0 ~ 1.00, 0.01 |
| Emissometer | 1983 | D&S (US) AE | 0 ~ 1.00, 0.01 |

| | | | |
|---|---|---|---|
| Schedule | 1-1 | Assemble counterpart team | Sep - Oct 95 |
| | 1-2 | Establishment cooperation links | Sep 95 - Aug 96 |
| | 1-3 | Fellowship | Nov - Dec 95 |
| | 1-4 | Procure funds for equipment | Sep - Nov 95 |
| | 1-5 | Tender and procure equipment/ facilities | Dec 95 - Sep 96 |
| | 1-6 | Install equipment | Sep - Dec 96 |
| | 1-7 | Fielding of international expert | Nov 96 |

Duration 18 months

*Part 2 (PROTOTYPES)*

Output Fully developed and prototype-tested evacuated-(glass)tube collectors (ETC) of Ø 100 - 150mm and characterized by

(i) tube-in-tube configuration for heat-transfer medium inflow and outflow (concentric-tube type)

(ii) tubular heat-transfer medium inflow and volume storage in a large-diameter outer tube (storage type)
(iii) single- or double heat pipes with bent absorbers (bent absorber type)
(iv) larger-diameter glass-tube ETCs of Ø 120mm and Ø 150mm, respectively, of the configurations (i) to (iii)

Activities
2-1 Design new types of high-performance ETCs
2-2 Carry out R&D and technical investigations on
- absorber coating surfaces with high absorption/low emittance
- TIG welding (for storage type absorbers)
- metal-glass sealing of glass-tube diameters > 100mm
- outgassing characteristics of different materials
2-3 Fellowship of one person for 6 m/m to receive training abroad on surface sputtering technologies suitable for absorbers of solar-thermal absorbers (suggestion: Australia)
2-4 Fellowship of two persons for 3 m/m each to receive training abroad on glass tube fabrication (suggestion: The Netherlands)
2-5 Fabricate prototype specimens of new ETC types
2-6 Performance-test ETC prototypes
2-7 Evaluation of prototypes manufactured; report generation

Responsible: Dr. He Zinian, Solarthermal Department, Beijing Solar Energy Research Institute (BSERI)

Support required:

| *Type of Activity* | *Cost of Activity (in US-$)* | *Remarks* |
|---|---|---|
| Training abroad: Fellowships | $ 91,000 | 1 x 6 m/m; 2 x 3 m/m |
| Experts: Consultants | None | |
| *Totals: (i) equipment*<br>*(ii) training; experts* | *None*<br>*$ 91,000* | |

Schedule

| | | |
|---|---|---|
| 2-1 | Design new types of ETCs | Oct - Dec 95 |
| 2-2 | Carry out R&D and technical investigations | Oct 95 - Aug 96 |
| 2-3 | Fellowship 1 (sputtering technologies) | Jan - Jun 96 |
| 2-4 | Fellowships 2 (glass tube fabrication) | Apr - Jun 96 |
| 2-5 | ETC prototype fabrication | Jan 96 - Mar 97 |
| 2-6 | ETC prototype performance-testing | Jul 96 - Jun 97 |
| 2-7 | Evaluation; report | Jul - Sep 97 |

Duration 24 months

*Part 3 (DEMO)*

Output: Design, install, operate (together with customer) and performance-monitor fully operational demonstration facilities for solar-thermal utilization, using new types of ETCs, e.g.

(i) an absorption-type solar air-conditioning system of about 200 $kW_t$, adequate for a medium-size hotel (using concentric-tube type or heat-pipe ETCs)
(ii) a solar-thermal process heat generating plant with a capacity of about 30~50 m3/d of 90°C hot water, suitable for a small industrial enterprise (using concentric-tube ETCs)
(iii) domestic hot water (DHW) systems of about 4 $m^2$ absorber area, with 100mmØ and 150mmØ glass tubes, respectively (using storage-type and bent-absorber-type ETCs).

(see also Annex C-1)

Activities
3-1 Select sites and establish relations with users
3-2 Design demonstration systems, specify system components
3-3 Procure funding for equipment and plant performance monitoring
3-4 Procure system components, incl. sensors and D/A systems for performance monitoring

3-5 Installation and start-up of demonstration systems, incl D/A systems
3-6 Operation and performance-monitoring of demonstration systems
3-7 Fielding of one international expert to advise on the design and operation of solar air-conditioning systems, for 1 m/m (suggestion: Singapore)
3-8 Fellowship for two persons, for 1 m/m each, to receive training abroad on solar-thermal systems (suggestion: Germany and Singapore)
3-9 Optimization of demonstration plant operation
3-10 Evaluation of demonstration plant operation; report generation

Responsible: Dr. He Zinian, Solarthermal Department, Beijing Solar Energy Research Institute (BSERI)

Equipment/assistance required (costs estimated, not including transportation and import taxes, if any)

| *Type of Equipment/-Activity* | *Cost of Equipment/-Activity (in US-$)* | *Remarks* |
|---|---|---|
| Solar space-conditioning system | | |
| (i) ETCs | $ 78.000 | D = Ø130mm; 400 m² |
| (ii) Circulation system | $ 78,000 | |
| (iii) Absorption cooling unit | $ 80.000 (import) | P = 200 kW, |
| (iv) Auxiliary gas boiler | $ 50.000 | P = |
| (v) Engineering design | $ 10.000 | |
| (vi) Installation, commissioning | $ 20.000 | |
| (vii) Measurement and D/A system | $ 15.000 | |
| Subtotal: | $ 331.000 | |
| Solar industrial process heat system | | |
| (i) ETCs | $ 78.000 | D = Ø130mm; 400 m² |
| (ii) Circulation system | $ 78.000 | |
| (iii) Engineering design | $ 10.000 | |
| (iv) Installation, commissioning | $ 20.000 | |
| (v) Measurement and D/A system | $ 15.000 | |
| Subtotal: | $ 201.000 | |
| Storage-type domestic hot water systems | | |
| (i) ETCs (Ø100mm & Ø130mm) | $ 9.000 | |
| (ii) Measurement and D/A systems (3) | $ 9.000 | D = Ø130mm and Ø100mm |
| Subtotal: | $ 18.000 | |
| Training abroad; Fellowships | $ 28.000 | 2 x 1 m/m |
| Experts; Consultants | $ 22.000 | 1 x 1 m/m |
| *Totals: (i) equipment* | *$ 550.000* | |
| *(ii) training; experts* | *$ 50.000* | |

Schedule:

| | | |
|---|---|---|
| 3-1 | Site selection; user relation establishment | Oct 96 - Mar 97 |
| 3-2 | System design, system component specification | Oct 96 - Jan 97 |
| 3-3 | Funding procurement | Oct 96 - Jan 97 |
| 3-4 | Procurement of components and measurement systems | Feb - Jul 97 |
| 3-5 | Installation and start-up of systems | Aug - Nov 97 |
| 3-6 | Operation and performance-monitoring | Nov 97 - Aug 98 |
| 3-7 | Fielding of one international expert (A/C systems) | Jan 97 |
| 3-8 | Fellowship for two persons (S/T systems) | Jan - Feb 97 |
| 3-9 | Optimization of plant operations | Dec 97 - Sep 98 |
| 3-10 | Evaluation, reporting | Sep - Oct 98 |

Duration: 25 months

Collaboration: BSERI considers to collaborate with other institutions in the specification and design of the solar-assisted space-conditioning demonstration and solar industrial process heat systems. candidate institutions are, inter alia, (i) the Solar Heating and Cooling Technology Experiment and Demonstration Center in the Yuzhong District near the city of Lanzhou, (ii) the Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, Guangdong Province, (iii) the Air Conditioning Research Institute, Chinese Academy of Architectural Science, and (iv) the Gansu Natural Energy Research Institute, Gansu Province

*Part 4 (FACTORY)*

<u>Output</u> Design and construction of a full-scale production line for high-performance solar evacuated-tube-collectors (ETC) for a capacity of (i) 30–40,000 $m^2$/a or (ii) 80–100,000 $m^2$/a.

<u>Activities</u>:

- 4-1 Carry out basic engineering design for an optimized production line for output capacities of 40,000 $m^2$ and 100,000 $m^2$, taking results/conclusions of Part 2 into account, and determine infrastructure needs (water, electricity, effluent treatment, transportation, availability of skilled personnel, etc.)
- 4-2 Determine, for both capacity options, the costs for investment, production, operations and maintenance, and carry out an economic analysis
- 4-3 Specify production equipment (for both options)
- 4-4 Decide about plant construction and on plant capacity
- 4-5 Select site for production line
- 4-6 Procure funding for plant investment
- 4-7 Prepare exact drawings and elaborate engineering details for plant construction
- 4-8 Fielding of one international expert to advise on glass-tube technology and to provide training in glass-tube handling/processing, for 2 m/m
- 4-9 Fellowship of up to 4 persons for 1 m/m each to receive training in handling and operating of vacuum technology
- 4-10 Tender and procure production equipment
- 4-11 Construction of plant (building and infrastructure)
- 4-12 Installation of plant equipment
- 4-13 Commissioning and start-up of plant operations
- 4-14 Optimization of plant operations

<u>Responsible</u>: Dr. He Zinian, Solarthermal Department, Beijing Solar Energy Research Institute (BSERI)

<u>Assistance required</u>:

| *Type of Activity* | *Cost of Activity (in US-$)* | *Remarks* |
|---|---|---|
| Equipment | $ ???? | Not specified so far |
| Local Construction & Infrastructure | $ ???? | Not specified so far |
| Training abroad; Fellowships | $ 56,000 | 4 x 1 m/m |
| Experts, Consultants | $ 37,000 | 1 x 2 m/m |
| *Totals (i) equipment*<br>*(ii) training; experts* | *None*<br>*$ 93,000* | |

<u>Schedule</u>:

| | | |
|---|---|---|
| 4-1 | Plant engineering design | Jan - Jun 96 |
| 4-2 | Cost determination; economic analysis | May - Jun 96 |
| 4-3 | Equipment specification | Jul - Sep 96 |
| 4-4 | Plant construction decision | Oct 96 |
| 4-5 | Site selection | Oct - Dec 97 |
| 4-6 | Procure funding | Oct - Dec 97 |
| 4-7 | Detail planning | Jan - Jun 97 |
| 4-8 | Fielding of international expert (glass-tube technology) | Jan - Feb 97 |
| 4-9 | Training for four persons (vacuum technology) | Feb 97 |
| 4-10 | Tendering and procurement | Jul - Dec 97 |
| 4-11 | Plant construction | Jul - Dec 97 |
| 4-12 | Equipment installation | Jan - Mar 98 |
| 4-13 | Commissioning and start-up | Apr - Sep 98 |
| 4-14 | Optimization of plant operation | Oct 98 - Mar 99 |

<u>Duration</u> 54 months

Suggested Aggregate Activity Funding (for all Project Parts)

| *Equipment Activity* | *Total Cost (in US-$)* | *Government Grants (SPC SSTC)* | *Commercial Loans (domestic currency)* | *Grants from Intl Organizations (UNDP, UNIDO)* | *Foreign Government Grants* |
|---|---|---|---|---|---|
| Tech Assistance; Training | $ 277,000 | | | 100% | |
| Personnel (management, engineering, evaluation, etc.) | $ 10,000+ | 50% | 50% | | |
| Equipment for | | | | | |
| (i) Part 1 | | | | | |
| imported | $ 580,000 | 16% | 60% | 14% | 10% |
| domestic | $ 208,000 | 13% | 48% | 13% | 27% |
| (ii) Part 3 | | | | | |
| imported | $ 80,000 | 16% | 60% | 14% | 10% |
| domestic | $ 464,000 | 13% | 48% | 13% | 27% |
| (iii) Part 4 | | | | | |
| imported | $ ???? | | | | |
| domestic | $ ???? | | | | |
| Local Construction (Part 4) | $ ???? | 30% | 70% | | |
| Transport & Installation (Part 3) | $ ???? | 56% | | 44% | |

## E. Inputs

Chinese Inputs

(i) Beijing Solar Energy Research Institute (BSERI) will name and assign one staff member as responsible Project Director who, on behalf of SERI, will be personally responsible for technical/scientific results and managerial execution of all Project Parts. BSERI will consult with the National Project Coordinator (NPC) and Chief Technical Advisor (CTA) when intending (or being asked) to replace this individual

(ii) BSERI will make – as far as required – facilities and equipment available to the Project and will assign an adequate number of qualified staff for carrying out the Project.

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

(iv) It is expected that the Chinese Government (SPC, SSTC, ACCA 21) will contribute, in a timely manner, about US-$ 2.4 Mio (in the form of direct grants and/or loans) to BSERI for executing the Project

UNDP/UNIDO Inputs

11 International Experts

11-01 Chief Technical Advisor (CTA). 5 m/m
this person, to be recruited for making visits to the Project 5 times (for 1 month) over the Project's duration, will provide overall guidance in the implementation of the four Project parts and will closely interact with the National Project Coordinator (NPC) and the person responsible for the Project execution. The CTA shall be an expert in solar-thermal technologies and have experience in operating and measuring solar systems

11-02 Consultant on solar-thermal performance measurement and measuring equipment. 1 m/m
the expert will make one visit to assist in the design and equipment specification of performance monitoring and data acquisition (D/A) equipment.

11-03 Consultant on solar-assisted space-conditioning and related equipment:
the expert will make one visit to assist in the optimal layout and design of a solar-assisted space conditioning system for a medium-size hotel 1 m/m

11-04 Consultant on glass-tube handling and processing. 2 m/m
the expert will make one visit to assist in training local technicians in the art of handling and processing glass-tubes (stress-free flange formation and glass-to-glass fusing)

15 UNIDO Staff Travel

31 Individual Fellowships

31-1 Training in the field of solar-thermal system simulation and in the technology of solar-assisted space conditioning and industrial process heat systems
(for Part 1; one person for 2 m/m) 2 m/m

31-2 Training in the field of surface sputtering technologies which are suitable for producing selective absorptive surfaces (for Part 2. one person for 6 m/m) 6m/m

31-3 Training in the field of stress-free glass-tube welding, fabrication and handling
(for Part 2: two persons. 3 m/m each) 6 m/m

31-4 Training in the field of solar-thermal system design and operation
(for Part 3: two persons. 1 m/m each) 2 m/m

31-5 Training in the field of vacuum-technology and operation of vacuum systems
(for Part 4: four persons. 1 m/m each) 4 m/m

32 Study Tours

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

41 Expandable Equipment

None

42 Non-Expendable Equipment

See Part D for itemization of required non-expendable equipment and associated cost estimates

F **Risks**

*Potential Risks* *Estimated Likelihood*

1. Marketing and Product Dissemination. BSERI is an R&D entity which operates a manufacturing company, SUNPU Co. on the same premises. This manufacturing arm successfully adopted the technology to produce Sunstrip® absorbers and successfully established a pilot production line for heat-pipe evacuated-tube-collectors (ETC) of high quality (lifetime >12 years). Presently about 180,000 $m^2$/a of Sunstrip® absorbers are produced and profitably sold on the domestic and international market (a second production line for Sunstrip® absorbers is being planned); on the prototype line of heat-pipe ETC, already substantial orders for products are manufactured (and reportedly with attractive profit margin).

BSERI/SUNPU intend to market the high-efficiency ETC with tube diameters >100mm the same way, e.g. as half-finished product wholesale to regional/local installers of solar-thermal systems. At present the knowledge is limited whether the local market can absorb 40.000 $m^2/a$, respectively 100.000 $m^2/a$, of ETCs which are hoped to be produced. If the ETC of Ø>100mm are produced with the same quality as demonstrated in the prototype production line – and since there are no more than three competitors worldwide producing ETCs – there is good prospect that high-efficiency, large-diameter ETC can be sold also outside of China. For these reasons, the risks that the newly developed ETCs cannot be sold is considered Low/Medium

2 Complexity of Larger Solar-Thermal System Applications: The knowledge worldwide about solar industrial process heat (solar IPH) and, specifically, solar-assisted space-conditioning systems is quite limited. While the supply security in both applications can be assured by back-up auxiliary sources (gas, oil), the design of such system must carefully be adapted to and optimized for the specific application needs. For instance, heating and warm-water needs need to be taken into account when designing an optimal solar -assisted space-conditioning systems, the ambient conditions of temperature and humidity play a decisive role when deciding what cooling principle shall be applied (absorption-, adsorption-, desiccant-cooling, etc.), provided that mature technology of adequate capacity is commercially available, the design becomes even more challenging if solar-assisted space conditioning needs to be designed for already existing buildings.

The risks that the solar IPH and solar-assisted space conditioning systems which are demonstrated in this project operate nominally (i.e. according to design and expectations), thus setting an example for further replication, is considered Medium/High

3 Lifetime of ETC: The feasibility and viability of solar evacuated-tube-collectors (ETC) has been repeatedly proven (for a variety of concepts and designs) and some design are commercially available worldwide. The performance of these collectors surpasses those of flat-plate solar collectors significantly under large $\Delta T$, a criterion under inclinate temperature conditions. Provided that the developments in this Project are successful as expected, the manufacturing cost of ETCs in China may well approach those of the flat-plate type.

While operation according to specifications of heat-pipe ETCs from BSERI/SUNPU's pilot line can be expected for well over 12 years (extrapolated from laboratory results), the critical factor of ETCs remains lifetime, i.e. the maintenance of the vacuum-tightness of the glass-metal seal for >20 years and better under the wide-range thermal cycling stress these seals are subjected to over this time. To guarantee such lifetime for a variety of materials and material combinations (glass; metal; metal surfaces) and ETC designs (e.g. tube diameter) requires that adequate manufacturing techniques are developed and ETC manufacture is carefully controlled. The risk that the lifetime of ETCs developed and manufactured in this Project is therefore considered Medium

## G Prior Obligations and Pre-Requisites

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

The Chinese Government (ACCA 21; SPC; SSTC) and the participating institution (BSERI) will provide funds for all the counterpart activities as envisaged in this Project Document. 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 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 de 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 Chief Technical Advisor (CTA), the Project implementing entity (BSERI, represented by the Project Director (PD)), and by representatives of the funding authorities. Task status to date will be reported by the respective PD and overall Project assessment will be provided by the NPC (written reports to be submitted by PD 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, and the likelihood of attaining the success of the Project.

The NPC shall further prepare and submit to each Project review meeting a Project Performance 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 PD 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. I 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 revisions may be made to this Project Document with the signature of the UNIDO representative 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) Mandatory 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 US-$)* | *National Grants in RMB/yuan (in US-$ equivalent)* | *Comm. Loans in RMB/yuan (in US-$ equivalent)* | *Grants from Intl. Organizations (UNDP, UNIDO) (in US-$)* | *Other External Inputs (in US-$)* |
|---|---|---|---|---|---|
| Personnel (Engineering; Operation; Evaluation) | $ | $ | $ | $ 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 CTA – Project Technical Advisor

| | |
|---|---|
| Post Number: | xx/yyy/95/zzz |
| Post Title: | Chief Technical Advisor (CTA) |
| Duration - | One man/month per year over a period of four years, starting October 1995, with the possibility of up to two additional man/month over the duration of the Project. |
| Duty Station: | Beijing, with possible travel to ETC application sites in the country and abroad (UNIDO, Vienna), plus work (reporting) at home base |
| Purpose of Job: | To reinforce the Chinese technical capability in developing and manufacturing high-efficiency evacuated-tube-collectors (ETC), to expand the application and utilization of ETC, to assist in reducing the rapid increase in demand for fossil-based energy, and to upgrade the R&D capability in the field of advanced solar-thermal components and systems. |
| Duties | The PTA will closely collaborate with the National Project Coordinator (NPC) and the Project-responsible organization/person in the coordination, implementation and follow-up of the program of work established in the Project. Specifically, the CTA<br><br>(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.<br><br>(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;<br><br>(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.<br><br>(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.<br><br>(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 solarthermal technologies (components, systems, system applications) and in the management of scientific/-technological programs and projects.<br><br>Experience in the collaboration with foreign partners will be an asset |
| Languages | English |

A-2 Consultant on Solar-Thermal System Performance Measurement and Measurement Systems

A-3 Consultant on Design and Operation of Solar-Assisted Space-Conditioning Systems

A-4 Consultant on the Technology of Glass-metal Seals and Glass-Metal Seal Manufacture

Annex B: Work Organization; Implementing Arrangements

**Annex C:**

C-1 Solar Demonstration Installations (Basic Draft Specifications)

| *Demonstration* | *Basic Specifications* |
|---|---|
| *Solar space-conditioning system*<br>(using tube-in-tube collectors (ETC) of 130mmØ) | Cooling type: Absorption<br>Absorbent: Li-Br<br>Refrigerant: Water<br>Refrigerant circulation control: by insolation<br>Cooling capacity: ~200 kW,<br>Collector aperture: ~ 400 m²<br>Auxiliary heating: gas<br>Yearly solar-mode system efficiency: >50%<br>Application: medium-size hotel, 220 rooms |
| *Solar industrial process heat system*<br>(using tube-in-tube and/or bent-absorber heat-pipe collectors (ETC) of 130mmØ) | Two-loop system<br>Anti-freeze protection in primary loop<br>Hot water supply capacity: ~20 m³/d<br>Hot water temperature: 70-90 °C<br>Collector aperture: ~400 m²<br>Yearly system efficiency: >50%<br>Application: medium-size industrial plant (e.g. dairy) |
| *Domestic hot water (DHW) systems*<br>(i) using storage-type collectors (ETC) of large-diameter (Ø=130mm) | Hot water output: 240 l/d<br>Max. water temperature: 50-60°C<br>Collector aperture area: 4 m²<br>Daily efficiency: summer >55%, winter >45%<br>Application: (a) synthetic test, (b) one-family house |
| (ii) using storage-type collectors (ETC) of small-diameter (Ø=100mm) | Hot water output: 190 l/d<br>Max. water temperature: 50-60°C<br>Collector aperture: 4 m²<br>Daily efficiency: summer >55%, winter >45%<br>Application: (a) synthetic test, (b) one-family house |
| (iii) using TWD-insulated storage collectors | Hot water output: 240 l/d<br>Max. water temperature: 50-60 °C<br>Collector aperture: 3.6 m2<br>Daily efficiency: ??? summer, ??? winter<br>Application: (a) synthetic test, (b) one-family house |

C-2 Overall Time Schedule