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COMMERCIALIZATION OF BNL DESIGN SOLAR COLLECTOR IN INDIA

PHASE I REPORT

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TABLE OF CONTENTS

		Page
1.	Introduction	1
2.	India-US Differences in Solar Applications	2
3.	Commercial Readiness of the BNL Solar Collector Technology	3
	First Generation Design	4
	Succeeding Generation Designs	6
4.	Market Demand for Solar Thermal Energy in India	6
	Current Demand	6
	Projected Demand	8
5.	Survey of Solar Thermal Installations	11
	System Performance	11
	Collector Durability	12
	System Costs	13
	User Acceptability	13
6.	Comparison of BNL Collector and Local Conventional Collectors	14
7.	Tentative Commercialization Plan	15
8.	Discussions with DNES/STEC	16
ANNEX 1.	Solar Projects Installed under Central Government Plan	18

LIST OF TABLES

		Page
1.	Flat-Plate Collector Area Installed/Under Construction.....	8
2.	Sectoral Breakdown on Solar Installations.....	9
3.	Estimates of Collector Materials Cost.....	15

LIST OF FIGURES

1. Innovation Incubation Intervals (Approximate)..... 4

1. INTRODUCTION

The development of new technologies is generally influenced by a perceived need. In the case of alternate energy technologies this was prompted by a looming shortage of conventional energy sources such as fossil fuels and their potential environmental health hazards. The general search for clean renewable energy sources has been an active technical topic now for several years and has resulted in a number of concepts and demonstrations to show that they can work.

The history of solar energy applications during this period is best viewed in the context of the overall energy scene. The U.S. and other countries depend on energy resources for their maintenance and growth. Critical shortages of these resources can and do have severe effects on nations and their ability to survive. In the U.S. and other developed countries energy shortages, or, equivalently, high energy costs, have contributed to economic recessions. In the developing nations, energy shortages have a critical impact on economic and social development efforts.

The oil shortages in the early 1970's provide important lessons of the impact of energy on society. They also brought political forces into play by bringing attention to the need for energy sources. Solar energy was one of the most popular technologies during this period and resulted in a series of rapidly installed solar energy programs in the US and other countries. It was realized early in the program that the economics of solar applications was a major hurdle. To improve its chances for commercial acceptance, generous tax subsidies were provided and life cycle costing procedures were used to place solar technology in a better commercial light. The most successful method of justification in the U.S. reached its commercial zenith with questionable though creative initiatives such as third party financing.

The perception in the U.S. is that its "energy crisis" had passed when oil surpluses emerged again. Also, the dollar-denominated world oil prices first stabilized and then fell. This led to a gradual decline in the interest in alternative energy sources. Additionally, with the advent of a new administration, the previous emphasis on Federal renewable energy programs was reversed, resulting in a sharp decline in program support for solar research and development.

About this time, 1980-81, BNL revealed its discovery of a method to substantially reduce the cost of solar energy collection. These technical discoveries were inspired by the recognition that for solar applications to succeed it had to be commercially competitive. Unlike the tax subsidies and other financial rationalizations, the BNL methodology was based exclusively on developing cost effective technologies. The BNL approach involved a research initiative specifically directed to radically reducing the cost of solar hardware and its installation. Through a method of cost guided research, a number of discoveries were made that permitted the use of less costly materials, simpler designs and a more effective use of the polymeric materials. The projected cost of this new concept was many times less expensive than conventional solar collector designs. The technical evolution that has

continued as part of DOE supported research at BNL was to investigate and develop the material science necessary to meet and possibly exceed cost goals initiated in the BNL solar collector development activity.

Due to the nature of such discoveries it was felt that developing countries could also benefit from an exploration into cost effective solar technologies. During the Energy Management Training Program at BNL, the potentially low cost BNL technology was introduced in renewable energy seminars by Dr. Vinod Mubayi and Dr. David Jhirad where it evinced considerable interest among some of the participants. This led to its eventual introduction as part of an USAID supported institutional support program with the Solar Thermal Energy Center in India. The object of this technical collaboration was to help accelerate the technical base for this and other advanced solar technologies so that it could effectively be assimilated into the Indian environment as a viable energy alternative.

While the resulting collaboration and subsequent testing of an early version of the BNL low cost solar collector was overwhelmingly successful as evaluated by all active participants in the program there remained questions by AID officials in New Delhi concerning the viability of solar thermal energy in India as well as appropriate ways to accelerate the new BNL solar technology into the Indian market environment. The present study is being undertaken to answer these questions and to offer a preliminary plan for rapid commercial introduction. It is meant to represent an efficient and novel approach to effect commercialization of an advanced solar technology into the Indian commercial sector. The plan is also complemented by the parallel program to continue institutional support between BNL and STEC. It is believed that the institutional programs to evaluate advanced solar energy applications will insure credibility and confidence to the overall effort while the solar collector technology matures in the commercial sector.

2. INDIA-US DIFFERENCES IN SOLAR APPLICATIONS

In the current environment in the U.S., the need for solar energy has diminished due to a drop in the prices of conventional energy, notably imported oil. In addition the solar industry never really matured in the U.S. What appears to be a solar thermal industry is in reality a conglomeration of very small-scale businesses many of whom are barely holding on and in constant fear of the removal of tax credits which, at the Federal level, are due to expire at the end of this year. The major oil companies that once had an interest in solar thermal technology have since surrendered their solar participation to the fragmented smaller counterparts who have little alternative but to stick it out with their current technology. Furthermore, the Federal government has, since 1980, drastically reduced its support for solar energy development suggesting that it belongs in the private sector. This reduction has been most acute for solar thermal technologies. To make matters worse, the fragile solar industry remains dependent on old, non-cost effective technologies with essentially no capital base to pursue new technological development ventures.

Based on these observations, new solar technologies that offer a breakthrough are not in a receptive environment at least from the point of view

of "taking off." What we can expect to occur in the U.S. is a more gradual acceptance of their potential as they mature in the limitations of a conservative market. Should future events threaten U.S. energy supplies, there will be a renewed interest in solar energy, producing a very receptive attitude towards potentially cost reducing technologies such as the BNL collector technology.

In contrast, the current attitude in India towards solar energy is more positive. Firstly, the solar resource is comparatively abundant over most of the country; secondly, there is an acute shortage of conventional energy supplies. The combination of these two factors have led the government, at both Central and State levels, to launch an active promotional program for solar energy development. While specific elements of this program can be effectively critiqued, there is little doubt that its emplacement has created an infrastructure within which new solar technology developments can be usefully pursued. The BNL solar collector technology offers the potential of a low-cost, high performance and light-weight collector which can be expected to make a significant impact on the emerging Indian solar industry. Beyond that, a more subtle benefit of the polymer film solar technology is that it will introduce Indian industry to a higher technology in materials which it dearly needs. It is expected that the new polymer film solar collector will play an important part in establishing solar as an important energy source both in India and potentially in the U.S.

Other factors must also be understood to fully appreciate the degree of progress made in introducing and verifying the potential of this new low cost solar collector technology. It is not generally understood that most new technologies require relatively long periods to achieve market maturity. This period is usually in the range of 25 years or longer depending on various market influences. The table in Figure 1 represents the incubation intervals for various popular technologies. This is in compliance with a recent study sponsored by the Gas Research Institute in assessing the needed factors to accelerate market maturity. In the context of these examples the BNL collector is tracking quite well a plan for commercial introduction. The role played by USAID is catalytic both in the commercialization supported here and in the foundation of acceptance provided in encouraging institutional collaboration.

3. COMMERCIAL READINESS OF THE BNL SOLAR COLLECTOR TECHNOLOGY

The BNL polymer film, ultra light solar collector has been in the process of research and development at BNL for the last five years. Over this period, a significant amount of experience has been gained on the use and performance of new low cost materials for solar energy collection and their packaging. The unique construction method developed produces a lighter weight, higher performance and lower cost collector design. The experience has resulted in the identification of three generations of collector designs. The first generation, which can be designated as BNL-1, is the collector supplied to STEC and tested at their facility in Dundahera, Haryana.

INNOVATION	CONCEPTION	REALIZATION	INCUBATION INTERVAL (YEARS)
ANTIBIOTICS	1910	1940	30
AUTOMATIC TRANSMISSION	1930	1946	16
BALL-POINT PEN	1938	1945	7
CELLOPHANE	1900	1912	12
COTTON PICKER	1924	1941	17
CREASE-RESISTANT FABRIC	1918	1932	14
DRY SOUP MIXES	1943	1962	19
FILTER CIGARETTES	1953	1955	2
FLUORESCENT LIGHTING	1901	1934	33
FROZEN FOODS	1908	1923	15
GYROCOMPASS	1852	1908	56
HEART PACEMAKER	1928	1960	32
HELICOPTER	1904	1941	37
HYBRID CORN	1908	1933	25
INSTANT CAMERA	1945	1947	2
INSTANT COFFEE	1934	1956	22
LIQUID SHAMPOO	1950	1958	8
LONG PLAYING RECORDS	1945	1948	3
MAGNETIC RECORDINGS	1900	1937	37
MINUTE RICE	1931	1949	18
NUCLEAR ENERGY	1919	1965	46
NYLON	1927	1939	12
PENICILLIN	1928	1943	15
PHOTOGRAPHY	1782	1838	56
RADAR	1904	1939	35
RADIO	1890	1914	24
ROLL-ON DEODORANT	1948	1955	7
SAFETY RAZOR	1895	1906	11
SELF-WINDING WATCH	1923	1939	16
SILICONE	1904	1942	38
STAINLESS STEEL	1904	1920	16
TELEGRAPH	1820	1837	17
TELEVISION	1884	1947	63
TRANSISTOR	1940	1956	16
VIDEO TAPE RECORDER	1950	1956	6
XEROX COPYING	1935	1950	15
ZIPPER	1883	1913	30

Figure 1. Innovation Incubation Intervals (Approximate)

Based on the results of the test at STEC and the fact that the collector has suffered no measurable degradation in the severe environment of Dundahera over a ten-month period (November 1984-to date), we believe that the BNL-1 design represents a practical, realistic and commercially ready product requiring a minimal amount of additional production development before introduction into the Indian environment. The collector can be manufactured with non-automated production and labor-intensive manufacturing techniques suitable for Indian industrial conditions. Succeeding generations of the BNL concept will require additional development before commercial introduction can occur. The principal goal of research and development on the later generation technologies is to further reduce cost through the use of alternate polymer materials and improve system application versatility. This is to be accomplished by the development of new materials specific to the design and the creation of production techniques suitable for high volume manufacture.

First Generation Design

All the BNL solar collectors utilize a unique, patented design referred to as monocoque construction. This design allows the use of extremely light weight materials in a prestressed configuration which results in a collector of high strength relative to its light weight. The first general concept (BNL-1) utilizes monocoque construction and polymer films for the glazing and back seal and a conventional metal fin and tube absorber plate for the absorber-heat exchanger. This collector, which has been tested at STEC, is approximately one fourth to one fifth the weight of the conventional collector made in India (12 kg as opposed to 50-60 kg). A preliminary analysis of costs shows that the materials costs, including imported components, in the BNL-1 design would be about half of those commonly used in the conventional design, at Indian prices.

In terms of the commercial readiness of BNL-1, it is envisaged that a small amount of additional materials testing would be required to test the thermal stability of Indian manufactured polymer foam. This rigid foam functions both as insulating material and a structural compression member imparting rigidity to the collector when the films are under tension. Furthermore, an approximately six month development effort will be required for the tooling of the collector frame and the jigging needed for collector assembly including the design of a special oven for the thermal shrinking of the polymer films onto the frame of the collector. Indian made adhesives will also require some tests for durability and thermal stability. However, unlike the insulating foam substrate, which would be impractical to import, the adhesives can be imported in the first phase of manufacture without significant addition to cost.

Out of six components needed for collector assembly we envisage that four will be indigenous and two, the selectively coated absorber plate and the flourocarbon polymer film for glazing, would be imported in the initial phase of manufacture. Progressive indigenization over a period of three to five years should result in a completely indigenous collector of very high performance and low cost in comparison to current technology. This effort will benefit greatly from the experience being gained at BNL in the later generation designs.

Succeeding Generation Designs

R and D work at Brookhaven on successive generation designs is focused both on thin material concepts for the heat exchanger as well as on efforts to replace the more expensive flourocarbon polymer films used in the glazing with much less costly base polymers such as polyolefins which can, in principle, be chemically stabilized for high durability under solar exposure. Proof-of-concept of thin foil, ultrasonically welded absorbers has already been demonstrated at BNL and further refinements are underway. Similarly, experiments on chemical additives to very low cost polymers which can lead to films having stability to ultraviolet exposure and high temperatures are also going on. The experience gained from this R and D will be very useful in further commercial improvements of the BNL design which could be transferred eventually to India. Projection on materials cost and manufacturing techniques made at BNL reveal that if the R and D efforts are continued and prove successful, the cost of solar thermal energy could eventually be cheaper than equivalent useful thermal energy derived from petroleum.

4. MARKET DEMAND FOR SOLAR THERMAL ENERGY IN INDIA

Current Demand

The present market for solar thermal energy technologies in India is almost completely restricted to solar hot water and, in a smaller number, hot air systems. A few projects utilizing concentrating systems for producing steam and/or thermally generated electric power have been carried out but these are restricted to the R and D stage. Similarly, a few projects employing solar space heating have also been done in remote, mountainous areas but these are also at the R and D level.

Based on interviews with knowledgeable observers, including officials of DNES/STEC, state "nodal" agencies responsible for implementing solar energy projects in different states, and flat plate collector/hot water systems manufacturers, it has been roughly estimated that between 90%-95% of the hot water systems installed or under installation have been funded by government programs. This includes systems funded under Central Government programs by DNES and systems installed under State Government projects. The remaining 5%-10% of the installations are in the private sector and are believed to be mostly small, domestic systems (100 liters per day of hot water at 60°C).

The market for solar hot water and hot air systems, in terms of economic subsectors, can be divided into the following categories:

(i) **Domestic hot water:** typical system size and temperatures are 100 - 200 liters per day at 60°C.

(ii) **Institutional buildings:** includes hotels, hospitals/health centers, school and college dormitories, rest houses, etc. Typical systems size and temperatures range from 500 - 1000 liters/day to upwards of 30,000 liters/day, for large hotels, at 60°C.

(iii) **Commercial establishments:** laundries, canteens, restaurants, etc. System size and temperatures are in the range of 500 - 2000 liters/day at temperatures between 60°C - 80°C.

(iv) **Industries:** a fairly large range of industries offer a potential market for both hot water and hot air systems. In India these include textiles, chemicals, paints and products, dairy, etc. for hot water systems and agroforestry based processing industries including timber, tea, pepper, cardamom, etc. for hot air systems. Systems installed have ranged up to the largest installation of 75,000 liters/day (textile and dairy industries) with temperatures in the range of 55°C to 85°C.

The most straightforward way to characterize current demand is in terms of annual area of collector installed. Detailed data gathered from DNES and the state nodal agencies on number of systems installed or under construction and the collector area under both Central and State projects are shown in summary form in Table 1.

This data set reveals that total collector area in the country already installed or under installation in sanctioned projects comes to a total of about 43,000 square meters of which 13,500 square meters (or about 30%) is in the central Sector and the remainder in the State sector.

The most active state in the state agency program is seen to be U.P. with a total of 154 systems installed or under construction and a collector area of around 11,000 square meters. This is followed by by Gujarat with 102 systems and 6500 m^2 of collector area, and the Union Territory of Delhi with 49 projects and 3500 m^2 of collector area. The Central Government programs are more evenly distributed over the country. The largest number of installations under the Central program is in Madhya Pradesh with a few very large projects in the dairy industry.

Table 2 shows the sectoral breakdown of solar projects in the Central Government program among domestic, institutional, commercial and industrial sectors. The majority of collector area installed (53%) is in the institutional sector (hotels, hospitals, schools and college dormitories, etc.) and Delhi, perhaps understandably, has the greater share of these. Roughly 45% of the collector area installed under the Central projects is in the industrial sector (mainly dairy and textile industries); Madhya Pradesh and Tamil Nadu account for the largest area in this category. The commercial sector (mainly canteens in office buildings) accounts for only 2% of collector area. A similar sectoral breakdown of collector area installed under the state projects is being carried out with data soon expected from India. This will be reported in the succeeding phases of this study.

Based on the fact that a large majority of the systems have been installed in the last two financial years (1983/84) and 1984/85), particularly in 1984/85, and considering the ratio of the number of systems installed to those under construction it can be roughly estimated that, under the current incentive schemes of government at both Central and State levels, the total annual demand for flat plate collectors is about 25,000 - 30,000 square meters of

Table 1

Flat-Plate Collector Area Installed/Under Construction

State Nodal Agency Programs

State	Systems	Total Collector Area (m^2)
U.P.	154	11,396
A.P.	26	971
Maharashtra	8	810
Punjab	33	2,145
Tamil Nadu	6	897
Delhi	49	3,512
Haryana	5	1,448
Bihar	3	310
Orissa	10	427
Gujarat	102	6,556
Subtotal	396	28,742

Central Government Program

All States	42	13,560
Railways	184	1,277
Total	622	43,318

Source: DNES

collector area. Adding to this the 10% of the total demand outside the government sector, we obtain a rough figure of about 27,000 - 33,000 square meters of collector area as the current annual demand. This translates into about 15,000 collectors per year of 2 square meter size, the average size of collector currently manufactured in the country.

Projected Demand

In the urban/industrial environment, the demand for a new product such as solar hot water systems in India is primarily influenced by three factors:

(i) Price of the system in comparison with the price and operating cost of conventional alternatives (such as electric resistance water heaters/oil fired/coal fired systems).

(ii) Durability and reliability of the system in comparison to conventional alternatives.

(iii) Financial incentives available to spur consumer demand.

Table 2

Sectoral Breakdown of Solar Installations

Central Government Projects [installed area (m^2) of solar collector]

State/U.T.	Domestic	Institutional	Commercial	Industrial	Total
Delhi		2918	50		2968
Haryana				345	345
Gujarat		475		220	695
Karnataka				136	136
Maharashtra		415		315	730
Andhra		340	135	416	891
U.P.		875	40	422	1319
M.P.		1984	32	1850	3866
Tamil Nadu				2300	2300
Assam		40			40
Rajasthan		60			60
Orissa		48		162	210
Punjab		100			
All States		7137	25[illegible]	[illegible]56	13560

Source: DNES

The government has announced a fairly generous program of incentives and subsidies for solar energy systems. In the case of institutional, commercial and industrial sectors, subsidies up to 75% are available for purchase of solar hot water/hot air systems while for domestic systems subsidies up to 50% are offered on the initial purchase price.

However, since many energy forms, including conventional energy forms such as electricity, coal and selected oil products (kerosene, diesel, LPG) are also subsidised by government, the attractiveness of the solar subsidy could be somewhat reduced as a factor in the user's decision. Durability and reliability, along with information dissemination, appear to play a large role in the user decision-making at least in the commercial and industrial sectors.

In the domestic sector, initial price is a major factor. Based on the current systems being marketed, the price of a 100 liter per day system delivering hot water at 60°C is about Rs. 8000/-. If one compares this with the price and operating cost of an electric water heater (known as "geyser" in India), of the same capacity, one obtains a payback period of roughly 6 - 7 years (assuming no rise in the subsidized electricity prices) which does not seem sufficiently attractive to an individual house owner give lack of information as well as problems of systems reliability and life. Besides, the initial cost, even with a 50% subsidy, would place it out of the reach of the vast number of lower income people who rely on fuels such as fuel wood for heating water. Lowering initial costs by a significant margin could thus open up a very large market especially if the systems are properly tested before installation for durability and performance.

The projected demand for solar hot water/hot air systems can be estimated on two factors:

(i) improvements in system cost and performance which can widen the potential range of consumers, and

(ii) projections made by the government agencies in the course of preparation of the 7th Five Year Plan.

The government has made provision for a subsidy of Rs. 60 crores for industrial and institutional hot water systems and Rs. 10 crores for domestic hot water systems during the course of the 7th Five-Year Plan. A further expenditure of about Rs. 6 crores is also envisaged for cooling systems which would also add to the demand for solar collectors. If the current rates of subsidy prevail, the Government programs themselves would imply a market of 100,000 - 150,000 sq. meters of collectors per year or about 50,000 - 75,000 collectors of equivalent 2 square meter size. However, lowering system cost by a factor of 50% or so would open up a very large domestic market in urban areas which are currently being served by electric water heaters. Industry data reveal that perhaps 300,000 water heaters for domestic residences are now sold annually. If even 10% of these are replaced by solar hot water systems, which, given the unreliability of electric supply in many parts of the country, is not an unreasonable estimate, it would add an extra 50,000 square meters to collector sales, besides having significant impacts on the electric supply system. (It is the judgement of the Delhi Electric Utility authorities, DESU,

potential load levelling implications with significant impact on the peak generation requirements).

A reduction in system cost by, say, 100%, could further open up the rural market for hot water which in aggregate terms is much larger. This has been stressed in a recent study by the Tata Energy Research Institute,* which shows that only about 3% of the energy utilized for domestic hot water comes from higher income urban areas using electricity. The remainder comes from lower income urban and rural households, many of them using non-commercial fuels such as wood, dung, residues, etc.

5. SURVEY OF SOLAR THERMAL INSTALLATIONS

As included in the Scope of Work, a summary of some of the users, industrial and institutional, of solar hot water systems was carried out during the trip to India. A total of nine installations were visted; five were institutional buildings, one was an office canteen and three were at industrial establishments. All of these had hot water systems installed under Central or State government projects. The institutional buildings included three hospitals and two schools and of the industries surveyed two were dairy processing plants and one a textile factory.

The project of the survey was to elicit relevant information in four broad categories:

(i) System performance

(ii) Component, especially collector, durability

(iii) System cost

(iv) User acceptability

System Performance

System performance is a composite function of component performance and reliability and system design. A high-performance collector placed in a poorly designed system can degrade system performance as much as a low-performance collector. This is particularly the case for large hot-water systems typical of industrial installation. Such systems incorporate a complex array of pumps, pipes, valves, heat exchanges and temperature sensors in addition to collectors and storage tanks. Improper design of the water circuitry, sub-optional selection of pump sizes which can increase parasitic losses, faulty connections, etc. can cause low system performance even if the solar collectors are functioning well. The ultimate measure of system performance is the delivery of hot water at the design level quantity and temperature over the operating period of the equipment. Based on this criterion, it was judged that four out of the nine systems were performing reasonably satisfactorily, two had experienced intermittent problems due to pump failures, two had experienced a prolonged shutdown because of collector breakdown to leakage, and another had problems external to the system due to the quality and reliability of the mains

* "Solar Domestic Hot Water in India - Socio-Economic Constraints on System Design," J. Painuly, A. Gadgil and T. Natrajan, Tata Energy Research Institute, New Delhi, 1984

water supply. Seven of the nine systems had been installed only within the last year and a half. Only one had operated more than two years. Since these systems have been installed as demonstration projects, most of them were provided with flow and temperature gauges to permit evaluation of system performance by the engineers of the funding agencies; DNES/STEC for Central Govt. projects and the relevant state nodal agencies for State Govt. projects. However, it was found that data was collected only intermittently by the users and the monitoring was also somewhat random due to staff shortages in the funding agencies. This made the judgement of system performance mainly subjective on the part of the users. However, this judgement has considerable merit since user perceptions are likely to be a key factor in promoting acceptance of the technology.

Collector Durability

All collectors made in India employ the conventional metal tube and fin absorber plate and glass cover as glazing assembled in a metal box with rubber seals, screws, fasteners and adhesives. A variety of insulation materials are commonly used for the back insulation including glass wool, mineral foam and polyurethane foam. It is estimated that less than half of the collectors manufactured employ selective coatings, the remainder use non-selective paints which implies that the collectors are not designed for high thermal performance.

Collector durability is a function both of the intrinsic quality of the materials utilized as well as the design and construction practices employed in assembling the materials into a finished product. Materials commonly used for the absorber plate in India include mostly galvanized iron (G.I.) sheet and, to a lesser extent, copper sheet although use of the latter is becoming more common in recent years by the larger manufacturers. This choice is due largely to materials cost, but G.I. sheet is subject to rapid corrosion as can be observed with many of the Indian collectors. Since selective coatings (e.g., black chrome) are not manufactured currently in the country they have to be imported. Thus the choice of non-selective paints and the associated lower performance could again be ascribed to materials cost; however, the quality of the paints available and the care which is exercised in application frequently leave something to be desired. Hence, chipping or peeling of the paint or, sometimes, outgassing can be observed which negatively impact collector performance and life.

The construction design used employs a large number of screws and fasteners and rubber gaskets bonded with adhesive to seal the collector frame. Increase in the number of individual components as well as the complexity of the design implies a corresponding increase in the possible failure rate.

These factors were all observed, to a lesser or greater extent, in a visual inspection of the collector's during visits to the facilities. In some cases, where a few of the collectors had not been properly conditioned prior to installation, outgassing of the black paint had occurred leading to the collector becoming non-functional. A frequent feature was loss of seal integrity due to peeling of the adhesive bonding the rubber gaskets to the frame. Since many of the installations were quite new, the effects of deterioration were still in an early stage; some of these could eventually have serious impacts on collector performance.

System Costs

All the installations visited had been heavily subsidized out of central or State Govt. programs. Three of the installations, in fact, all of them being on educational institutions, had been installed at no capital cost to the users. The others received a 75% subsidy on the installed cost. At this rate of subsidy, the solar hot water system is less costly to the user than a conventional system even ignoring the fuel costs. Of course, it has to be recalled that these installations are, in a sense, demonstration projects for proving the performance of the technology.

The current prices of solar hot water systems sold in India are as follows:

(a) Domestic System:
(100 liter/day at 60°C) = Rs. 7000 - 8000

(b) Institutional/Industrial Systems
(Upwards of 500 liter/day at 60-85°C)

= Rs. 5000 - 6000 on 100 lpd basis at 60°C

Rs. 7000 - 8500 on 100 lpd basis at 80°C

These prices have been derived from our information review of tender offers made to state nodal agencies on their sponsored projects as well as interviews with some of the major manufacturers.

Based on these prices, the economics of the current design of solar hot water systems available in India can be analyzed in terms of the savings of conventional energy produced by the solar system. For small systems the conventional alternative in India is an electrical resistance water heater, known as a "geyser." For large systems, the conventional alternative is an oil-fired or coal-fired boiler. At the subsidized prices of electricity, roughly half the economic cost of generation and distribution, a detailed economic calculation shows that the payback period at the unsubsidized cost of the solar system would amount to roughly 8 to 10 years. At the unsubsidized (economic cost) prices of electricity, this would be roughly halved. Comparison with the coal and oil-fired boilers at the prevailing (subsidized) coal and (unsubsidized) furnace oil prices respectively, shows payback periods of roughly 13 to 15 years (for coal) and 7 to 8 years (for oil).

User Acceptability

For the four users interviewed with systems performing according to design, acceptability appeared to be quite high. Two of the users indicated that they would be willing to purchase the system without any subsidy. From their point of view, the conventional systems were more unreliable due to the frequent breakdowns in power supply and, in one case, the unreliability of coal deliveries. Thus, in a startling reversal of the situation normally perceived in the United States, solar had become for them a firm source of energy and electricity or coal a stochastic source. Users with the unreliable systems indicated that they would be unwilling to buy outright without further improvements.

All users, particularly the ones with unreliable systems, indicated an interest in the new technology based on the BNL model collector. The low weight of the collector was particularly appealing to some because they had had to put structural reinforcement on their roof to bear the load of the conventional collector array.

6. COMPARISON OF BNL COLLECTOR AND LOCAL CONVENTIONAL COLLECTORS

Data gathered during the test of the BNL collector conducted at the STEC facility in the course of the BNL-STEC collaborative project has been utilized to perform an initial comparison between the BNL collector and the collectors locally manufactured in India. Since BNL collectors have not yet been tested as part of a system in India, comparison has to be based on two parameters, one related to collector thermal performance as measured by the collector efficiency and the other a projected measure of the likely cost of manufacture of the BNL design as compared with the conventional design.

(a) Thermal efficiency comparison between the BNL collector and the Indian manufactured collectors is based on data generated on both at the STEC facility in Haryana as well as efficiency curves on its products produced by one leading manufacturer in India. Data analysis shows that the $\Delta T/I$ intercept for the BNL collector is approximately 40 to 50 percent higher than the corresponding intercept for the Indian manufactured collectors. Thus the thermal performance of the BNL collector should be significantly higher in the operating range of the collector.

(b) A preliminary analysis of cost shows that the materials cost of the BNL collector would be roughly half that of the Indian collector. The major difference in cost arises from two categories: (i) The cover glazing in the BNL design is a polymer film while the conventional design uses low iron, tempered glass. The latter is manufactured in India in relatively small quantities and is expensive. For a two square meter panel, the imported cost of the polymer (which has been exempted from Indian Customs duty if used for solar application) material is lower than the cost of the glass by a factor of about six. This contributes a significant fraction of the difference in total materials cost. (ii) The remainder of the difference comes from the basic BNL design which is simpler and uses fewer components than the conventional design.

The cost difference between the BNL design and the conventional collector manufactured in India can be most conveniently analyzed in terms of the materials cost of the main components. The contribution to ex-factory cost arising out of the manufacturing process in terms of labor, energy, etc., is difficult to capture in the absence of detailed information from conventional collector manufacturers about their construction practices. We believe, however, that due to the inherently simpler nature of the BNL design and the fewer components it involves, the labor and energy costs of its manufacture would probably be less than that of the conventional collector.

A rough estimate of the basic materials costs in Indian currency for the first and advanced generation of the BNL design and the conventional collector

made in India is shown in Table 3. The cost comparison is made on the basis of the available component prices for both imported and domestic materials for a basic 2 square meter collector. It should be noted that the cost comparison should allow for consideration of the fact that the laboratory test of the BNL collector has indicated a higher thermal efficiency than similar laboratory tests performed on locally manufactured conventional collectors. This implies that for meeting a given load, fewer collectors of the BNL design would be required which would reduce overall system cost.

Table 3

Estimates of Collector Materials Cost*
(Rs.)

	BNL DESIGN		CONVENTIONAL DESIGN
	Generation 1	Advanced Generation	
Glazing	150	25	950
Absorber plate	700	250	700
Insulation	120	120	120
Frame	100	100	250
Back seal	50	25	--
Other**	50	50	100
Total	1150	470	2120

*Based on 2 square meter collector
**Mounting hardware, adhesives, etc.

7. TENTATIVE COMMERCIALIZATION PLAN

Commercialization of the BNL collector has been envisaged as a two-step process:

(i) Transfer of the BNL technology from the laboratory to the U.S. private sector through a company, Alkem Research and Technology, Inc., in which one of the principals, William G. Wilhelm, is the main developer of the collector concept and design.

(ii) Agreement between Alkem and a qualified Indian company to transfer the technology for collector manufacture in India.

The management of BNL has indicated its willingness and support for the first step. Discussions on the possible modalities and time frame for the second step were held with a number of interested parties during the trip to India in August. Participation in two solar energy seminars, the first one being the India-US Solar Symposium in Roorkee from Aug. 9-11, and the second a special seminar on plastic solar collectors organized by the Tata Energy Research Institute in New Delhi on Aug. 16 greatly facilitated the interaction with knowledgeable and active elements within the solar industry in India. The second seminar, in particular, was extremely useful as five major manufacturers were represented. All of them were extremely intrigued and interested in the new BNL technology. Two of them wanted to purchase samples immediately. There was a general recognition in the seminar that the budding solar thermal industry in India could not continue to grow indefinitely on subsidies alone but had to reach out for creative, low-cost solutions.

The following tentative plan for commercialization emerged out of the discussions:

(i) Alkem and the Indian party reach agreement on the modalities and financial terms of the venture. One form is a joint venture with Alkem holding a minority share, restricted to a maximum of 40 percent by the Indian Foreign Exchange Regulation Act (FERA), in the joint enterprise. An alternative is an agreement to transfer technology with payment of "know-how" fee and royalties on the collectors sold. Alternative U.S. and Indian tax implications of the two modalities are currently being explored by Alkem. This process is likely to take another one or two months. It should be noted that know-how fees and royalties are payable in either modality although the amounts likely to be approved by the Indian government would differ in the two cases.

(ii) After agreement is reached, the Indian partner has to submit an agreement for foreign collaboration to government for approval. This process normally takes eight to twelve weeks depending on the complexity of the case. DNES would be actively involved with the approval process, being the "technical" agency of government concerned with the matter.

(iii) Assuming approvals are granted, the manufacturing plan will be initiated to develop a schedule for production. A tentative schedule for this process done by Alkem indicates a period of approximately six months from initiation of the manufacturing plan to start of production.

8. DISCUSSIONS WITH DNES/STEC

During the trip to India in August, a number of meetings were held with DNES and STEC. Discussions took place both on the output of the BNL-STEC project and the contours of its possible continuation as well as on the possible outlines of the commercialization of the BNL collector in India. During this period, two visits were also made to the STEC facility in Haryana, to make a visual inspection of the collectors brought there last November and to check on the functioning of the instrumentation supplied to STEC.

On the commercialization angle, DNES indicated its desire to have the BNL technology come to India. Informally, they indicated that they would provide their assent in the foreign collaboration approval process to speed up a transfer of technology agreement between potential U.S. and Indian partners. DNES also foresaw no problem in making available data generated during BNL-STEC projects to interested individuals and organizations in India. They re-expressed their interest in a wider systems test of the collector, as part of a continuing BNL-STEC collaborative activity, to which the BNL side agreed as it would generate additional valuable information for systems design.

ANNEX 1

SOLAR PROJECTS INSTALLED

UNDER

CENTRAL GOVERNMENT PROGRAM

SOLAR THERMAL DEMONSTRATION EXTENSION SYSTEM (INSTALLED)

SOLAR WATER HEATING SYSTEMS

		Temp. °C	System Collector Area (m^2)
1.	Qutab Hotel, New Delhi	60	217
2.	Modern Bakeries, New Delhi	60	50
3.	Indo-Australian Cattle Breeding Farm, Haryana	60	45
4.	Haryana Breweries, Murthal, Haryana	60	300
5.	Jahangir Textile Mills, Ahmedabad (Gujarat)	80	175
6.	Jupitar Textile Mills, Ahmedabad (Gujarat)	80	45
7.	Silk Filature Factory, Kanakpur, Karnataka	60	100
8.	Leprosy Hospital, Pune, Maharashtra	60	100
9.	Leprosy Hospital, Pune, Maharashtra	80	15
10.	BHEL Canteen Hyderabad, A.P.	60	135
11.	A.P. Dairy Dev. Corporation, Warrangal (A.P.)	60	416
12.	BHEL Guest House, Haridwar (U.P.)	60	100
13.	BHEL Factory, Haridwar (U.P.)	60	"
14.	Central Electronics Canteen, Sahibabad, U.P.	60	30
15.	Rashtriya Chemicals & Fertilisers Bombay, Maharashtra	60	40
16.	Rashtriya Chemicals & Fertilisers Bombay, Maharashtra	80	60
17.	Tirumala Tirupathi Devasthanam, Tirupathi A.P.	60	100
18.	Asiad Village, New Delhi	60	40
19.	Janpath Hotel, New Delhi	60	689
20.	Hamidia Hospital, Bhopal, M.P.	85	60
21.	Hamidia Hospital, Bhopal, M.P.	85	30

SOLAR THERMAL DEMONSTRATION EXTENSION SYSTEM (INSTALLED) cont.

SOLAR WATER HEATING SYSTEMS	System Temp. °C	Collector Area (m^2)
22. Arogya Mnadal Hospital, Charutara, Gujarat	60	120
23. U.P. Bhavan, New Delhi	60	100
24. Lodhi Hotel, New Delhi	60	1077
25. IIM, Ahmedabad, Gujarat	60	120
26. M.Y. Hospital, Indore, M.P.	85	90
27. Western India Textile Mills, Bombay, Maharashtra	85	175
28. State Guest House, Lucknow, U.P.	60	100
29. Gomti Hotel, Lucknow, U.P.	60	100
30. Eye Hospital, Sitapur, U.P.	60	10
31. Srinagar Tourist Rest House, Srinagar, U.P.	60	60
32. Tourist Bungalow, Varanasi, U.P.	60	160
33. Digambar Jain Karhana, Junagarh, Gujarat	60	40
34. United Malwa Mills, Indore, M.P.	85	382
35. K.N. Katju Hospital, Bhopal, M.P.	85	42
36. G.S.I.T.S., Indore, M.P.	60	150
37. Bhopal Dairy, Bhopal, M.P.	60	464
38. Bhopal Dairy, Bhopal, M.P.	85	618
39. Tamilnadu Cooperative Textile Processing Unit, Erode, T.N.	70	1000
40. Madhavaram Dairy, T.N.	60	300
41. Ambur Milk Chilling Unit, T.N.	60	200
42. Villupuram Milk Chilling Unit, T.N.	60	200

SOLAR THERMAL DEMONSTRATION EXTENSION SYSTEM (INSTALLED) cont.

	SOLAR WATER HEATING SYSTEMS	System Temp. °C	Collector Area (m^2)
43.	MPEB Hospital, Rampur, Jabalpur, M.P.	85	64
44.	J.P. Hospital, Bhopal, M.P.	60	20
45.	J.P. Hospital, Bhopal, M.P.	85	42
46.	Astha Milk Chilling Centre, Astha, M.P.	70	200
47.	Burhanpur Dairy, Burhanpur, M.P.	85	62
48.	Khandwa Dairy, Khandwa, M.P.	85	124
49.	Distt. Hospital Sagar, M.P.	85	56
50.	Ujjain Hospital, Ujjain, M.P.	85	108
51.	Govt. Hospital, Raipur, M.P.	85	28
52.	"	"	"
53.	"	"	"
54.	Rishi Valley School, Chittor, A.P.	60	40
55.	KMVN Guest House, Champavat, Pithoragarh, U.P.	60	60
56.	"	"	"
57.	KMVN Guest House, Champavat, Pithoragarh, U.P.	60	10
58.	Secretariate Canteen Lucknow, U.P.	"	"
59.	Distt. Hospital, Rai-Bareilly, U.P.	"	"
60.	Circuit House, Bareilly, U.P.	"	"
61.	Distt. Hospital, Pilibhit, U.P.	"	"
62.	Circuit House, Meerut, U.P.	"	"
63.	Ladies Hospital, Bijnaur, U.P.	"	"

SOLAR THERMAL DEMONSTRATION EXTENSION SYSTEM (INSTALLED) cont.

SOLAR WATER HEATING SYSTEMS	System Temp. °C	Collector Area (m^2)
64. Balrampur Hospital, Lucknow, U.P.	"	"
65. Distt. Hospital Lakhimpur Kheri, KHERI, U.P.	"	"
66. T.B. Hospital, Pilibhit, U.P.	60	4
67. Distt. Hospital, Muzaffarnagar, U.P.	"	"
68. Distt. Hospital, Ghaziabad, U.P.	"	"
69. Distt. Hospital, Rampur, U.P.	"	"
70. Distt. Hospital, Bijnaur, U.P.	"	"
71. Primary Health Centre, Hapur, U.P.	"	"
72. Kukhartal Zila Parishad Inspection House, Muzaffarnagar, U.P.	"	"
73. Dhankutti Rest Home, Haridwar, U.P.	"	"
74. Collectorate Guest House, Bulandshahar, U.P.	"	"
75. P.W.D. Inspection House, Rai-Bareilly, U.P.	60	1.5
76. Irrigation Inspection House, Safipur, Unnao, U.P.	"	"
77. Irrigation Inspection House, Rai-Bareilly, U.P.	"	"
78. Farmers, Training Centre, Rai-Bareilly, U.P.	"	"
79. PWD Inspection House, Unnao, U.P.	"	"
80. Collectorate Guest House, Bareilly, U.P.	"	"
81. Inspection House Nawabganj, U.P.	"	"
82. Inspection House Faridpur, U.P.	"	"
83. PWD Inspection House, Meerut, U.P.	"	"
84. PWD Inspection House, Meerut, U.P.	"	"

SOLAR THERMAL DEMONSTRATION EXTENSION SYSTEM (INSTALLED) cont.

SOLAR WATER HEATING SYSTEMS	System Temp. °C	Collector Area (m^2)
85. PWD Rest Home, Saharanpur, U.P.	60	1.5
86. Canal Rest House, Saharanpur, U.P.	"	"
87. Zila Parishad Rest House, Saharanpur, U.P.	"	"
88. PWD Inspection House, Saharanpur, U.P.	"	"
89. Irrigation Inspection House, Bulandshahar, U.P.	"	"
90. Municipal Board Guest House, Bulandshahar, U.P.	"	"
91. PWD Inspection House, Bijnaur, U.P.	"	"
92. PWD Inspectior House, Allahabad, U.P.	"	"
93. PWD Inspection House, Allahabad, U.P.	"	"
94. Inspection House (Tubewell), Etah, U.P.	"	"
95. PWD Inspection House, Jalaun, U.P.	"	"
96. GDA Guest House, Chaziabad, U.P.	"	"
97. Flood Relief House Urai, Jalaun, U.P.	"	"
98. Primary Health Centre, Bilaspur, Rampur, U.P.	"	"
99. Police Line, Chaziabad, U.P.	"	"
100. Public Health Centre, Shamli, U.P.	"	"
101. Distt. Jail Muzaffarnagar, U.P.	"	"
102. CRPF Guest House, Rampur, U.P.	"	"
103. Distt. Hospital, Mathura, U.P.	"	"
104. Circuit House, Varanasi, U.P.	"	"
105. Primary Health Centre, Mathura, U.P.	"	"

SOLAR THERMAL DEMONSTRATION EXTENSION SYSTEM (INSTALLED) cont.

SOLAR WATER HEATING SYSTEMS	System Temp. °C	Collector Area (m^2)
106. Parvara Nagar Hospital, Parvaranagar, Maharashtra	60	300
107. Bharat Electronics Ltd., Ghaziabad, U.P.	"	202
108. Pathikashram Gandhi Nagar, Gujarat	"	30
109. Circuit House Gandhi Nagar, Gujarat	"	35
110. Circuit House Surat, Gujarat	"	40
111. Circuit House Rajkot, Gujarat	"	10
112. Circuit House, Ahmedabad, Gujarat	"	15
113. Circuit House Baroda, Gujarat	"	25
114. Jain Temple Kumbharia, Gujarat	"	40
115. Ranakpur Pali, Rajasthan	60	60
116. Military Canteen of Air Force Missiles School, Gopalpur on-sea Orissa	60	48
117. Gujarat Bhavan, New Delhi	60	60
118. IIT Canteen, New Delhi	60	30
119. Milk Chilling Centre, Dhankanal, Orissa	60-70	162
120. Erode Dairy, Erode, T.N.	70	400
121. Dharmapuri, Milk Chilling Centre, Dharmapuri, T.N.	60	200
122. Gurudwara Databandi Chhod, Gwalior, M.P.	85	24
123. "	60	16
124. Hoshanagabad Hospital, M.P.	60	36
125. E.S.I. Hospital Indore, M.P.	85	32
126. "	"	"

SOLAR THERMAL DEMONSTRATION EXTENSION SYSTEM (INSTALLED) cont.

SOLAR WATER HEATING SYSTEMS	System Temp. °C	Collector Area (m^2)
127. E.S.I. Hospital, M.P.	85	32
128. Distt. Hospital Bilaspur, M.P.	"	56
129. Medical College Hospital, Jabalpur, M.P.	60	56
130. Kamla Raja Hospital, Gwalior, M.P.	85	32
131. "	"	"
132. "	"	"
133. Kasturba Gram Indore, M.P.	"	18
134. "	"	"
135. "	"	"
136. "	60	38
137. "	"	"
138. "	"	"
139. Distt. Hospital Morena, M.P.	85	64
140. Regional College of Education, Bhopal, M.P.	60	72
141. "	"	"
142. "	"	"
143. "	"	"
144. Distt. Hospital, Seoni, M.P.	60	36
145. Distt. Hospital, Sehore, M.P.	60	30

SOLAR THERMAL DEMONSTRATION EXTENSION SYSTEM (INSTALLED) cont.

SOLAR WATER HEATING SYSTEMS	System Temp. °C	Collector Area (m^2)
146. Beggar Home, Banda Bahadur Marg, Delhi	60	10
147. "	"	"
148. "	"	"
149. "	"	"
150. Hindustan Organic Chemicals Ltd., Rasayani, Bombay, Maharashtra	65	36
151. BHEL, CED, Bangalore	"	36
152. BHEL, Jagdishpur, U.P.	"	20
153. Myor Textile Mills, Kanpur, U.P.	85	150
154. Circuit House, Gauhati, Assam	60	5
155. Circuit House, Nowgang, Assam.	"	"
156. Circuit House Jorhat, Assam.	"	"
157. Circuit House, Golaghat, Assam.	"	"
[illegible]. Circuit House, Haflong, Assam.	"	"
159. Circuit House, Silchar, Assam.	"	"
160. Tourist Lodge Gauhati, Assam.	"	"
161. Tourist Lodge Kaziranga, Assam.	"	"
162. Sant Aamagam, Karolbagh, Delhi	"	30
163. Orissa Bhavan, New Delhi	"	63
164. T.T.D. Turupati, A.P.	60	200
165. Shivalik Public School Punjab	80	100

SOLAR THERMAL DEMONSTRATION EXTENSION SYSTEM (INSTALLED) cont.

SOLAR WATER HEATING SYSTEMS	System Temp. °C	Collector Area (m^2)
166. Govt. School for Blind Boys, Banda, Bahadur Marg, Delhi	60	30
167. Hindu Rao Hospital, Delhi	60	21
168. "	"	31.5
169. "	"	10.5
170. Balak Ram Hospital Delhi	60	9.2
171. Rajan Babu T.B. Hospital, Delhi	80	20
172. "	60	10
173. "	"	"
174. Janak Puri Thana, New Delhi	"	30
175. Kota Guest House, New Delhi	"	19.6
176. "	"	19.6
177. Medical College Hospital Gwalior, M.P.	80	30
178. "	"	"
179. "	"	"
180. Central Jail, Indore M.P.	85	84
181. Officer's Canteen BHEL, Bhopal	85	32
182. Barwani Hospital, Barwani	85	60
183. Lady Elgin Hospital, Jabalpur, M.P.	85	30
184. GMVN, Guest House, Pauri, U.P.	60	60