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(A Preliminary Screening to Identify Critical Materials)

June 1979

Prepared for the U.S. Department of Energy
under Contract EY-76-C-06-1830

Pacific Northwest Laboratory
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SOME POTENTIAL MATERIAL SUPPLY CONSTRAINTS IN SOLAR SYSTEMS FOR HEATING AND COOLING OF BUILDINGS AND PROCESS HEAT

(A Preliminary Screening to Identify Critical Materials)

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June, 1979

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under Contract EY-76-C-06-1830

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S.I. TO ENGLISH CONVERSIONS

S.I. units are used almost exclusively in this report. Some of the pertinent conversions are:

Metric Ton	1 MT = 2204.6 lbs
Square Meter	1 m^2 = 10.764 ft^2
Joules	1054 J = 1 Btu
Megajoules	1054 MJ = 10^6 Btu
Gigajoules	1.054 GJ = 10^6 Btu
	1.054 x 10^9 GJ = 10^{15} Btu
	= 1 Quad
Insolation	1 GJ/m^2-yr = 88,143 Btu/ft^2-yr

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SUMMARY OF RESULTS AND RECOMMENDATIONS

Nine Solar Heating and Cooling of Buildings (SHACOB) designs and three Agricultural and Industrial Process Heat (AIPH) designs have been studied to identify potential future material constraints to their large scale installation and use.

The nine SHACOB and three AIPH systems were screened and found to be free of serious future material constraints. The screening was carried out for each individual system design assuming 500 million m^2 of collector area installed by the year 2000. Also, two mixed design scenarios, containing equal portions of each system design, were screened. The mixed design scenarios assumed 1) 500 M m^2 and 2) a billion m^2 of collector area installed by the year 2000.

To keep these scenarios in perspective, note that a billion m^2 containing a mixture of the nine SHACOB designs will yield an annual solar contribution of about 1.3 Quads or will displace about 4.2 Quads of fossil fuel used to generate electricity. For AIPH a billion square meters of the mixed designs will yield about 2.8 Quads/year.

Three materials were identified that could possibly restrain the deployment of solar systems in the specific scenarios investigated. They are iron and steel, soda lime glass and polyvinyl fluoride. All three of these materials are bulk materials. No raw material supply constraints were found.

Iron and steel exceeded the threshold for the cost criteria ($15/$m^2$) in two SHACOB systems, in one AIPH system, and in the AIPH mixed design scenarios. A cost of $15/$m^2$ represents about 5% of the installed cost of a system. Increases in the price of steel in the future could offset anticipated cost reductions due to learning and mass production and prevent some AIPH and SHACOB systems from becoming economically competitive. If steel prices should rise to an unacceptable level in the future there are several viable alternatives:

1) direct substitution of less expensive materials
2) more efficient use of steel in existing designs
3) redesign of components or functions
4) elimination of certain components, such as storage vessels
5) minimizing the length of pipe and duct runs

The general strategy for steel should be to minimize steel usage (and therefore price impact) and/or to have substitution alternatives available.

Glass consumption in the billion m^2 mixed SHACOB scenario exceeds 10% of the world consumption in the year 2000. The required growth rate in glass production of 3% per year should be easily attainable. Glass usage in the mixed design SHACOB scenario comes from 7 designs using double glazing, one design using single glazing and one design using evacuated tubes. There are other glazing alternatives, such as fiber reinforced polyester, polyvinyl fluoride (Tedlar*), FEP Teflon*, and polycarbonate from which over 6 billion m^2 of single glazing could be supplied without exceeding 10% of the year 2000 world consumption for any of the materials.

Polyvinyl fluoride consumption exceeds 18% of the world's consumption of fluorocarbons in the year 2000, when used as a single glazing material in 500 million m^2 of one system. Meeting this demand would require a growth rate of 8% per year, which is half that experienced by some other plastics in past ten year spans. Hence, ample production capacity should become available. In the mixed design scenarios, polyvinyl fluoride usage was not a problem since only one of the nine SHACOB systems uses it.

All three potential material problems could be managed by avoiding sudden surges in solar demand and by executing stable long term contracts for their supply.

*A trademark of E. I. DuPont

INTRODUCTION

The objectives of this study are to;

- Identify potential material supply constraints which could seriously impede the large scale future installation of SHACOB and AIPH systems.
- Provide a functional description of materials of construction of typical SHACOB and AIPH systems in computerized format suitable for interactive updating in workshops or future reviews.
- Provide a data base of statistics and production processes in machine accessible format for making this assessment and supporting future SHACOB and AIPH assessments.
- Show the sensitivity of potential shortages to the size of the SHACOB or AIPH implementation scenario.

The scope of the study includes flat plate and concentrating collector systems; generating hot water, hot water and space heating and hot water, space heating, and cooling in residences and public buildings, and in addition includes systems capable of supplying agricultural and industrial process heat.

Many additional systems could be studied, but the scope of systems studied would appear to have provided a reasonable first cut at identifying future potential material constraints.

SHACOB AND AIPH DESIGN DESCRIPTIONS

DESIGN DESCRIPTIONS

The system designs characterized for use in this study, are listed in Table 1. The designs were selected with the aid of DOE staff to be representative of plausible future systems. The design variations included in the systems characterized are shown in Table 2.

The material requirements for these systems were determined in detail and entered on the computer data base used in this study. Additional system designs may be added to the data base if desired. Also, design variations on existing systems can be studied by substituting data for a component (e.g., PVC pipe for copper pipe) or a subsystem (e.g., one collector type for another).

Detailed characterizations of each system, including material requirements, are in the Appendix. Some of the major material uses for each system are given in Table 3 for SHACOB systems and Table 4 for AIPH systems. There, the material uses are indicated for the principal parts of the system.

REFERENCE DESIGNS METHODOLOGY

It is important to draw a distinction between the reference system designs studied in this work and generic system designs. Generic systems are usually not representative of a real system, and may represent an "average" of several selected systems. Generic systems are often used in estimating material requirements for mature technologies, where the implementation scenario is well established and stable. If the technology changes, then the implementation scenarios changes, and the generic system no longer represents the "average" system. The complete material count must be done on a redefined generic system. A more-convenient method of updating material requirements is needed under changing

TABLE 1. System Designs Characterized

SHACOB DESIGNS

Space Heating - Solaron Corporation System using 273 ft^2 of steel flat plate collectors - air heat transport.

Space Heating and Domestic Hot Water - Solaron Corporation System using 273 ft^2 of steel flat plate collectors - air heat transport.

Domestic Hot Water - Sunworks copper flate plate collectors (74 ft^2) - water and ethylene glycol heat transport.

Space Heating and Domestic Hot Water - American Heliothermal Corporation System using 268 ft^2 of steel flate plate collectors - water and propylene glycol heat transport.

Space Heating and Domestic Hot Water - Ecosol Systems Inc. heat pump system using 258 ft^2 of KTA Corporation evacuated tube collectors - water heat transport.

Space Heating and Cooling and Domestic Hot Water - Kirtland Air Force Base, Exchange Main store using absorption chillers for cooling and 8320 ft^2 of Raypak, Inc., flat plate collectors with aluminum plate and copper tubing - water and ethylene glycol heat transport.

Passive Space Heating - Concrete Trombe wall behind 510 ft^2 of glazing.

Passive Space Heating - Water tank trombe wall behind 510 ft^2 of glazing.

Passive Space Heating - Direct gain, masonry walls behind 256 ft^2 of glazing.

AIPH DESIGNS

Industrial Process Hot water from Solar Ponds - Accelerates chemical leaching of uranium ore at the Sohio mining and milling complex in Bibo, NM. System design by Lawrence Livermore Laboratory uses 100,000 ft^2 of shallow solar ponds - water heat transport.

Industrial Process Heat for Kiln Drying Lumber - Installed on a conventional hardwood drying kiln at the Linden Lumber Company, Linden, AL. System design by Lockheed-Huntsville Research and Engineering Center uses 2,520 ft^2 of Chamberlain Manufacturing Corporation steel flat plate collectors - water heat transport.

Process Steam for Drying of Textiles at the Westpoint Pepperell Mill in Fairfax, AL - System design by Honeywell, Incorporated uses 8,300 ft^2 of parabolic-trough, concentrating collectors - water and steam heat transport.

TABLE 2. Design Variations in Systems Characterized (Quantity of each type listed)

Collector	SHACOB	AIPH
Flat Plate	5	1
Evacuated Tube	1	
Parabolic Trough		1
Solar Pond		1
Passive	3	
Heat Transfer		
Air	2	
Liquid	4	3
Application		
Residential	8	
Commercial	1	
Process Heat		3
Energy Use		
Direct	7	3
Heat Pump	1	
Absorption Chiller	1	

TABLE 3. Major Material Uses in SHACOB System Characterized

System	Collector	Pipe, Pumps, Valves	Storage	Heat Exchangers
Solaron-H	Glass C. Steel	C. Steel	Rock	
Solaron-H and HW	Glass C. Steel	C. Steel	Rock C. Steel	Copper
KTA and Ecosol-H and HW	Copper Aluminum	Copper Brass	C. Steel Concrete	C. Steel Copper
American Heliothermal H and HW	Glass C. Steel	C. Steel Prop. Glycol	C. Steel Glass Wool	Aluminum Copper
Sunworks HW	Copper Aluminum Glass Wool	Copper Ethylene Glycol	C. Steel Concrete Glass Wool	Copper
Kirtland AFB-BX H, C, and HW (non-residential)	Glass C. Steel Copper	C. Steel Glass Wool Ethylene Glycol Concrete	C. Steel Asphalt	C. Steel Copper
Passive - Direct Gain	Concrete Glass C. Steel			
Passive - Trombe Wall	Concrete Glass C. Steel			
Passive - Water Wall	Concrete Glass C. Steel			

Abbreviations: H = Space Heating
HW = Domestic Hot Water
C = Space Cooling
C. Steel = Carbon (mild) steel
Glass = Soda-lime sheet glass

TABLE 4. Major Material Uses in AIPH Systems Characterized

System	Energy Collection	Energy Transport	Energy Storage	Heat Exchangers
LMSC-Lumber Kiln	Carbon Steel Softwood Glass Glass Wool	Ethylene Glycol Urethane Copper PVC	Carbon Steel	Carbon Steel
LLL-Solar Pond	Concrete Sand Carbon Steel Foam Glass FRP Polyester	Transite Cast Iron Concrete	Sand Carbon Steel Urethane	
Honeywell-Textile	Carbon Steel Aluminum Copper Pitch	Carbon Steel Glass Wool Cast Iron Aluminum Neoprene		Carbon Steel Copper-Nickel, 10% Glass Wool

technology and scenarios, as is the case with solar energy. The reference system methodology facilitates updating.

For SHACOB and AIPH, a number of reference systems were established. They are real systems, with references to engineering drawings and specifications and with known performance. System components are compatible in size, performance, cost, corrosion resistance, etc. Where possible, actual system installations were selected as reference systems. A detailed list of material requirements was established for each system.

Total material requirements for any solar scenario can then be obtained simply be selecting the energy contribution by each technology and the mix of system designs for each technology.

SHACOB and AIPH designs were selected to cover the range of plausible future systems. Not all systems variations were included. Additional designs can be added in the future without disturbing the material requirements for the existing designs in the data base. They will merely supplement previous data already in place.

Most solar system designs will never wholly be replaced; but they will be modified, evolving as improvements are made in performance and cost. These improvements are likely to come at the component level. Updating of material requirements will be facilitated by having materials systematically accounted for, component by component, as is illustrated in Table 5. Each component is identified separately, according to general function. As components are significantly altered or eliminated by design, the data bank can be updated by simply removing the data for the old component and entering data for the new component. Hence, the effects of gradual changes of design on materials requirements can be monitored continuously with little effort.

In a similar manner, variations in a system design can be studied by substituting individual components (e.g., plastic pipe for copper pipe) or by substituting complete subsystems (e.g., one collector type for another).

TABLE 5. Materials Categories by Functional Component for SHACOB and AIPH

12.[a] Energy Collector

- 12.01 Miscellaneous
- 12.02 Glazing
- 12.03 Absorber
- 12.04 Energy Transport
- 12.05 Insulation
- 12.06 Reflector, Concentrator
- 12.07 Frame
- 12.08 Seals
- 12.09 Supports

13. Energy Transport

- 13.01 Miscellaneous
- 13.02 Pipe, Wire, or Duct
- 13.03 Insulation
- 13.04 Transport Fluid
- 13.05 Supports
- 13.06 Sealants
- 13.07 Valves and Dampers
- 13.08 Pumps and Fans
- 13.09 Site Dependent
- 13.10 Expansion Tanks

14. Energy Conversion

- 14.01 Miscellaneous
- 14.02 Heat Exchangers
- 14.03 Supports
- 14.04 Absorption Chiller
- 14.05 Steam Generator

15. Energy Storage

- 15.01 Miscellaneous
- 15.02 Primary Storage
- 15.03 Secondary Storage
- 15.04 Supports

17. Energy System Controller

- 17.01 Miscellaneous
- 17.02 Meters, Switches, Terminal Boards
- 17.03 Supports

22. Plant Utilities

(a) The numbering system here is taken from a larger list of functional components for solar technology. Numbers not appearing in this table represent functions that apply to solar technologies other than SHACOB and AIPH.

CHARACTERIZATION OF REFERENCE DESIGNS

Detailed characterizations of the reference SHACOB and AIPH designs are in Appendix B. Those characterizations are based upon either design documents and drawings (all three AIPH systems and the lone commercial size SHACOB system, Space Heating and Cooling and Domestic Hot Water - Ray Pak Collector, at Kirtland AFB) or published papers and rules of thumb for passive space heating, or manufacturers literature and drawings (all other SHACOB systems). For each system, a "component takeoff" was done first. Then each component was broken down into its materials of construction using drawings and bills of material from the component designer or manufacturer. In cases where drawings and bills of material were not available, schematics, component descriptions, sales literature, and verbal contact with the manufacturer subsituted adequately for detailed design drawings. Accuracy of material quantities is generally within 10%. Exact engineering materials or alloys of construction are listed where available.

The engineering alloys are converted within the computer program into their bulk material components using a transformation matrix which contains the actual alloy composition. For example, 60-40 solder is composed of 63% tin and 37% lead.

Solar energy implementations scenarios are often expressed in terms of yearly energy contribution for certain years rather than in square meters of collector installed. For purposes of comparison, it was necessary to develop estimates of the yearly energy contribution for each system design. Energy contribution calculations were taken from the design documents for all three AIPH systems and the commercial size SHACOB system, Space Heating and Cooling and Domestic Hot Water - Ray Pak Collector, at Kirtland AFB. For all the remaining active SHACOB systems, "f"- chart[1,2,3,4] was used. Computer simulations published by Balcomb et. al.,[5] were used to make estimates for the passive systems.

Location is an important factor in energy contribution. All three AIPH systems and the lone commercial size SHACOB system had been designed for specific locations.

Locations for the residential size SHACOB installations were based upon data given by Roach et al.,[6] for the economic feasibility of SHACOB systems and the expected number of new houses through 1985. It was assumed that the solar installation rate was proportional to the number of new houses in states where solar was economically competitive without government sponsored incentives. The solar installation rate was used to weight the energy contribution from a solar heating system in the location where the SHACOB system is feasible. Hence, a weighted average yearly solar contribution was arrived at. For residential space heating and hot water, a Washington, DC location yields yearly energy contribution equal to the weighted average solar contribution. For residential hot water, the weighted average solar contribution is met by locating the system in Manhattan, Kansas. Details of the energy contribution calculations are given in Appendix B.

MATERIALS REQUIREMENTS

The utilization of solar energy will require large quantities of materials. Tables 6, 7, 8 and 9 list the bulk materials and raw materials required to construct systems totaling 500 million square meters collector area. Material requirements are listed for 500 million square meters of each system design, as well as for 500 million square meters composed of equal portions of each system.

The raw material requirements listed are those required to produce the bulk material requirements listed.

In terms of sheer quantities, the largest material requirements are for iron and steel, aluminum, copper, copper ore, soda lime glass, sand and gravel, lumber, and water. Those are also the most universally used materials in solar systems. Conversely, other materials are used in only one or two systems, and there are many examples that can be observed by scanning the tables.

The magnitude of use of a material is not important in itself. However, the relationship of material use to availability is important along with a host of other factors such as: cost, import pattern, production growth rate required to meet solar demand, and the extent of known reserves and resources. The object of this report is to address these factors and to access their influence on the orderly and timely construction of solar energy systems to meet our national energy goals.

The following sections discuss the specific approach used in addressing those questions and the results of the study.

TABLE 6. Raw Material Requirements in Thousand Tons for SHACOB Systems at 500 Million Square Meters. Individual Systems at 500 m. sq. m. and Mixed System Scenario--All 9 Systems at 55.6 m. sq. m. each, Totaling 500 m. sq. m.

Materials	Raypak	KTA & Ecosol	Solaron R-HT	Solaron R-HT & HW	American Helio	Sunworks	Trombe W. Concrete	Trombe W. Water	Direct Ga.n W.	500 Million M^2 Mixed Scenarios
Antimony ore						184				20
Asbestos	57		1	1						7
Bauxite	8,372	24,864	1,002	1,228	5,648	23,554	7,739	7,775	7,760	9,779
Borate	321		571	591	381	270				237
Butane	160	9	140	149	3	70				59
Chromite	28			11		43		84	17,981	19
Clays	614	943	179	198	356	192	8,882	1,012		3,376
Coal	66,344	30,780	23,722	25,555	42,289	17,658	18,176	29,295	25,861	31,100
Coal Bit/Lig	12,328	379	18	18	43,718	47,250	18,228	18,342	18,585	17,666
Copper ore	783,155	911,905	26,186	126,301	84,593	1,149,795				342,711
Feldspar	8 2	58	1,023	1,023	536	9	726	726	727	628
Fluorospar	522	776	135	150	371	378	151	266	166	325
Gypsum	56	248				35	2,921	265	5,927	1,051
Iron ore	296,553	100,212	95,332	104,011	189,549	39,807	31,554	112,843	41,545	112,468
Lead ore	469	1,047	1,354	1,813	16	781				609
Lithium ore	3,659									407
Manganese ore	1,700	543	619	663	1,130	171	183	656	240	657
Mercury	9									1
Natural gas	2,917	2,818	482	736	786	2,913	4,089	659	8,235	2,628
Nickel ore	395			142		980				169
N_2 fixed										0
O_2	16		16	22	286					38
Petroleum	5,113	1,869	606	665	4,344	3,456	370	921	430	1,976
Salt	13,889	16,538	9,443	9,582	8,343	15,966	10,477	10,704	10,493	11,724
Sand & gravel	7,249	11,442	130,505	130,570	4,822	2,310	134,664	16,903	267,967	78,555
Sodium Nitrate			5	5						1
Stone	739	21,024				2,969	247,756	22,460	502,740	88,703
Sulfur	443	1,430	48	61	285	1,178	382	395	383	512
Tin ore	251,298	359,454		137,900		608,930				150,963
Zinc ore	8,352	3,305	24,956	24,958	12,124	202				8,217
Cotton	7									1
Flax seed		153					171	171		55
Milk byprod		2	1	1		5				1
Lumber	1,955	2	6,832	6,832	424	3,810	1	2	1	2,208
Sea water	1,557,522	4,610	41	55		24				173,723
Soybean	78						87	87		28
Tungnuts		104					116	116		37
Water	165,668	108,898	148,839	151,166	74,583	140,000	3,863	78,844	6,557	97,680
Wheat			21	21						5
Misc	1,617	1,406	609	753	619	1,562	51	181	67	763
Steam	103,499	140,354	27,221	30,070	66,104	123,678	44,890	61,356	47,019	71,634
Limestone	42,072	29,414	19,337	20,332	28,394	17,604	95,983		182,696	51,586
Coal Byprod	200,316	496,328	40,120	41,523	1,797	482,020	312,894			209,934
Electricity	5,165,978	1,048,171	181,317	188,488	973,557	2,355,017				1,107,392
Coal byprod 2	169,155	182,679				377,104				81,058
Petroleum byprod	69,080									7,682
TOTAL[(a)]	3,339,309	1,819,244	519,244	775,583	569,704	2,205,784	631,460	364,063	1,145,380	1,262,327

a. Not including byproduct and electricity.

TABLE 7. Bulk Material Requirements in Metric Tons for SHACOB Systems at 500 Million Square Meters. Individual Systems at 500 m. sq. m. and Mixed Systems Scenario-- All 9 Systems at 55.6 m. sq. m. Each, Totaling 500 m. sq. m.

Materials	Raypak	KTA & Ecosol	Solaron R-HT	Solaron R-HT & HW	American Helio	Sunworks	Trombe W. Concrete	Trombe W. Water	Direct Gain W.	500 Million M^2 Mixed Scenarios
Aluminum	1,525,102	4,914,794		37,430	974,850	4,571,000	1,529,750	1,529,750	1,533,000	1,847,663
Antimony						1,750				195
Asbestos	56,276									6,258
Bromine	97,330									10,823
Cadmium	4,515									502
Carbon black		129,270					143,902	143,902		46,379
Cement	350,332	5,163,711				729,120	60,852,404	5,516,594	123,480,000	21,805,448
Chromium	116					7,000				791
Copper	3,550,798	4,145,022	115,245	570,315	384,513	5,225,500				1,555,843
Glass, Fiber	1,283,500		2,285,200	2,364,000	1,525,590	1,078,000				949,241
Glass, Sodalim	8,836,500	625,500	10,578,900	10,578,900	5,762,671	7,983,000	7,807,000	7,807,000	7,812,000	6,661,600
Gypsum	28,122									3,127
Iron & Steel	51,070,088	16,116,000	16,783,560	18,132,746	33,379,590	5,004,622	5,524,394	19,966,678	7,230,754	19,260,778
Lead	14,085	31,442		13,790		23,457				9,204
Lithium	8,450									940
Magnesium		6,349								706
Ferromanganese	307,879	97,586	101,309	109,453	201,486	31,178	33,346	120,523	43,646	116,361
Mercury	323									36
Nickel	453					7,000				829
Sand, Gravel	375,971	10,696,259	122,140,008	122,140,008		1,510,320	126,051,400	11,427,231	255,789,000	72,293,480
Stone	783,977	21,023,682				2,968,560	247,756,208	22,460,422	502,740,000	88,702,888
Silicon	5,899	7,172				11,200				2,699
Silver	194	6,255								717
Tin	25,130	35,945		13,790		60,893				15,096
Water	100,098,832	79,480,200			59,325,152	21,511,000		76,065,504		37,416,652
Zinc	418,383	184,106	1,401,852	1,401,852	681,149	11,200				455,758
Stainless Steel	43,667			17,730		35,000				10,719
Alkyd resin		27,105					30,173	30,173		9,725
Glue			73,284	73,284						16,298
Lumber	1,773,105		6,829,597	6,829,597	420,090	3,808,000				2,186,235
Phenolic Resin	9,353	47,955	9,850	9,850		161,000				26,466
PVC Plastic	225,105									25,032
Rubber	144,480		126,080	133,960		63,000				51,988
Silicones	299,925		126,080	126,080		28,000				64,505
Teflon	3,806				20,100	2,100				2,890
Nylon		10,425			4,020					1,606
Cotton Fibers	6,547									728
Kraft Fibers	2,806									312
Urethane	285,735	308,580				637,000				136,922
Asphalt	1,354,500									150,620
Neoprene	47,537				291,450	315,000	119,215	119,215	123,900	113,014
Ethylene glycol	1,457,700					763,000				246,942
Polyethylene	4,386									488
Polyvanyl Fluor.		75,060								8,347
EPDM Rubber	26,768									2,977
Paint thinner		52,125					58,025	58,025		18,701
NA Dichrom.								75,960		8,447
Polycarbonate			27,580	37,430	10,050					8,347
Proplyene gly.					1,039,170					115,556
Vitreous Enamel			171,390	171,390	2,010					38,341
TOTAL	174,482,725	143,184,543	160,769,935	162,761,605	104,021,891	56,501,900	449,905,817	145,320,977	898,743,300	254,409,220

TABLE 8. Raw Material Requirements in Thousands of Metric Tons for AIPH Systems, Individual Systems at 500 m. sq. m. and All 3 Systems Totaling 500 m. sq. m. in the Combined Scenario.

Materials	Chamberlain Lumber Kiln	LLL Solar Pond	Honeywell Concentrating	500 Million M^2 Mixed Scenario
Asbestos	1	191	5	131
Bauxite	26,910	106	18,615	30,482
Borate	282	54	331	445
Chromite	621		121	496
Clays	914	7,518	155	5,736
Coal	112,533	9,621	23,654	97,400
Coal, Bitum.	43,999	2,338	220,873	178,496
Copper ore	289,563	15,381	166,585	314,982
Feldspar	940	120	14	717
Fluorspar	1,052	50	378	988
Gypsum		2,475		1,654
Iron ore	486,035	21,488	79,607	392,203
Lead ore	147	2	13	108
Lime			0	0
Manganese	2,845	127	462	2,293
Mercury			0	0
Molybdemum ore			480	321
Natural gas	2,037	4,183	611	4,563
Nickel ore			2,719	8,676
Nitrogen Fix.		0	0	0
Oxygen	141		0	94
Petroleum	5,504	235	879	4,421
Propane			197	131
Salt	32,420	1,123	14,771	32,274
Sand & Gravel	7,392	143,857	1,053	101,738
Silver ore	10,651	162		7,223
Stone		207,636		138,701
Sulfur	1,372	21	954	1,568
Tin ore	74,554	1,999	14,035	60,513
Zinc ore	13,376	733	3,415	11,706
Cotton	556			371
Milk byprod.	27	0	0	18
Lumber	38,490	129	5	25,801
Seawater	5	0	233	159
Water	874,551	56,665	7,347	626,960
Wheat		0		0
Misc.	1,520	94	416	1,356
Steam	239,973	5,648	109,136	236,978
Limestone	71,837	74,078	18,817	110,041
Coal byprod.	833,807	593,838	128,274	1,039,354
Electricity	4,274,689	253,503	198,225	3,157,247
Coal byprod. 2	370,329	24,531		263,766
TOTAL[a]	2,340,748	556,034	685,881	2,399,744

a. Not including byproduct and electricity.

TABLE 9. Bulk Material Requirements in Metric Tons for AIPH Systems at 500 Million Square Meters. Individual Systems at 500 m. sq. m. and Mixed Scenario--All 3 Systems at 167 m. sq. m. each, Totaling 500 m. sq. m.

Materials	Chamberlain Lumber Kiln	LLL Solar Pond	Honeywell Concentrating	500 Million M^2 Mixed Scenario
Aluminum	5,192,320	1,267	3,569,043	2,926,719
Asbestos	2,562	190,338	2,000	64,441
Cadmium	207,095	172		913
Cement		51,571,012		17,224,718
Chromium			16,099	74,547
Copper	1,316,198	69,914	757,203	715,867
Glass fibers	1,127,280	214,500	1,325,346	890,820
Glass sodalime	10,103,247	1,287,000	154,800	3,856,046
Iron, Steel	85,477,352	3,723,924	13,718,863	34,375,328
Lead	4,407	67	392	1,625
Magnesium			323	108
Ferromanganese	516,352	23,257	83,382	208,079
Mercury			13	4
Molybdenum			640	214
Nickel	102,694		18,024	40,320
Porcelain		185	65	83
Sand & Gravel		139,926,624	56,115	46,754,236
Stone		207,635,520		69,350,264
Silicon	4,532	8,994	8,437	7,335
Silver	1,494	23	221	507
Sulfur				74
Tin	7,455	200	1,404	3,026
Water	41,632,500	52,975,000	1,059,090	31,952,642
Zinc	722,307	39,225	191,846	318,428
Stainless Steel			114,616	38,282
Acrylic			84,495	28,221
Epoxy resin			252,840	84,449
Glue		1,463		488
Lumber softwood	38,003,000			12,693,002
Phenolic resin	796,355		7,095	268,352
Pvc plastic	309,575	39,127	6,192	118,535
Teflon	1,494		9,804	3,774
Cotton fibers	555,954			185,689
Kraft fibers	238,266	64,350		101,074
Urethane	625,555	41,438		222,776
Neoprene		15,470	161,250	59,024
Pitch			702,405	234,603
Polyvinyl fluo.		19,175		6,404
EPDM rubber	239,120		65	79,888
Polyester resin		500,500		167,167
TOTAL	187,187,114	458,348,745	22,302,068	223,058,072

METHODS, MODELS, AND ASSUMPTIONS USED TO IDENTIFY POTENTIAL MATERIALS CONSTRAINTS[7,8]

One usually thinks of the flow of materials proceeding from raw materials to the engineering materials (Figure 1). Take, for example, copper. Copper ore is mined and sent to a mill and smelter. The bulk material copper that leaves this process may be formed into an engineering material like brass. This brass may then be incorporated into a solar device. The tracking process used by the critical materials assessment model follows the opposition direction. First, the amount of brass in the solar device is characterized. Then this engineering material is translated into its bulk materials one of which is copper. At this point, the bulk material copper would be reviewed for possible capacity constraints. Next, the copper would be translated into its raw materials, copper ore, asbestos, clays, coal, fluorspar, etc. The copper ore and all of the other raw materials are then checked for potential capacity constraints and for availability of reserves and resources.

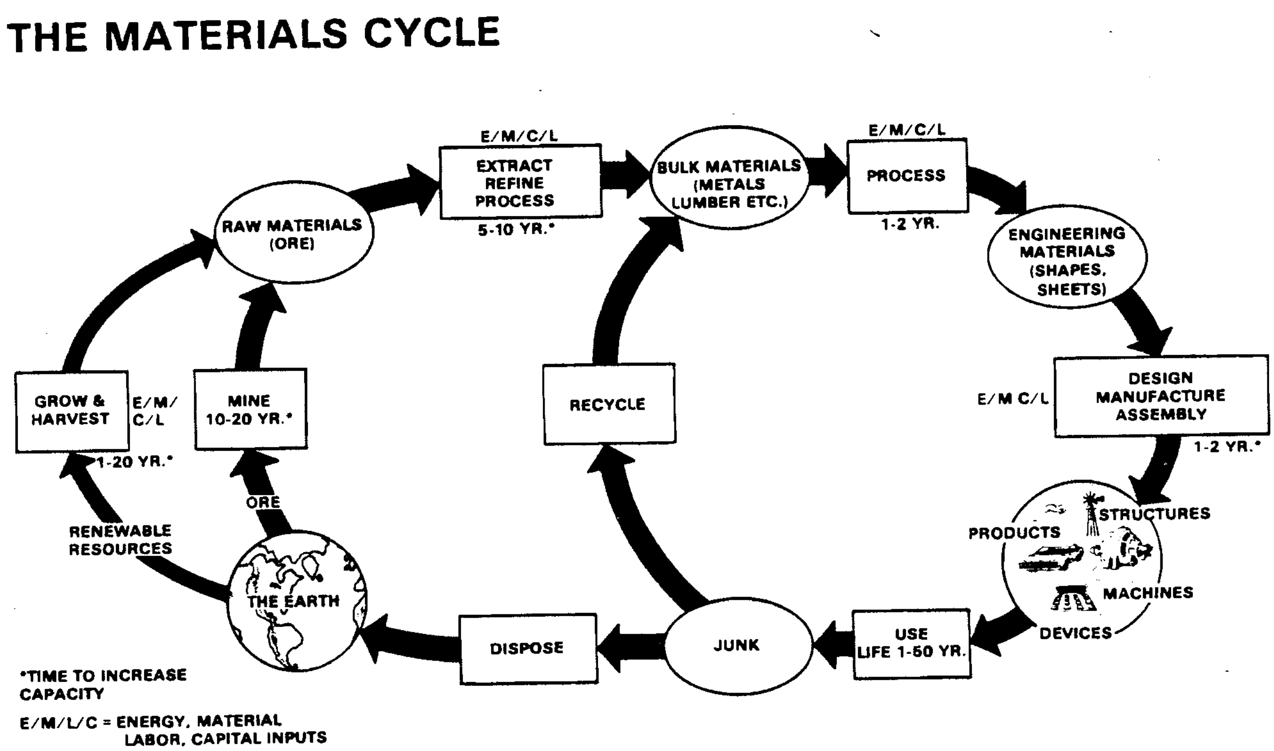

FIGURE 1. The Materials Cycle

This process of tracking the materials and examining their use for potential constraints involves large quantities of data and consequent arithmetic. Thus, much of the methodology was organized and placed on an interactive computer system.

That part of the methodology which was placed on the computer includes all of the steps down to and including those steps labeled screening in Figure 2. Figure 3 shows the flexibility which resulted from making the program interactive. The top blocks of user supplied input is all available to change at the terminal, while the cases are being examined. The bottom left block lists material which is entered by card deck. Of course, this material can also be updated periodically, but cannot be changed at the terminal.

The specific questions raised by the computer and answered from the stored data base are shown on Figure 4 which highlights the logic of the methodology. The questions raised by the computer are reviewed subsequently in a manual process where materials are classified as "A", "B", or "C" materials.

"A" materials are those materials regarded as causing possible constraints in the large scale implementation of particular solar designs and thus requiring further review. "B" materials are those that exceed some threshold levels, but also show by the printed data that they are not likely to present a serious constraint to future deployment. An example is antimony. It is largely imported and is derived as a byproduct, but it is used in such small quantities that it is unlikely to be a serious problem. Thus, it is classified as a "B" material. "A" materials on the other hand, require further study using data not supplied in the computer printout and may in fact require a mitigating strategy to avoid serious constraints in future solar systems construction schedules. "C" materials are those materials that do not exceed any of the threshold levels and are not expected to present future material constraints.

These threshold levels may be changed at any time from the computer terminal. The threshold values used for this study are shown in Table 10 for bulk materials and Table11 for raw materials. Following the tables, the sensitivity of the study to the major assumptions is discussed.

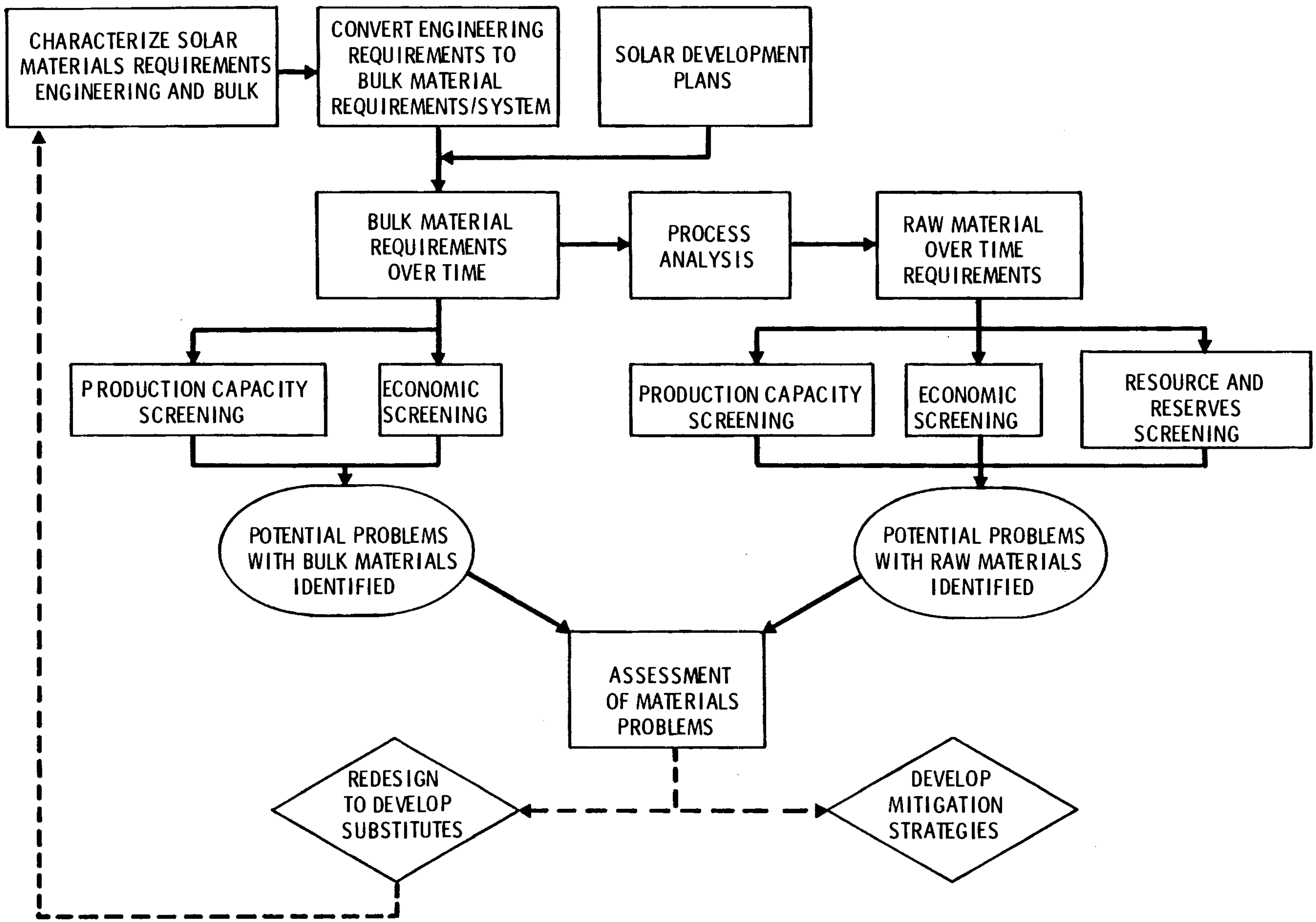

FIGURE 2. Flow Chart of Materials Assessment Methodology

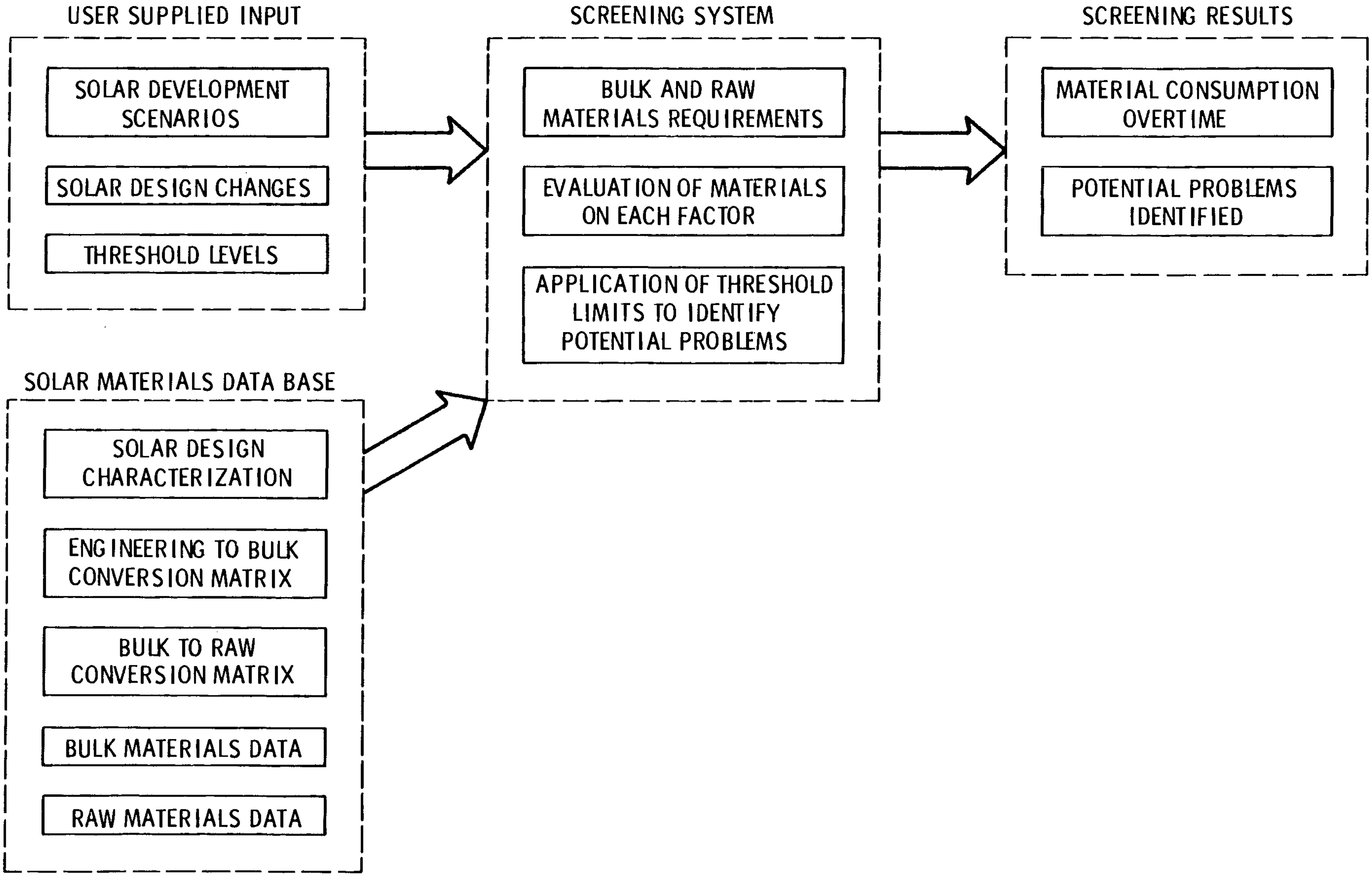

FIGURE 3. Interactive Screening System

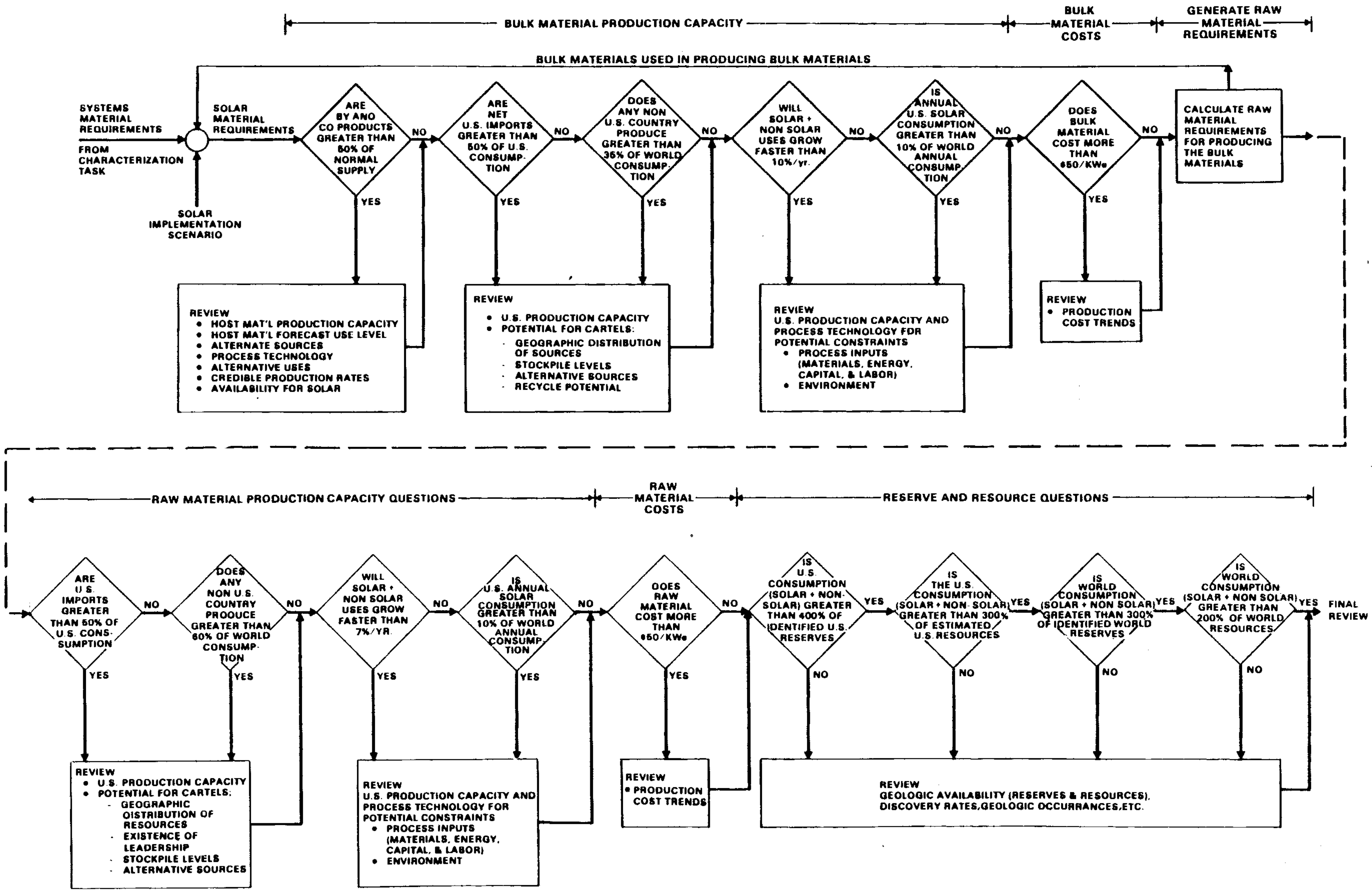

FIGURE 4. Assessment of Potential Materials Problems

TABLE 10. Bulk Material Threshold Criteria

Factor	Value Selected	Reason Selected
Percent supplied as a byproduct	50%	If a large percentage of normal supply is derived as a by-product, it may be extremely difficult to expand production. In our judgment, when 50% of normal supplies are dependent on the production of a primary material, ones ability to expand production significantly is uncertain.
Percent of current consumption that is imported	50%	When a large percentage of a material originates outside of the U.S., the uncertainty surrounding future materials prices and availability is increased. Fifty percent of current materials consumption resulting from imports may not represent a problem if all imports do not originate in a few countries. However, the 50% level was selected as a general level of concern.
Percent of world consumption supplied by the largest suplier country outside of the U.S.	35%	Price leadership and the possibilities of cartels and geopolitical problems are important when approximately 35% of current supply originates in a single non-U.S. supplier.
Production growth rate necessary to meet forecasted world consumption and solar requirements	10%	A sustained compound growth rate of 10% per year is unusual for most bulk material production processes and frequently puts severe pressures on capital, labor, and the environment.
The largest single year market share consumed by solar over the period of the development plan (solar's % of world's consumption)	10%	When a single consumer of a material represents 10% of world consumption, the possibility exists to significantly influence market prices.
The contributions to capital costs per unit of peak power	$15/M^2$	$\$15/M^2$ would represent about 5% of the selling price of a typical system.

TABLE 11. Raw Material Threshold Criteria

Factor	Value Selected	Reason Selected
Percent of current consumption that is imported	50%	When a large percentage of a material originates outside of the U.S., the uncertainty surrounding future materials prices and availability is increased. Fifty percent of current materials consumption resulting from imports may not represent a problem if all imports do not originate in a few countries. However, the 50% level was selected as a general level of concern.
Percent of world consumption supplied by the largest supplier country outside of the U.S.	60%	Raw materials suppliers tend to be larger and, therefore, control a larger percentage of the market than bulk material suppliers. When a single supplier controls 60% of world consumption, raw materials availability is a potential problem.
Production growth rate necessary to meet forecasted world consumption and solar requirements	7%	The time required to develop raw material supplies is from 5-20 years and a 7% compound growth rate appears to be an appropriate level of concern.
Largest single year market share consumed by solar over the period of the solar development plan	10%	When a single consumer of a material represents 10% of world consumption, the possibility exists to significantly influence market prices.
Percent of the world reserves that will be consumed by the year 2000	300%	A frequently used rule of thumb for appropriate reserve margins is 10 years at current consumption. With respect to using world reserves, we anticipate possible problems if we wish to consume 3 times known reserves over the next 20 years. This represents planned consumption of 300% of known world reserves.
Percent of the U.S. reserves that will be consumed by the year 2000	400%	Because U.S. reserves are much more certain, extensive use of reserves, up to 4 times the currently known reserves, may not be a problem.

TABLE 11. (Continued)

Factor	Value Selected	Reason Selected
Percent of world resources that will be consumed by the year 2000	200%	The definition of resources includes presently uneconomic deposits and, therefore, consumption of a larger percentage may be a problem. A reasonable estimate appears to be in the range of 200%. Thus, if we plan on consumption of 2 times currently known resources we anticipate raw material availability problems.
Percent of U.S. resources that will be consumed by the year 2000	300%	U.S. resources have less uncertainty than do world resources. We estimate that up to 3 times currently known deposits can be consumed by 2000.
The contribution to capital costs of raw materials per unit of peak power	$\$15/M^2$	$\$15/M^2$ would represent about 5% of the selling price of a typical system.

THE EFFECT OF THE ASSUMPTIONS MADE IN THE STUDY

A major part of the study centers around the assumption that 500 million square meters of collectors will be installed for a given design by the year 2000. Both the total quantity and the rate at which installation occurs are important for specific criteria.

For SHACOB, a total installation of 500 million square meters of collector area will yield an annual solar contribution of nearly 0.7 Quads or will displace approximately 2.0 Quads of fossil fuel used in generating electricity. If the average SHACOB residential installation is 40 square meters [9] then 500 million square meters of collectors would represent nearly 13 million residential SHACOB installations.

For AIPH, a total installation of 500 million square meters of collectors will yield an annual solar contribution of one to two Quads depending upon the mix of types of AIPH systems installed.

The rates at which various technologies will be installed in the future is, of course, unknown; however, a number of studies have examined past technology diffusion rates and some things are foreseeable. Technologies are unlikely to be installed in a uniform manner (constant rate) for a sustained period. They are more likely to be described by a function which has been described as an "S" curve. This study assumes the year 2000 as the end point of the study and we felt that most solar technologies could better be described by an exponential growth curve which approximates the first part of an "S" curve (see Figure 5).

The maximum rate is about 15% of the total for the exponential curve chosen assuming a starting date of 1985. This is, of course, about 2 1/2 times the rate which would be encountered if a uniform rate of installation were assumed. We feel that the analysis resulting is properly more conservative than a uniform rate would entail and yet doesn't unduly penalize the technology. In practical terms you can't start a business at full speed instantly and on the other hand, we shouldn't assume a scenario which is so severe on a single year that this alone causes a shock to materials supply chains which could actually limit the solar installations to a more rational rate.

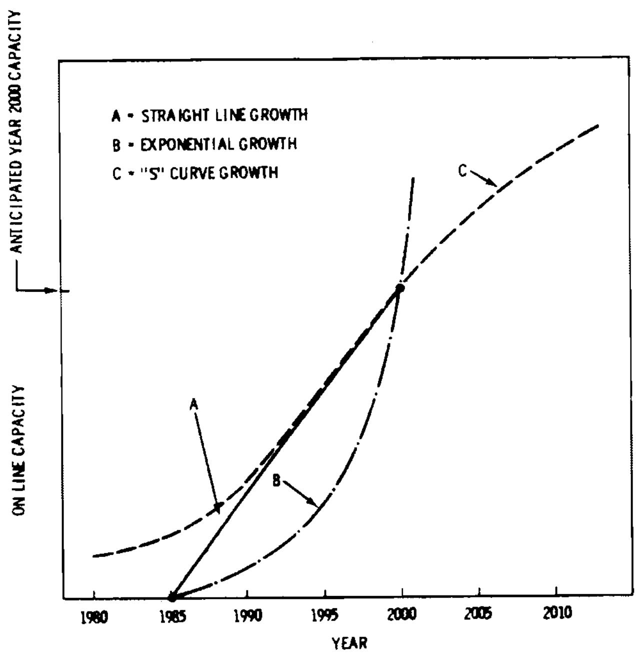

FIGURE 5. Growth Curves for Solar Systems Deployment. Exponential growth assumed in this study.

The selection of levels for the screening criteria used in the computer model are very important in determining which materials are selected for further review. The following paragraphs will describe the values selected and give some of the rationale behind the selection and an indication of its sensitivity to putting materials into the "critical zone" for bulk and also for raw materials.

Bulk Material Criteria Threshold Levels

Percent Supplied as a Byproduct

This criteria has been set to respond at the 50% level. In effect, we have set the level to indicate if a material is primarily obtained as a byproduct. It is difficult to defend this exact value, but fortunately, the raising of this number to the 65%, or lowering it to 35%, would not add or subtract even one material from those triggered in this study.

Any material which has its "mode" of supply coming as a byproduct should be watched in the future since changes in the primary product process could totally eliminate the secondary material source. However, we have in this study, ruled that a material having more than 50% of its normal supply derived as a byproduct does not cause the material to become "critical" (i.e., an "A" material), unless solar's percent of consumption is also large or the world production growth rate is excessive or the cost per square meter for the system is excessive.

World Production Growth Rate

This particular indicator was set for this study to raise a flag at a 10%/yr. We realize that this level is easily exceeded for some materials but that for others it is difficult to reach. We set it at 10% and then review those materials for which the flag is raised to see if we should really consider it to be truly critical to the technology. A single value for this one doesn't fit every material.

Solar's Percent of World Consumption

We used 10% for this threshold level. This is the general range in which solar needs might start to drive the market. This could mean opportunities for reductions in cost (by purchasing materials in large quantities) or it could signal suppliers they have someone who "needs the product" and thus, forcing up the price of materials. In any case, suppliers will no longer consider solar just another little piece of the market. This one can be plus or minus depending on risk perceived by those supplying the solar market. It is considered to be an important indicator.

Percent From Largest Country Outside United States

We used 35% for the threshold level here. The level chosen is not critical for this study for two reasons. The first reason is that few materials would switch categories if you went to 40% or reduced to 30% and the second is that getting a flag on this one is enough to raise a material into the "B" category where you should watch it in the future, but we require heavy usage or a high dollar content to reinforce the potential impact on the construction of future system (i.e., become truly critical).

Cost Per Unit of Output

We have selected $\$15/M^2$ for this threshold level. This level is one at which future prices become very interesting. A doubling or tripling of prices in the future could jeopardize the "learning curve" reductions expected for the technology unless appropriate action is taken.

In other words, if bulk material costs add up to some significant cost level, this may form an uncomfortably high floor under expected cost in the future. This criteria alone is enough to indicate a need for a careful review of mitigating strategies and future price trends.

Net Percent Imported

We have selected 50% as the threshold level for this criteria. This again is a criteria which by itself is not highly critical to the construction of solar technologies unless large quantities of the material are used for solar or the material is an expensive part of the design. Changing the level to 75% or 25% will not affect the number of materials significantly which are designated as "A" materials, although it would substantially change the number of materials in the "B" plan (should be watched in the future).

Raw Material Criteria Threshold Levels

World Production Growth Rate

The 7% threshold selected for this criteria is heuristically selected. The consequences of increasing this level in this study would be negligible. Decreasing the threshold substantially would be hard to justify since many raw materials have had sustained growth rates in this range. Decreasing the level would add many materials to the "B" list of materials to be watched in the future. High production growth rates are primarily an indication of potential market pressures which could increase the costs. High growth rates are not necessarily terribly important to solar needs unless they are accompanied by high costs in solar or the high growth rate was occasioned by solar needs which would show up as a high "Solar Percent of World Production."

Maximum Percent for Solar

We selected 10% for this threshold level. This criteria is felt to be important, but it is difficult to justify selection of a specific level. We have examined the impact of changing the level and find that a change affects few materials in this study as many of the materials are also used in large quantities in the manufacturing industry and in construction activities.

U.S. Reserves and Resources Consumed by the Year 2000 and World Reserves and Resources Consumed by the Year 2000

The four threshold levels selected (400%, 300%, 300%, and 200%) cannot be defended in any precise way, but minor changes in these criteria do not really affect the outcome of the study. This is because most of those materials which exceed these threshold values in this study are used in small quantities and/or do not cost must per kWe in the system, or their use is so large that raising the limit wouldn't change the result anyway.

The Percentage From the Largest Non U.S. Country

The selection of 50% for this threshold level is not critical. Raising it to 60% or lowering it to 40% would not change the status of a single "A" level material.

Present Costs in $\$/M^2$

The selection of $\$15/M^2$ corresponds to roughly 5% of system cost. Intensive efforts will no doubt be applied by a manufacturer to decrease the usage or substitute for any material getting into this general range. But up to this level, in all probability, it would be possible to reduce costs by reducing other cost segments even if this one went up. Above the 5% level, somewhere a given material could place a highly resistant floor under the minimum of a learning curve. Costs in $\$/M^2$ are regarded as a highly significant criteria.

Net Percentage Imported

This criteria by itself is not considered to be sufficient to cause a material to be a probable barrier to solar deployment unless it is accompanied by high usage rates in solar and/or a high $\$/M^2$ for the study. Changing the level from the 50% chosen for the study to 60% or 40% will cause a number of materials to move into or out of the should be watched category, but won't cause many changes in the materials classified as real potential barriers to the deployment of solar.

RESULTS AND RECOMMENDATIONS

The nine SHACOB and three AIPH systems were screened by the computer and found to be relatively free of serious future material constraints. The screening was carried out in scenarios composed of one individual system design totaling 500 million m^2 of collector area installed by the year 2000. Also mixed design scenarios, containing equal portions of each system design, were carried out separately for SHACOB and AIPH at 500 million m^2 and a billion m^2 of collector area installed by the year 2000.

To keep these scenarios in perspective, note that a billion m^2 containing a mixture of the nine SHACOB designs will yield an annual solar contribution of about 1.3 Quads or will displace about 4.2 Quads of fossil fuel used to generate electricity. For AIPH a billion m^2 of the mixed designs will yield about 2.8 Quads/year.

Three materials were identified that could possibly restrain the deployment of solar systems in the specific scenarios investigated. Iron and steel exceeded the threshold for the cost criteria ($15/$m^2$) in two SHACOB systems, in one AIPH system, and in the AIPH mixed design scenarios. Glass consumption in the billion m^2 mixed SHACOB scenario exceeds 10% of the world consumption. Polyvinyl fluoride consumption exceeds 18% of the world consumption for one SHACOB system. All three of these materials are bulk materials. No raw material constraints were found.

The complete results of the computer screening for all the scenarios are given in Appendix A. The screening results are summarized in Tables 12, 13, 14, and 15, where the problem materials are classified either "A" materials - needing further review as a possibly serious problem for future large scale use, or as "B" materials - not likely to present a serious constraint. Materials not

TABLE 12. Problem Bulk Materials in SHACOB Systems

Individual Systems at 500 Million Square Meters by the Year 2000.
Mixed Designs at 500 and 1000 Million Square Meters - Equal Portions of All Nine Designs.

Bulk Material	Sunworks Res HW	Solaron Res HT	Solaron Res HT + HW	Amer Helio H + HW	KTA and Ecosol Heat Pump Sys	Ray Pak HT + Cool + HW	Trombe Wall Concrete	Trombe Wall Water	Direct Gain Masonry Wall	Mixed Designs 500 X 10^6 M^2	Mixed Designs 1000 X 10^6 M^2
Antimony	B									B	B
Asbestos						B				B	B
Cadmium						B				B	B
Carbon Black					B		B	B		B	B
Chromium	B					B				B	B
Glass, Soda Lime											**A**
Iron, Steel				**A**		**A**					
Ferromanganese	B	B	B	B	B	B	B	B	B	B	B
Mercury						B				B	B
Nickel						B				B	B
Silver					B					B	B
Tin	B		B		B	B				B	B
Zinc	B	B	B	B	B	B				B	B
Polyvinylfluoride					**A**						

A = Significant Problem - Additional Assessment Necessary
B = Potential Problem - Supply Should be Monitored

TABLE 13. Problem Raw Materials in SHACOB Systems

Individual Systems at 500 Million Square Meters by the Year 2000.

Mixed Designs at 500 and 1000 Million Square Meters - Equal Portions of All Nine Designs.

Raw Material	Sunworks Res HW	Solaron Res HT	Solaron Res HT + HW	Amer Helio H + HW	KTA and Ecosol Heat Pump Sys	Ray Pak HT + Cool + HW	Trombe Wall Concrete	Trombe Wall Water	Direct Gain Masonry Wall	Mixed Designs 500 X 10^6 M^2	Mixed Designs 1000 X 10^6 M^2
Antimony Ore	B									B	B
Asbestos	B	B	B	B	B	B	B	B	B	B	B
Bauxite	B	B	B	B	B	B	B	B	B	B	B
Chromite	B		B			B		B		B	B
Copper Ore	B	B	B	B	B	B				B	B
Fluorspar	B	B	B	B	B	B	B	B	B	B	B
Lithium Ore						B				B	B
Manganese Ore	B	B	B	B	B	B	B	B	B	B	B
Mercury Ore						B				B	B
Nickel Ore	B		B			B				B	B
Petroleum	B	B	B	B	B	B	B	B	B	B	B
Tin Ore	B		B		B	B				B	B
Zinc Ore	B	B	B	B	B	B				B	B
Petroleum Byproduct						B				B	B

B = Potential Problem - Supply Should be Monitored

TABLE 14. PROBLEM BULK MATERIALS IN AIPH SYSTEMS

INDIVIDUAL SYSTEMS AT 500 MILLION SQUARE METERS BY THE YEAR 2000

MIXED DESIGNS AT 500 AND 1000 MILLION SQUARE METERS EQUAL PORTIONS OF ALL THREE DESIGNS

BULK MATERIAL	LLL Solar Pond	Chamberlain Lumber Kiln	Honeywell Concentrating	Mixed Designs 500 x 10^6 M^2	Mixed Designs 1000 x 10^6 M^2
Asbestos Ore	B(b)		B	B	B
Cadmium	B	B		B	B
Chromium		B	B	B	B
Iron, Steel		**A**(a)		**A**	**A**
Ferromanganese	B	B	B	B	B
Mercury			B	B	B
Nickel		B	B	B	B
Silver	B	B		B	B
Tin	B	B	B	B	B
Zinc	B	B	B	B	B

(a) A = Significant problem - additional assessment necessary.
(b) B = Potential problem - supply should be monitored.

TABLE 15. PROBLEM RAW MATERIALS IN AIPH SYSTEMS

INDIVIDUAL SYSTEMS AT 500 MILLION SQUARE METERS BY THE YEAR 2000

MIXED DESIGNS AT 500 AND 1000 MILLION SQUARE METERS EQUAL PORTIONS OF ALL THREE DESIGNS

RAW MATERIAL	LLL Solar Pond	Chamberlain Lumber Kiln	Honeywell Concentrating	Mixed Designs 500×10^6 M^2	Mixed Designs 1000×10^6 M^2
Asbestos Ore	B(a)	B	B	B	B
Bauxite	B	B	B	B	B
Chromite		B	B	B	B
Copper Ore	B	B	B	B	B
Fluorspar	B	B	B	B	B
Manganese Ore	B	B	B	B	B
Mercury Ore			B	B	B
Nickel Ore		B	B	B	B
Petroleum	B	B	B	B	B
Tin Ore	B	B	B	B	B
Zinc Ore	B	B	B	B	B

(a) B = Potential problem--supply should be monitored.

exceeding the screening criteria threshold values are classed as "C" materials - posing no problems. "C" materials are not listed in Tables 12, 13, 14, and 15. Please keep in mind that the A-B-C ratings are scenario specific.

The reasons for classifying the materials as either "A" or "B" will become clear in the following discussions of the "A" and "B" materials.

"A" MATERIALS IN SHACOB AND AIPH SYSTEMS

Table 16 contains all the screening factors for the "A" bulk materials found in the scenarios investigated. Since none of the raw material criteria were exceeded, the supply of raw materials does not constrain bulk material supplies. We need concern ourselves only with the bulk material criteria in Table 16.

Iron, Steel

In five scenarios, steel exceeds the threshold level from cost ($\$15/m^2$) only. All other factors are well below the threshold and shall not concern us. The quantity of supplies will be adequate. Steel cost varies from \$23 to $\$59/m^2$ ($\$2.14$ to $\$5.48/ft^2$), which is in the order of 10% of the total system installed cost. Doubling the cost of steel decidedly affects economic viability of the system, and for this reason alone, steel represents a potential constraint to SHACOB and AIPH.

Fortunately, the steel industry is mature and competitive and prices have been relatively stable. However, if the present situation ceases to continue mitigating strategies will be necessary and could include:

1. Enter into long term supply contracts with favorable price agreements.
2. Minimize steel usage by more efficient mechanical design or by eliminating certain components such as storage tanks.
3. Have substitute materials ready for use when the relative costs become favorable.

Table 16. Screening Factors in Scenarios Where "A" Bulk Materials Were Found

Factors	Material Usage Mt.	Percent Supplied as By-Produce	World Prodn Growth Rate 1976-2000	Solar's % of World Consumption	% from Largest Country	Cost per Unit Output ±/SM	Net Percent Imported
Threshold Levels	---	58	18 %/yr	18	35	15	50
Scenario[a]							
Iron, Steel							
Amer Heliothermal H & HW	33,379,590	1	3	0	16	23[a]	10
RayPak-HT + Cool + HW	51,070,088	1	3	1	16	35[a]	10
Chamberlain Lumber Kiln	85,477,352	1	3	1	16	59[a]	10
AlPH-Mixed Systems	34,375,328	1	3	0	16	24[a]	10
AlPH-Mixed-$10^9 m^2$	68,750,656	1	3	1	16	24[a]	10
Glass, Soda Lime							
SHACOB-Mixed-$10^9 m^2$	13,299,237	0	3	10[a]	5	4	5
PVF (Polyvinyl Fluoride)							
KTA & Ecoxol Heat Pump Sys	75,060	0	8	18[a]	5	32	5

a. All scenarios at 500 x $10^6 m^2$ unless otherwise noted.

The high iron and steel costs shown in Table 16 are due to the use of iron and steel in all three principal components - piping, storage vessels, and collectors. For a more detailed description of steel uses, refer to the individual system characterizations in Appendix B.

Soda Lime Glass and Polyvinyl Fluoride

In the mixed design SHACOB scenario of one billion m^2 by the year 2000, 10% of the world's consumption of soda lime glass is consumed by SHACOB systems (Table 16). All other criteria are well below the threshold levels. There are no raw material supply constraints to glass production. The projected production growth rate of 3% should be attained easily enough. Soda lime glass is used as a double glazing in seven of the SHACOB system designs, as a single glazing in one design, and as evacuated tubes in the remaining design.

Polyvinyl fluoride (PVF) single glazing used in one system deployed to 500 million m^2 by the year 2000 will account for 18% of the world's consumption of fluorocarbons. All other criteria are well below the threshold levels, except for production growth rate at 8% which is modest for the plastics industry which has routinely expanded at rates of 10% to 15% in the past. No raw material constraints to PVF production were found in the raw material screening.

Both PVF and soda lime glass are used solely for collector glazings in SHACOB and AIPH systems. Since both of these "A" materials show up because of a potential for solar to drive the market, we recommend that future price trends in these industries be watched closely and that surges in demand due to solar are prevented since these could easily cause prices to rise sufficiently to affect the economics of the designs. Both materials are produced by a limited number of responsible manufacturers. The capital requirements of both industries are considerable. And long term production contracts will materially ease the prospects of any unexpected price increases.

The situation for the other popular glazing alternatives is similar, as shown in Table 17. Table 17 also shows the amount of each glazing material that could be installed by the year 2000 without exceeding 10% of the world's consumption in any single year. For the exponential growth rate used in this study, the largest single year installation is in the year 2000 and is equal to 15% of the total installations. Under these assumptions, a total of nearly 6.2 billion m^2 of single glazing is possible. Over half of that is FRP polyester. Clearly, solar collectors represent a large market potential for the suppliers of glazing materials. Long term production contracts would be mutually beneficial to both suppliers and users of glazing materials.

"B" MATERIALS IN SHACOB AND AIPH SYSTEMS

"B" materials in SHACOB and AIPH systems will be discussed jointly because the reasons for classifying them as "B" materials are the same. Eleven bulk and fifteen raw materials were classified "B" in various scenarios as previously shown in Tables 12, 13, 14, and 15.

The specific screening criteria exceeded by each "B" bulk materials are given in Table 18. Only three criteria are involved. They say:

1. More than 50% of the supply comes as a byproduct whose production is limited by the production rate of the principal product, or
2. More than 35% is produced by a single foreign country, or
3. More than 50% of the U.S. supply is imported.

These factors pose no supply problem in the scenarios studied because in all cases the solar consumption as a percentage of world consumption and cost to solar are low.

TABLE 17. Some Glazing Material Alternatives

Glazing Material	Typical Thickness Inches	One Billion m^2 Installed by Year 2000: Material Usage 10^6 MT	One Billion m^2 Installed by Year 2000: Solars % of World Consumption	Area With Solar Limited to of Consumption In Year 2000 $10^9 m^2$
PVF (Tedlar)[a]	.004	.153	30	.26
FEP (Teflon)[a]	.002	.109	19	.48
Glass	.125	7.94	6	1.68
FRP Polyester (70 w/o Polyester)	.035	.994	3	3.52
Polycarbonate	.0625	1.91	34	.22
TOTAL				6.16

[a] A registered trademark of E.I. DuPont Co.

TABLE 18. CRITERIA EXCEEDED BY "B" BULK MATERIALS[a] IN SHACOB AND AIPH SYSTEMS

FACTORS	Percent Supplied as Byproduct	% From Largest Country	Net Percent Imported
THRESHOLD LEVELS	50	35	50
BULK MATERIALS			
Antimony	X		X
Asbestos		X	X
Cadmium	X		X
Carbon Black	X		
Chromium			X
Ferromanganese	X		X
Mercury			X
Nickel			X
Silver	X		
Tin			X
Zinc			X

(a) "B" materials are those whose impacts on solar energy devices will be negligible unless extreme shifts occur in the current pattern of supply.

Since the solar share of world consumption is low, the material will be available in the quantities required by solar even if the total U.S. supply is limited severely by cartels, political action or decrease in production. Under conditions of limited supply and hence, increased competition for the material, increased prices are anticipated. Even then a large price increase would be required to push the already low materials cost to solar (cost/m^2) to an unacceptable level and force the use of substitutes.

The same type of reasoning was used in classifying the "B" raw materials. The specific criteria exceeded by each "B" raw material is shown in Table 19. Two criteria are identical to those just discussed - Net Percent Imported and Percent From Largest Foreign Country. The effect of these two raw material factors on solar is minimal because the solar use and cost to solar for each of these raw materials is small (circa 1% and \$1/m^2 and less).

Exceeding the criteria for United States reserves and resources means either that more of the raw material will be imported in the future or that U.S. reserves and resources will have to increase. Historically, reserves and resources have generally increased with time due to continued exploration, development, and improved technology or increased prices which shift previously uneconomic deposits into the reserve category. Whether or not U.S. reserves and resources increase, the raw materials will be available worldwide in sufficient amounts since the criteria for world reserves and resources were not exceeded. Again, supply disruptions will have little effect because solar usage and cost to solar are small for all these materials.

World production growth rate of 7% was exceeded by one material, lithium ore. Once again the small solar requirement will be satisfied even if the world

TABLE 19. CRITERIA EXCEEDED BY "B" RAW MATERIALS[a] IN SHACOB AND AIPH SYSTEMS

FACTORS	% U.S. Reserves Consumed by 2000	% U.S. Resources Consumed by 2000	Net Percent Imported	% From Largest Country Non-US	World Production Growth Rate
THRESHOLD LEVELS	400	300	50	60	7 %/Yr
RAW MATERIALS					
Antimony Ore	X	X	X		
Asbestos	X		X		
Bauxite	X		X		
Chromite	X	X	X		
Copper Ore	X	X			
Fluorspar	X		X		
Lithium Ore					X
Manganese Ore			X		
Mercury Ore		X	X		
Nickel Ore	X	X	X		
Petroleum	X				
Tin Ore	X	X	X		
Zinc Ore			X		
Tung Nuts			X	X	
Petroleum Byproduct	X				

(a) "B" materials are those whose impacts on SHACOB and AIPH systems will be negligible unless extreme shifts occur in the current pattern of supply, or unless solar usage increases substantially.

production rate does not meet demand. Higher prices resulting from demand exceeding supply will not raise the already low cost to solar significantly. Since solar's percent of world consumption is low, it follows that the growth rate is high because of projected non-solar demands for the raw material. In other words, the production growth rate is largely independent of solar demand.

Taking a broader perspective, one sees that all the other criteria exceeded by "B" materials, both bulk and raw, are largely independent of solar demand. They are exogenous criteria. Any material in a solar device that exceeds at least one of the exogenous criteria is always classed as a "B" material or higher. So long as the material's share of world consumption or its cost to the solar device are low, it remains a "B" material.

If solar usage of a "B" material increases enough, either one or both of the endogenous criteria (solar's share of world consumption and the cost to solar) will be exceeded. When these endogenous criteria are exceeded, the material is classified as an "A" material. In that situation, exogenous factors could significantly affect the availability and cost of the material to solar.

In summary, materials which are present in a solar device and exceed any of the exogenous criteria are classified as "B" materials so long as their use in the solar device is small. Their impacts on SHACOB and AIPH systems will be negligible - unless extreme shifts occur in the current pattern of supply, or unless solar usage increases sufficiently to put them into the "A" material category.

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APPENDIX A

ACTUAL COMPUTER RUNS OF BULK AND RAW MATERIAL SCREENING FACTORS

SHACOB and AIPH System Identifications

Design Number	Short Title	Full Title
SHACOB		
25	SUNWORKS RES HW	DOMESTIC HOT WATER-SUNWORKS COLLECTOR
26	SOLARON-RES HT	SPACE HEATING - SOLARON SYSTEM
27	SOLARON-RES HT + HW	SPACE HEATING AND DOMESTIC HOT WATER - SOLARON
28	AMER HELIOTHERMAL H + HW	SPACE HEATING AND DOMESTIC HOT WATER - AMERICAN HELIOTHERMAL
29	KTA AND ECOSOL HEAT PUMP SY	SPACE HEATING AND DOMESTIC HOT WATER - KTA AND ECOSOL HEAT PUMP SYSTEM
30	RAYPAK - HT + COOL + HW	SPACE HEATING AND COOLING AND DOMESTIC HOT WATER - RAYPAK COLLECTOR
31	TROMBE WALL CONCRETE	PASSIVE SPACE HEATING - CONCRETE TROMBE WALL
32	TROMBE WALL WATER	PASSIVE SPACE HEATING - WATER-TANK TROMBE WALL
33	DIRECT GAIN MASONRY WALL	PASSIVE SPACE HEATING - DIRECT GAIN, MASONRY WALLS
AIPH		
40	LLL SOLAR POND	PROCESS HOT WATER, URANIUM MILLING - LLL SOLAR POND
41	CHAMBERLAIN - LUMBER KILN	PROCESS HEAT, LUMBER KILN - CHAMBERLAIN COLLECTORS
42	HONEYWELL CONCENTRATING	PROCESS STEAM, TEXTILE DRYING - HONEYWELL CONCENTRATING COLLECTORS

BULK MATERIAL REQUIREMENTS FOR SUNWORKS RES HW

SOLAR SCENARIO:
INTRODUCTION YEAR -- 1985
CUMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY-PRODUCT		WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT $/SM	NET PERCENT IMPORTED	
THRESHOLD LEVELS	---	50.		10. %/YR	10.	35.	15.	50.	
MATERIALS									
ALUMINUM	4571000.	0.		7.	1.	13.	9.	14.	
ANTIMONY	1750.	100.	*	5.	0.	22.	0.	55.	*
CEMENT	729120.	0.		3.	0.	18.	0.	4.	
CHROMIUM	7000.	0.		3.	0.	31.	0.	100.	*
COPPER	5225500.	1.		6.	3.	12.	14.	45.	
GLASS, FIBER	1078000.	0.		7.	4.	5.	1.	2.	
GLASS, SODA LIM	7938000.	0.		3.	6.	5.	5.	5.	
IRON , STEEL	5004622.	1.		3.	0.	16.	3.	10.	
LEAD	23157.	13.		5.	0.	11.	0.	18.	
FERROMANGANESE	31178.	100.	*	2.	0.	9.	0.	99.	*
NICKEL	7000.	7.		3.	0.	28.	0.	75.	*
SAND ! GRAVEL	1510320.	0.		4.	0.	10.	0.	0.	
STONE	2960360.	0.		3.	0.	3.	0.	0.	
SILICON	11200.	0.		3.	0.	14.	0.	8.	
TIN	60893.	25.		2.	2.	29.	2.	65.	*
WATER	21511000.	0.		3.	0.	0.	0.	0.	
ZINC	11200.	25.		3.	0.	21.	0.	88.	*
STAINLESS STEEL	35000.	0.		3.	0.	10.	0.	15.	
LUMBER, SOFTWOOD	3800000.	0.		4.	0.	20.	0.	12.	
PHENOLIC RESIN	161000.	0.		7.	0.	5.	0.	1.	
RUBBER, SBR	63000.	0.		6.	0.	5.	0.	4.	
SILICONES	28000.	0.		7.	1.	5.	0.	1.	
TEFLON	2100.	0.		7.	0.	5.	0.	1.	
URETHANE	637000.	0.		7.	6.	5.	9.	5.	
NEOPRENE	315000.	0.		3.	7.	5.	1.	1.	
ETHYLENE GLYCOL	763000.	0.		7.	1.	5.	1.	9.	

RAW MATERIAL REQUIREMENTS FOR SUNWORKS RES HW

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
COMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	200.	60.	300.	200.	15.	50.
MATERIALS										
ANTIMONY ORE	184.	5.	0.	1219. *	1131. *	22.	76.	64.	0.	55. *
ASBESTOS	0.	3.	0.	539. *	28.	34.	190.	129.	0.	90. *
BAUXITE	23554.	5.	1.	2269. *	303. *	28.	14.	9.	1.	89. *
BORATE	270.	5.	1.	11.	0.	50.	10.	0.	0.	3.
BUTANE	70.	1.	0.	20.	2.	15.	12.	1.	0.	5.
CHROMITE	43.	3.	0.	3353. *	424. *	27.	17.	4.	0.	66. *
CLAYS	192.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	20943.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	47250.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COPPER ORE	1149795.	6.	3.	1045. *	458. *	12.	86.	25.	5.	37.
FELDSPAR	738.	3.	2.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	378.	5.	0.	704. *	151.	22.	200.	120.	0.	50. *
GYPSUM	35.	3.	0.	175.	0.	10.	11.	0.	0.	37.
IRON ORE	39887.	5.	0.	55.	7.	11.	15.	6.	0.	35.
LEAD ORE	781.	3.	0.	77.	38.	11.	126.	13.	0.	33.
MANGANESE ORE	171.	3.	0.	100.	4.	24.	6.	11.	0.	100. *
NATURAL GAS	2915.	5.	0.	245.	277.	30.	93.	9.	1.	5.
NICKEL ORE	980.	3.	0.	4435. *	5322. *	37.	54.	23.	0.	75. *
NITROGEN, FIXED	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
PETROLEUM	3456.	3.	0.	562. *	210.	22.	110.	36.	1.	40.
SALT	21917.	6.	0.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	7468.	4.	0.	0.	0.	0.	0.	0.	0.	0.
STONE	2969.	3.	0.	0.	0.	3.	0.	0.	0.	0.
SULFUR	1178.	3.	0.	94.	1.	15.	90.	0.	0.	28.
TIN ORE	600930	2.	2.	4478. *	1343. *	29.	73.	20.	1.	65. *
ZINC ORE	202.	0.	0.	146.	33.	19.	154.	8.	0.	88. *
MILK BYPRODUCTS	5.	3.	0.	0.	0.	20.	0.	0.	0.	1.
LUMBER	3810.	1.	0.	0.	0.	12.	0.	0.	1.	18.
SEA WATER	24.	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATER	140589.	3.	0.	17.	2.	0.	3.	0.	0.	0.
MISC.	1562.	0.	0.	0.	0.	0.	0.	0.	2.	0.
STEAM	125355.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	23657.	3.	1.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	482028.	1.	1.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	2355017.	3.	0.	0.	0.	0.	0.	0.	0.	0.
COAL BYPRODUCT 2	377104.	1.	1.	6.	1.	6.	13.	1.	0.	10.

BULK MATERIAL REQUIREMENTS FOR SOLARON - RES HT

SOLAR SCENARIO:
INTRODUCTION YEAR - 1985
CUMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY PRODUCT		WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT $/SM	NET PERCENT IMPORTED	
THRESHOLD LEVELS	---	50.		· 10. %/YR	10.	35.	15.	50.	
MATERIALS									
COPPER	115245.	1.		6.	0.	12.	0.	45.	
GLASS, FIBER	2285200.	0.		7.	8.	5.	2.	2.	
GLASS, SODA LIM	10578900.	0.		3.	8.	5.	6.	5.	
IRON , STEEL	16783560.	1.		3.	0.	16.	12.	10.	
FERROMANGANESE	101309.	100.	*	2.	0.	9.	0.	99.	*
SAND ! GRAVEL	122140000.	0.		4.	0.	10.	0.	0.	
ZINC	1401852.	25.		3.	2.	21.	2.	88.	*
GLUE, PHENOL, FOR	73284.	0.		7.	2.	5.	0.	5.	
LUMBER, SOFTWOOD	6829597.	0.		4.	0.	20.	1.	12.	
PHENOLIC RESIN	9850.	0.		7.	0.	5.	0.	1.	
RUBBER, SBR	126080.	0.		6.	0.	5.	0.	4.	
SILICONES	126080.	0.		7.	3.	5.	1.	1.	
POLYCARBONATE	27580.	0.		7.	1.	5.	0.	5.	
VITREOUS ENAMEL	171390.	0.		7.	2.	10.	0.	0.	

RAW MATERIAL REQUIREMENTS FOR SOLARON - RES HT

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
COMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX. % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	200.	200.	15.	50.
MATERIALS										
ASBESTOS	1.	3.	0.	539. *	28.	34.	190.	129.	0.	93. *
BAUXITE	1002.	5.	0.	2213 *	295.	28.	14.	9.	0.	89. *
BORATE	571.	5.	1.	11.	0.	50.	11.	0.	0.	3.
BUTANE	140.	1.	0.	20.	2.	10.	12.	1.	0.	5.
CLAYS	179.	2.	0.	0.	0.	10.	0.	0.	0.	3.
COAL	23722.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	18.	1.	0.	6.	1.	6.	13.	1.	0.	10.
COPPER ORE	26186.	6.	0.	985. *	432. *	12.	85.	24.	0.	37.
FELDSPAR	1023.	3.	2.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	135.	5.	0.	703. *	151.	22.	200.	120.	0.	50. *
IRON ORE	95332.	5.	0.	56.	7.	11.	15.	6.	0.	35.
LEAD ORE	1354.	3.	0.	78.	38.	11.	126.	13.	0.	33.
MANGANESE ORE	619.	3.	0.	100.	4.	24.	6.	11.	0.	100. *
NATURAL GAS	482.	5.	0.	245.	277.	30.	93.	9.	0.	5.
OXYGEN	16.	4.	0.	0.	0.	22.	0.	0.	0.	0.
PETROLEUM	606.	3.	0.	562. *	210.	22.	110.	36.	0.	40.
SALT	9443.	6.	0.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	130505.	4.	0.	0.	0.	0.	0.	0.	1.	0.
SODIUM NITRATE	5.	4.	0.	0.	0.	5.	0.	0.	0.	10.
SULFUR	48.	3.	0.	93.	1.	15.	90.	0.	0.	28.
ZINC ORE	24956.	0.	2.	151.	35.	19.	155.	8.	1.	88. *
MILK BYPRODUCTS	1.	3.	0.	0.	0.	20.	0.	0.	0.	1.
LUMBER	6832.	1.	0.	0.	0.	12.	0.	0.	2.	18.
SEA WATER	41.	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATER	148839.	3.	0.	17.	2.	0.	3.	0.	0.	0.
WHEAT	21.	3.	0.	0.	0.	10.	0.	0.	0.	0.
MISC.	609.	0.	0.	0.	0.	0.	0.	0.	1.	0.
STEAM	27221.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	19337.	3.	1.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	40120.	1.	0.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	181317.	3.	0.	0.	0.	0.	0.	0.	0.	0.

BULK MATERIAL REQUIREMENTS FOR SOLARON - RES HT + HW

SOLAR SCENARIO:
INTRODUCTION YEAR - 1985
CUMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY-PRODUCT	WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT $/SM	NET PERCENT IMPORTED
THRESHOLD LEVELS	----	50.	10. %/YR	10.	35.	15.	50.
MATERIALS							
ALUMINUM	37430.	0.	7.	0.	13.	0.	14.
COPPER	570315.	1.	6.	0.	12.	2.	45.
GLASS, FIBER	2364000.	0.	7.	8.	5.	2.	2.
GLASS, SODA LIM	10575000.	0.	3.	8.	5.	6.	5.
IRON , STEEL	18132746.	1.	3.	0.	16.	12.	10.
LEAD	13790.	13.	5.	0.	11.	0.	18.
FERROMANGANESE	109453.	100. *	2.	0.	9.	0.	99. *
SAND ! GRAVEL	122140000.	0.	4.	0.	10.	0.	0.
TIN	13790.	25.	2.	1.	29.	0.	65. *
ZINC	1401852.	25.	3.	2.	21.	2.	88. *
STAINLESS STEEL	17730.	0.	3.	0.	10.	0.	15.
GLUE,PHENOL,FOR	73284.	0.	7.	2.	5.	0.	5.
LUMBER,SOFTWOOD	6829597.	0.	4.	0.	20.	1.	12.
PHENOLIC RESIN	9850.	0.	7.	0.	5.	0.	1.
RUBBER, SBR	133960.	0.	6.	0.	5.	0.	4.
SILICONES	126000.	0.	7.	3.	5.	1.	1.
POLYCARBONATE	37430.	0.	7.	1.	5.	0.	5.
VITREOUS ENAMEL	171390.	0.	7.	2.	10.	0.	0.

RAW MATERIAL REQUIREMENTS FOR SOLARON - RES HT + HW

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
COMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX. % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD, RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	300.	200.	15.	50.
MATERIALS										
ASBESTOS	1.	3.	0.	539. *	28.	34.	190.	129.	0.	90. *
BAUXITE	1228.	5.	0.	2214. *	295.	28.	14.	9.	0.	89. *
BORATE	591.	5.	1.	11.	0.	50.	11.	0.	0.	3.
BUTANE	149.	1.	1.	20.	2.	10.	12.	1.	0.	5.
CHROMITE	11.	3.	0.	3350. *	424. *	27.	17.	4.	0.	66. *
CLAYS	198.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	25555.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	18.	1.	0.	6.	1.	6.	13.	1.	0.	10.
COPPER ORE	126301.	6.	0.	990. *	434. *	12.	85.	24.	0.	37.
FELDSPAR	1023.	3.	2.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	150.	5.	0.	703. *	151.	22.	200.	120.	0.	50. *
IRON ORE	104011.	5.	0.	56.	7.	11.	15.	6.	0.	35.
LEAD ORE	1813.	3.	0.	78.	38.	11.	126.	13.	0.	33.
MANGANESE ORE	663.	3.	0.	100.	4.	24.	6.	11.	0.	100. *
NATURAL GAS	736.	5.	0.	245.	277.	30.	93.	9.	0.	5.
NICKEL ORE	142.	3.	0.	4431. *	5317. *	37.	54.	23.	0.	75. *
NITROGEN, FIXED	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
OXYGEN	22.	4.	0.	0.	0.	22.	0.	0.	0.	0.
PETROLEUM	665.	3.	0.	562. *	210.	22.	110.	36.	0.	40.
SALT	9582.	6.	0.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	130970.	4.	0.	0.	0.	0.	0.	0.	1.	0.
SODIUM NITRATE	5.	4.	0.	0.	0.	5.	0.	0.	0.	10.
SULFUR	61.	3.	0.	93.	1.	15.	90.	0.	0.	28.
TIN ORE	137900.	2.	1.	4366. *	1310. *	29.	73.	20.	0.	65. *
ZINC ORE	24958.	0.	2.	151.	35.	19.	155.	8.	1.	88. *
MILK BYPRODUCTS	1.	3.	0.	0.	0.	20.	0.	0.	0.	1.
LUMBER	6832.	1.	0.	0.	0.	12.	0.	0.	2.	18.
SEA WATER	55.	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATER	151166.	3.	0.	17.	2.	0.	3.	0.	0.	0.
WHEAT	21.	3.	0.	0.	0.	10.	0.	0.	0.	0.
MISC.	753.	0.	0.	0.	0.	0.	0.	0.	1.	0.
STEAM	30070.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	20332.	3.	1.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	41523.	1.	0.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	188488.	3.	0.	0.	0.	0.	0.	0.	0.	0.

BULK MATERIAL REQUIREMENTS FOR AMER HELIOTHERMAL H+HW

SOLAR SCENARIO:
INTRODUCTION YEAR - 1985
CUMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY-PRODUCT	WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT $/SM	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	50.	10. %/YR	10.	35.	15.	50.
MATERIALS							
ALUMINUM	974850.	0.	7.	0.	13.	2.	14.
COPPER	384513.	1.	6.	0.	12.	1.	45.
GLASS, FIBER	1525590.	0.	7.	6.	5.	1.	2.
GLASS, SODA LIM	5762671.	0.	3.	5.	5.	3.	5.
IRON , STEEL	33379590.	1.	3.	0.	16.	23. *	10.
FERROMANGANESE	201486.	100. *	2.	0.	9.	0.	99. *
WATER	59325152.	0.	3.	0.	0.	0.	0.
ZINC	681149.	25.	3.	1.	21.	1.	88. *
LUMBER, SOFTWOOD	420090.	0.	4.	0.	20.	0.	12.
TEFLON	20100.	0.	7.	4.	5.	0.	1.
NYLON	4020.	0.	7.	0.	5.	0.	1.
NEOPRENE	291450.	0.	3.	7.	5.	1.	1.
POLYCARBONATE	10050.	0.	7.	0.	5.	0.	5.
POLYPROPYLENE G	1039170.	0.	7.	6.	5.	1.	5.
VITREOUS ENAMEL	2010.	0.	7.	0.	10.	0.	0.

RAW MATERIAL REQUIREMENTS FOR AMER HELIOTHERMAL H+HW

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
COMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX. % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	300.	220.	15.	50.
MATERIALS										
ASBESTOS	0.	3.	0.	539. *	28.	34.	190.	329.	0.	90. *
BAUXITE	5648.	5.	0.	2225. *	297.	28.	14.	9.	0.	89. *
BORATE	381.	5.	1.	11.	0.	59.	10.	0.	0.	3.
BUTANE	3.	1.	0.	20.	2.	10.	12.	1.	0.	5.
CLAYS	356.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	42289.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	43718.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COPPER ORE	34593.	6.	0.	980. *	433. *	12.	85.	24.	0.	37.
FELDSPAR	536.	3.	1.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	371.	5.	0.	704. *	151.	22.	200.	120.	0.	50. *
IRON ORE	189549.	5.	1.	56.	7.	11.	15.	6.	1.	35.
LEAD ORE	16.	3.	0.	77.	38.	11.	126.	13.	0.	33.
MANGANESE ORE	1130.	3.	0.	100.	4.	24.	6.	11.	0.	100. *
NATURAL GAS	786.	5.	0.	245.	277.	30.	93.	9.	0.	5.
OXYGEN	286.	4.	0.	0.	0.	22.	0.	0.	0.	0.
PETROLEUM	4344.	3.	0.	563. *	210.	22.	110.	36.	1.	40.
SALT	8343.	6.	0.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	4822.	4.	0.	0.	0.	0.	0.	0.	0.	0.
SODIUM NITRATE	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
SULFUR	285.	3.	0.	93.	1.	15.	90.	0.	0.	28.
ZINC ORE	12124.	0.	1.	149.	34.	19.	155.	8.	0.	88. *
LUMBER	424.	1.	0.	0.	0.	12.	0.	0.	0.	18.
SEA WATER	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATER	74583.	3.	0.	17.	2.	0.	3.	0.	0.	0.
MISC.	619.	0.	0.	0.	0.	0.	0.	0.	1.	0.
STEAM	66104.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	28394.	3.	1.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	1797.	1.	0.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	973557.	3.	0.	0.	0.	0.	0.	0.	0.	0.

BULK MATERIAL REQUIREMENTS FOR KTA AND ECSOL HT PUMP SY

SOLAR SCENARIO:
INTRODUCTION YEAR - 1985
CUMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY-PRODUCT		WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION		% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT $/SM	NET PERCENT IMPORTED	
THRESHOLD LEVELS	---	50.		10. %/YR	10		35.	15.	50.	
MATERIALS										
ALUMINUM	4914794.	0.		7.	1.		13.	10.	14.	
CARBON BLACK	129270.	100.	*	2.	0.		12.	0.	0.	
CEMENT	5163711.	0.		3.	0.		18.	0.	4.	
COPPER	4140022.	1.		6.	2.		12.	11.	45.	
GLASS, SODA LIM	625500.	0.		3.	1.		5.	0.	5.	
IRON , STEEL	16116000.	1.		3.	0.		16.	11.	10.	
LEAD	31442.	13.		5.	0.		11.	0.	10.	
MAGNESIUM	6349.	30.		6.	0.		26.	0.	0.	
FERROMANGANESE	97536.	100.	*	2.	0.		9.	0.	99.	*
SAND ! GRAVEL	10696259.	0.		4.	0.		10.	0.	0.	
STONE	21023682.	0.		3.	0.		3.	0.	0.	
SILICON	7172.	0.		3.	0.		14.	0.	8.	
SILVER	6255.	70.	*	5.	4.		14.	2.	46.	
TIN	35945.	25.		2.	1.		29.	1.	65.	*
WATER	79480200.	0.		3.	0.		0.	0.	0.	
ZINC	184106.	25.		3.	0.		21.	0.	88.	*
ALKYD RESIN	27105.	0.		7.	0.		5.	0.	1.	
PHENOLIC RESIN	47955.	0.		7.	0.		5.	0.	1.	
NYLON	10425.	0.		7.	0.		5.	0.	1.	
URETHANE	308580.	0.		7.	3.		5.	4.	5.	
POLYVINYL FLUOR	75060.	0.		8.	18.	*	5.	3.	5.	
PAINT THINNER	52125.	0.		3.	1.		5.	0.	5.	

RAW MATERIAL REQUIREMENTS FOR KTA AND ECSOL HT PUMP SY

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
CUMMULATIVE CAPACITY 2000 -- 500. M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX. % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	200.	200.	15.	50.
MATERIALS										
ASBESTOS	0.	3.	0.	539. *	28.	34.	190.	129.	0.	90. *
BAUXITE	24864.	5.	2.	2273. *	303. *	28.	14.	9.	1.	89. *
BUTANE	9.	1.	0.	20.	2.	10.	12.	1.	0.	5.
CLAYS	943.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	30780.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	379.	1.	0.	6.	1.	6.	13.	1.	0.	10.
COPPER ORE	911905.	6.	2.	1032. *	452. *	12.	86.	25.	4.	37.
FELDSPAR	58.	3.	0.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	776.	5.	0.	707. *	152.	22.	201.	120.	0.	50. *
GYPSUM	248.	3.	0.	175.	0.	10.	11.	0.	0.	37.
IRON ORE	100212.	5.	0.	56.	7.	11.	15.	6.	0.	35.
LEAD ORE	1047.	3.	0.	78.	38.	11.	126.	13.	0.	33.
MANGANESE ORE	543.	3.	0.	100.	4.	24.	6.	11.	0.	100. *
NATURAL GAS	2818.	5.	0.	245.	277.	30.	93.	9.	1.	5.
NITROGEN, FIXED	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
PETROLEUM	1869.	3.	0.	562. *	210.	22.	110.	36.	0.	40.
SALT	16538.	6.	0.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	11442.	4.	0.	0.	0.	0.	0.	0.	0.	0.
SILVER ORE	44579.	4.	3.	381.	101.	14.	210.	57.	0.	45.
STONE	21024.	3.	0.	0.	0.	3.	0.	0.	0.	0.
SULFUR	1430.	3.	0.	94.	1.	15.	90.	0.	0.	28.
TIN ORE	359454.	2.	1.	4419. *	1326. *	29.	73.	20.	0.	65. *
ZINC ORE	3305.	0.	0.	147.	33.	19.	154.	8.	0.	88. *
FLAX SEED	153.	1.	1.	0.	0.	25.	0.	0.	0.	20.
MILK BYPRODUCTS	?	3.	0.	0.	0.	20.	0.	0.	0.	1.
LUMBER	2.	1.	0.	0.	0.	12.	0.	0.	0.	18.
SEA WATER	4610.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SOYBEAN	78.	3.	0.	0.	0.	12.	0.	0.	0.	0.
WATER	168898.	3.	0.	17.	2.	0.	3.	0.	0.	0.
MISC.	1406.	0.	0.	0.	0.	0.	0.	0.	1.	0.
STEAM	140354.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	29414.	3.	1.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	496328.	1.	2.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	1048171.	3.	0.	0.	0.	0.	0.	0.	0.	0.
COAL BYPRODUCT 2	182679.	1.	1.	6.	1.	6.	13.	1.	0.	10.

BULK MATERIAL REQUIREMENTS FOR RAYPAK - HT + COOL + HW

SOLAR SCENARIO:
INTRODUCTION YEAR - 1985
CUMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY PRODUCT	WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT $/SM	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	50.	10. %/YR	10.	35.	15.	50.
MATERIALS							
ALUMINUM	1525102.	0.	7.	0.	13.	3.	14.
ASBESTOS	50275.	0.	3.	0.	49. *	0.	98. *
BARITE	97330.	0.	6.	1.	10.	0.	19.
CADMIUM	4515.	100. *	4.	2.	15.	0.	57. *
CEMENT	350332.	0.	3.	0.	18.	0.	4.
CHROMIUM	116.	0.	3.	0.	31.	0.	100. *
COPPER	3558799.	1.	6.	2.	12.	9.	45.
GLASS, FIBER	1203058.	0.	7.	5.	5.	1.	2.
GLASS, SODA LIM	8810000.	0.	3.	7.	5.	5.	5.
GYPSUM	28122.	0.	3.	0.	10.	0.	37.
IRON , STEEL	51070088.	1.	3.	1.	16.	35. *	10.
LEAD	14085.	13.	5.	0.	11.	0.	18.
LITHIUM	8450.	0.	7.	5.	1.	0.	1.
FERROMANGANESE	307079.	100. *	2.	0.	9.	0.	99. *
MERCURY	323.	2.	3.	0.	19.	0.	58. *
NICKEL	453.	7.	3.	0.	28.	0.	75. *
SAND ! GRAVEL	375971.	0.	4.	0.	10.	0.	0.
STONE	738977.	0.	3.	0.	3.	0.	0.
SILICON	5899.	0.	3.	0.	14.	0.	8.
SILVER	194.	70. *	4.	0.	14.	0.	46.
TIN	25130.	25.	2.	1.	29.	1.	65. *
WATER	100098832.	0.	3.	0.	0.	0.	0.
ZINC	418383.	25.	3.	1.	21.	1.	88. *
STAINLESS STEEL	43667.	0.	3.	0.	10.	0.	15.
LUMBER, SOFTWOOD	1773105.	0.	4.	0.	20.	0.	12.
PHENOLIC RESIN	9353.	0.	7.	0.	5.	0.	1.
PVC PLASTIC	225105.	0.	7.	0.	5.	0.	0.
RUBBER, SBR	144180.	0.	6.	0.	5.	0.	4.
SILICONES	299925.	0.	7.	7.	5.	2.	1.
TEFLON	3806.	0.	7.	1.	5.	0.	1.
COTTON FIBERS	6547.	0.	3.	0.	16.	0.	1.
KRAFT FIBERS	2806.	0.	3.	0.	10.	0.	15.
URETHANE	285735.	0.	7.	3.	5.	4.	5.
ASPHALT	1354500.	0.	3.	0.	5.	0.	5.
NEOPRENE	47537.	0.	3.	1.	5.	0.	1.
ETHYLENE GLYCOL	1457700.	0.	7.	1.	5.	2.	9.
POLYETHYLENE	4386.	0.	7.	0.	5.	0.	5.
EPDM RUBBER	26768.	0.	7.	0.	5.	0.	5.

RAW MATERIAL REQUIREMENTS FOR RAYPAK - HT + COOL + HW

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
COMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX. % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	--	7. %/YR	10.	400.	300.	60.	200.	200.	15.	50.
MATERIALS										
ASBESTOS	57.	3.	0.	539. *	28.	34.	190.	29.	0.	90. *
BAUXITE	8372.	5.	1.	2231. *	298.	28.	14.	9.	0.	89. *
BORATE	321.	5.	1.	11.	0.	50.	10.	0.	0.	3.
BUTANE	160.	1.	1.	20.	2.	10.	12.	1.	0.	5.
CHROMITE	28.	3.	0.	3351. *	424. *	27.	17.	4.	0.	66. *
CLAYS	614.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	66344.	1.	0.	6.	1.	6.	13.	1.	2.	10.
COAL BITUM/LIGNT	12320.	1.	0.	6.	1.	6.	13.	1.	0.	10.
COPPER ORE	783100.	6.	2.	1025. *	449. *	12.	86.	25.	3.	37.
FELDSPAR	822.	3.	2.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	532.	5.	0.	705. *	151.	22.	201.	120.	0.	50. *
GYPSUM	56.	3.	0.	175.	0.	10.	11.	0.	0.	37.
IRON ORE	296553.	5.	1.	57.	8.	11.	15.	6.	1.	35.
LEAD ORE	469.	3.	0.	77.	38.	11.	126.	13.	0.	33.
LITHIUM ORE	3659.	7. *	5.	55.	20.	1.	50.	18.	1.	1.
MANGANESE ORE	1700.	3.	1.	100.	4.	24.	6.	11.	0.	100. *
MERCURY	9.	1.	0.	386.	576. *	19.	13.	36.	0.	58. *
NATURAL GAS	2917.	5.	0.	245.	277.	30.	93.	9.	1.	5.
NICKEL ORE	395.	3.	0.	4432. *	5318. *	37.	54.	23.	0.	75. *
NITROGEN, FIXED	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
OXYGEN	16.	4.	0.	0.	0.	22.	0.	0.	0.	0.
PETROLEUM	5113.	3.	0.	563. *	210.	22.	110.	36.	1.	40.
SALT	13889.	6.	0.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	7249.	4.	0.	0.	0.	0.	0.	0.	0.	0.
SILVER ORE	1379.	4.	0.	372.	93.	14.	207.	56.	0.	40.
STONE	739.	3.	0.	0.	0.	3.	0.	0.	0.	0.
SULFUR	443.	3.	0.	93.	1.	15.	90.	0.	0.	28.
TIN ORE	251290.	2.	1.	4393. *	1318. *	29.	73.	20.	0.	65. *
ZINC ORE	8352.	0.	1.	148.	34.	19.	154.	8.	0.	88. *
COTTON	7.	2.	0.	0.	0.	16.	0.	0.	0.	1.
MILK BYPRODUCTS	0.	3.	0.	0.	0.	20.	0.	0.	0.	1.
LUMBER	1955.	1.	0.	0.	0.	12.	0.	0.	1.	18.
SEA WATER	1557522.	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATER	165668.	3.	0.	17.	2.	0.	3.	0.	0.	0.
MISC.	1617.	0.	0.	0.	0.	0.	0.	0.	2.	0.
STEAM	103499.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	42072.	3.	2.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	200316.	1.	1.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	5165978.	3.	0.	0.	0.	0.	0.	0.	0.	0.
COAL BYPRODUCT 2	169155.	1.	1.	6.	1.	6.	13.	1.	0.	10.
PETROLEUM BYPRO	69000.	3.	0.	564. *	211.	22.	110.	36.	0.	40.

BULK MATERIAL REQUIREMENTS FOR TROMBE WALL CONCRETE

SOLAR SCENARIO:
INTRODUCTION YEAR - 1985
CUMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY-PRODUCT	WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT $/SM	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	50.	10. %/YR	10.	35.	15.	50.
MATERIALS							
ALUMINUM	1529750.	0.	7.	0.	13.	3.	14.
CARBON BLACK	143902.	100. *	2.	0.	12.	0.	0.
CEMENT	60852404.	0.	3.	1.	18.	4.	4.
GLASS, SODA LIM	7807000.	0.	3.	6.	5.	4.	5.
IRON , STEEL	5524394.	1.	3.	0.	16.	4.	10.
FERROMANGANESE	33346.	100. *	2.	0.	9.	0.	99. *
SAND ! GRAVEL	126051400.	0.	4.	0.	10.	1.	0.
STONE	247756208.	0.	3.	0.	3.	1.	0.
ALKYD RESIN	30173.	0.	7.	0.	5.	0.	1.
NEOPRENE	119215.	0.	3.	3.	5.	0.	1.
PAINT THINNER	58025.	0.	3.	1.	5.	0.	5.

RAW MATERIAL REQUIREMENTS FOR TROMBE WALL CONCRETE

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
CUMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	300.	300.	15.	50.
MATERIALS										
ASBESTOS	0.	3.	0.	530. *	28.	34.	190.	29.	0.	90. *
BAUXITE	7739.	5.	0.	2230. *	297.	28.	14.	9.	0.	89. *
CLAYS	8862.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	10176.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	10220.	1.	0.	6.	1.	6.	13.	1.	1.	10.
FELDSPAR	726.	3.	2.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	151.	5.	0.	703. *	151.	22.	200.	120.	0.	50. *
GYPSUM	2921.	3.	0.	176.	0.	10.	11.	0.	0.	37.
IRON ORE	31554.	5.	0.	55.	7.	11.	15.	6.	0.	35.
MANGANESE ORE	183.	3.	0.	100.	4.	24.	6.	11.	0.	100. *
NATURAL GAS	4089.	5.	0.	245.	277.	30.	93.	9.	1.	5.
PETROLEUM	370.	3.	0.	562. *	210.	22.	110.	36.	0.	40.
SALT	10477.	6.	0.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	134664.	4.	0.	0.	0.	0.	0.	0.	1.	0.
STONE	247756.	3.	0.	0.	0.	3.	0.	0.	1.	0.
SULFUR	382.	3.	0.	93.	1.	15.	90.	0.	0.	28.
FLAX SEED	171.	1.	1.	0.	0.	25.	0.	0.	0.	20.
LUMBER	1.	1.	0.	0.	0.	12.	0.	0.	0.	18.
SOYBEAN	87.	3.	0.	0.	0.	12.	0.	0.	0.	0.
WATER	3863.	3.	0.	17.	2.	0.	3.	0.	0.	0.
MISC.	51.	0.	0.	0.	0.	0.	0.	0.	0.	0.
STEAM	44890.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	95983.	3.	4.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	312894.	1.	1.	6.	1.	6.	13.	1.	0.	10.

BULK MATERIAL REQUIREMENTS FOR TROMBE WALL WATER

SOLAR SCENARIO:
INTRODUCTION YEAR - 1985
CUMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY-PRODUCT	WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT $/SM	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	50.	10. %/YR	10.	35.	15.	50.
MATERIALS							
ALUMINUM	1529750.	0.	7.	0.	13.	3.	14.
CARBON BLACK	143902.	100. *	2.	0.	12.	0.	0.
CEMENT	5516594.	0.	3.	0.	18.	0.	4.
GLASS, SODA LIM	7807000.	0.	3.	6.	5.	4.	5.
IRON , STEEL	19966678.	1.	3.	0.	16.	14.	10.
FERROMANGANESE	120523.	100. *	2.	0.	9.	0.	99. *
SAND ! GRAVEL	11427231.	0.	4.	0.	10.	0.	0.
STONE	22460422.	0.	3.	0.	3.	0.	0.
WATER	76065504.	0.	3.	0.	0.	0.	0.
ALKYD RESIN	30173.	0.	7.	0.	5.	0.	1.
NEOPRENE	119215.	0.	3.	3.	5.	0.	1.
PAINT THINNER	50025.	0.	3.	1.	5.	0.	5.
SODIUM DICHROMA	75960.	0.	3.	2.	5.	0.	5.

RAW MATERIAL REQUIREMENTS FOR TROMBE WALL WATER

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
COMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX. % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000		% U.S. RESOURCES CONSUMED BY 2000		% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED	
THRESHOLD LEVELS	---	7. %/YR	10.	400.		300.		60.	300.	200.	15.	50.	
MATERIALS													
ASBESTOS	0.	3.	0.	539.	*	28.		34.	190.	[illegible]29.	0.	93.	*
BAUXITE	7775.	5.	0.	2230.	*	297.		28.	14.	9.	0.	89.	*
CHROMITE	84.	3.	0.	3357.	*	425.	*	27.	17.	4.	0.	66.	*
CLAYS	1012.	2.	0.	0.		0.		10.	0.	0.	0.	6.	
COAL	29295.	1.	0.	6.		1.		6.	13.	1.	1.	10.	
COAL BITUM/LIGNT	18342.	1.	0.	6.		1.		6.	13.	1.	1.	10.	
FELDSPAR	726.	3.	2.	5.		0.		10.	13.	0.	0.	5.	
FLUORSPAR	266.	5.	0.	704.	*	151.		22.	200.	120.	0.	58.	*
GYPSUM	265.	3.	0.	175.		0.		10.	11.	0.	0.	37.	
IRON ORE	112843.	5.	0.	56.		7.		11.	15.	6.	0.	35.	
MANGANESE ORE	656.	3.	0.	100.		4.		24.	6.	11.	0.	100.	*
NATURAL GAS	659.	5.	0.	245.		277.		30.	93.	9.	0.	5.	
PETROLEUM	921.	3.	0.	562.	*	210.		22.	110.	36.	0.	40.	
SALT	10704.	6.	0.	0.		0.		5.	0.	0.	1.	9.	
SAND/GRAVEL	16903.	4.	0.	0.		0.		0.	0.	0.	0.	0.	
STONE	22460.	3.	0.	0.		0.		3.	0.	0.	0.	0.	
SULFUR	395.	3.	0.	93.		1.		15.	90.	0.	0.	28.	
FLAX SEED	171.	1.	1.	0.		0.		25.	0.	0.	0.	20.	
LUMBER	2.	1.	0.	0.		0.		12.	0.	0.	0.	18.	
SOYBEAN	87.	3.	0.	0.		0.		12.	0.	0.	0.	0.	
WATER	78844.	3.	0.	17.		2.		0.	3.	0.	0.	0.	
MISC.	181.	0.	0.	0.		0.		0.	0.	0.	0.	0.	
STEAM	61356.	5.	0.	1.		0.		10.	0.	0.	0.	0.	
LIMESTONE	28068.	3.	1.	0.		0.		5.	0.	0.	0.	2.	
COAL, BY PROD	312894.	1.	1.	6.		1.		6.	13.	1.	0.	10.	
ELECTRICITY	46032.	3.	0.	0.		0.		0.	0.	0.	0.	0.	

BULK MATERIAL REQUIREMENTS FOR DIRECT GAIN MASONRY WALL

SOLAR SCENARIO:
INTRODUCTION YEAR - 1985
CUMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY PRODUCT	WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT $/SM	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	50.	10. %/YR	10.	35.	15.	50.
MATERIALS							
ALUMINUM	1533000.	0.	7.	0.	13.	3.	14.
CEMENT	123480000.	0.	3.	1.	18.	9.	4.
GLASS, SODA LIM	7812000.	0.	3.	6.	5.	4.	5.
IRON , STEEL	7230754.	1.	3.	0.	16.	5.	10.
FERROMANGANESE	43646.	100. *	2.	0.	9.	0.	99. *
SAND ! GRAVEL	255780000.	0.	4.	0.	10.	1.	0.
STONE	582740000.	0.	3.	1.	3.	3.	0.
NEOPRENE	123900.	0.	3.	3.	5.	0.	1.

RAW MATERIAL REQUIREMENTS FOR DIRECT GAIN MASONRY WALL

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
COMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX. % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	300.	200.	15.	50.
MATERIALS										
ASBESTOS	0.	3.	9.	539. *	28.	34.	193.	129.	0.	98. *
BAUXITE	7760.	5.	0.	2230. *	297.	28.	14.	9.	0.	89. *
CLAYS	17981.	2.	0.	0.	0.	10.	9.	0.	1.	0.
COAL	25061.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	18585.	1.	0.	6.	1.	6.	13.	1.	1.	10.
FELDSPAR	727.	3.	2.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	166.	5.	0.	703. *	151.	22.	200.	120.	0.	50. *
GYPSUM	5927.	3.	1.	177.	0.	10.	11.	0.	0.	37.
IRON ORE	41546.	5.	0.	55.	7.	11.	15.	6.	0.	35.
MANGANESE ORE	240.	3.	0.	100.	4.	24.	6.	11.	0.	100. *
NATURAL GAS	8235.	5.	0.	246.	277.	30.	93.	9.	2.	5.
PETROLEUM	430.	3.	0.	562. *	210.	22.	110.	36.	0.	40.
SALT	10493.	6.	0.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	267967.	4.	0.	0.	0.	0.	0.	0.	1.	0.
STONE	502740.	3.	0.	0.	0.	3.	0.	0.	3.	0.
SULFUR	383.	3.	0.	93.	1.	15.	90.	0.	0.	28.
LUMBER	1.	1.	0.	0.	0.	12.	0.	0.	0.	18.
WATER	6557.	3.	0.	17.	2.	0.	3.	0.	0.	0.
MISC.	67.	0.	0.	0.	0.	0.	0.	0.	0.	0.
STEAM	47019.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	182696.	3.	7.	0.	0.	5.	0.	0.	1.	2.

BULK MATERIAL REQUIREMENTS FOR LLL SOLAR POND

SOLAR SCENARIO:
INTRODUCTION YEAR - 1985
CUMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY-PRODUCT	WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT $/SM	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	50.	10. %/YR	10.	35.	15.	50.
MATERIALS							
ALUMINUM	1267.	0.	7.	0.	13.	0.	14.
ASBESTOS	190938.	0.	3.	0.	40. *	0.	90. *
CHROMIUM	172.	100. *	4.	0.	15.	0.	57. *
CEMENT	51571012.	0.	3.	1.	18.	4.	4.
COPPER	69914.	1.	6.	0.	12.	0.	45.
GLASS, FIBER	214500.	0.	7.	1.	5.	0.	2.
GLASS, SODA LIM	1287000.	0.	3.	1.	5.	1.	5.
IRON & STEEL	3723924.	1.	3.	0.	16.	3.	10.
LEAD	67.	13.	5.	0.	11.	0.	10.
FERROMANGANESE	23257.	100. *	2.	0.	9.	0.	99. *
PORCELAIN	185.	0.	0.	0.	10.	0.	0.
SAND ! GRAVEL	139926624.	0.	4.	0.	10.	1.	0.
STONE	207635520.	0.	3.	0.	3.	1.	0.
SILICON	8094.	0.	3.	0.	14.	0.	0.
SILVER	23.	70. *	4.	0.	14.	0.	46.
TIN	200.	25.	2.	0.	29.	0.	65. *
WATER	52975000.	0.	3.	0.	0.	0.	0.
ZINC	39225.	25.	3.	0.	21.	0.	88. *
GLUE, PHENOL, FOR	1463.	0.	7.	0.	5.	0.	5.
POLYESTER RESIN	500500.	0.	7.	2.	5.	1.	0.
PVC PLASTIC	39127.	0.	7.	0.	5.	0.	0.
KRAFT FIBERS	64350.	0.	3.	0.	10.	0.	15.
URETHANE	41438.	0.	7.	0.	5.	1.	5.
NEOPRENE	15470.	0.	3.	0.	5.	0.	1.
POLYVINYL FLUOR	19175.	0.	7.	5.	5.	1.	5.

RAW MATERIAL REQUIREMENTS FOR LLL SOLAR POND

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
CUMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	300.	200.	15.	50.
MATERIALS										
ASBESTOS	191.	3.	0.	540. *	28.	34.	190.	129.	0.	33. *
BAUXITE	106.	5.	0.	2211. *	295.	28.	14.	9.	0.	89. *
BORATE	54.	5.	0.	11.	0.	58.	10.	0.	0.	3.
CLAYS	7510.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	9021.	1.	0.	6.	1.	6.	13.	1.	0.	10.
COAL BITUM/LIGNT	2338.	1.	0.	6	1.	6.	13.	1.	0.	10.
COPPER ORE	15381.	6.	0.	984. *	431. *	12.	85.	24.	0.	37.
FELDSPAR	128.	3.	0.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	50.	5.	0.	702. *	151.	22.	200.	120.	0.	50. *
GYPSUM	2475.	3.	0.	176.	0.	10.	11.	0.	0.	37.
IRON ORE	21488.	5.	0.	55.	7.	11.	15.	6.	0.	35.
LEAD ORE	2.	3.	0.	77.	38.	11.	126.	13.	0.	33.
MANGANESE ORE	127.	3.	0.	100.	4.	24.	6.	11.	0.	100. *
NATURAL GAS	4183.	5.	0.	245.	277.	30.	93.	9.	1.	5.
NITROGEN, FIXED	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
PETROLEUM	235.	3.	0.	562. *	210.	22.	110.	36.	0.	40.
SALT	1123.	6.	0.	0.	0.	5.	0.	0.	0.	9.
SAND/GRAVEL	143857.	4.	0.	0.	0.	0.	0.	0.	1.	0.
SILVER ORE	162.	4.	0.	372.	98.	14.	207.	56.	0.	45.
STONE	207636.	3.	0.	0.	0.	3.	0.	0.	1.	0.
SULFUR	21.	3.	0.	93.	1.	15.	90.	0.	0.	28.
TIN ORE	1999.	2.	0.	4333. *	1300. *	29.	73.	20.	0.	65. *
ZINC ORE	733.	0.	0.	146.	33.	19.	154.	8.	0.	88. *
MILK BYPRODUCTS	0.	3.	0.	0.	0.	20.	0.	0.	0.	1.
LUMBER	129.	1.	0.	0.	0.	12.	0.	0.	0.	18.
SEA WATER	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATER	56665.	3.	0.	17.	2.	0.	3.	0.	0.	0.
WHEAT	0.	3.	0.	0.	0.	10.	0.	0.	0.	0.
MISC.	94.	0.	0.	0.	0.	0.	0.	0.	0.	0.
STEAM	5648.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	74078.	3.	3.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	593838.	1.	2.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	253503.	3.	0.	0.	0.	0.	0.	0.	0.	0.
COAL BYPRODUCT 2	24531.	1.	0.	6.	1.	6.	13.	1.	0.	10.

BULK MATERIAL REQUIREMENTS FOR CHAMBERLAIN - LUMBER KIL

SOLAR SCENARIO:
INTRODUCTION YEAR - 1985
CUMMULATIVE CAPACITY 2000 - 569. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY PRODUCT		WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT $/SM		NET PERCENT IMPORTED	
THRESHOLD LEVELS	----	50.		10. %/YR	10.	35.	15.		50.	
MATERIALS										
ALUMINUM	5192320.	0.		7.	1.	13.	10.		14.	
CADMIUM	2562.	100.	*	4.	1.	15.	0.		57.	*
CHROMIUM	207895.	0.		3.	1.	31.	0.		100.	*
COPPER	1316198.	1.		6.	1.	12.	3.		45.	
GLASS, FIBER	1127280.	0.		7.	4.	5.	1.		2.	
GLASS, SODA LIM	10103247.	0.		3.	8.	5.	6.		5.	
IRON , STEEL	85477352.	1.		3.	1.	16.	59.	*	10.	
LEAD	4487.	13.		5.	0.	11.	0.		18.	
FERROMANGANESE	516352.	100.	*	2.	0.	9.	0.		92.	*
NICKEL	102694.	7.		4.	1.	28.	1.		75.	*
SILICON	4532.	0.		3.	0.	14.	0.		8.	
SILVER	1494.	70.	*	4.	1.	14.	0.		46.	
TIN	7455.	25.		2.	0.	29.	0.		65.	*
WATER	41632500.	0.		3.	0.	0.	0.		0.	
ZINC	722307.	25.		3.	1.	21.	1.		88.	*
LUMBER, SOFTWOOD	38003000.	0.		4.	1.	20.	3.		12.	
PHENOLIC RESIN	796355.	0.		7.	2.	5.	2.		1.	
PVC PLASTIC	389575.	0.		7.	0.	5.	1.		0.	
TEFLON	1494.	0.		7.	0.	5.	0.		1.	
COTTON FIBERS	555954.	0.		3.	1.	16.	1.		1.	
KRAFT FIBERS	238266.	0.		3.	0.	10.	0.		15.	
URETHANE	625558.	0.		7.	5.	5.	9.		5.	
EPDM RUBBER	239120.	0.		7.	3.	5.	0.		5.	

RAW MATERIAL REQUIREMENTS FOR CHAMBERLAIN - LUMBER KIL.

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
CUMMULATIVE CAPACITY 2000 - 500 M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX. % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	300.	300.	15.	50.
MATERIALS										
ASBESTOS	1.	3.	0.	539. *	28.	34.	190.	129.	0.	90. *
BAUXITE	26910.	5.	2.	2278. *	304. *	28.	14.	9.	1.	89. *
BORATE	292.	5.	1.	11.	0.	50.	10.	0.	0.	3.
CHROMITE	621.	4.	2.	3408. *	431. *	27.	17.	4.	0.	66. *
CLAYS	914.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	112533.	1.	0.	6.	1.	6.	13.	1.	3.	10.
COAL BITUM/LIGNT	43999.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COPPER ORE	203563.	6.	1.	909. *	438. *	12.	85.	25.	1.	37.
FELDSPAR	940.	3.	2.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	1052.	5.	1.	709. *	152.	22.	201.	120.	0.	50. *
IRON ORE	486035.	5.	1.	58.	8.	11.	15.	6.	2.	35.
LEAD ORE	147.	3.	0.	77.	38.	11.	126.	13.	0.	33.
MANGANESE ORE	2845.	3.	1.	100.	4.	24.	6.	11.	1.	100. *
NATURAL GAS	2037.	5.	0.	245.	277.	30.	93.	9.	0.	5.
NICKEL ORE	10269.	3.	1.	4487. *	5384. *	37.	54.	23.	0.	75. *
NITROGEN, FIXED	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
OXYGEN	141.	4.	0.	0.	0.	22.	0.	0.	0.	0.
PETROLEUM	5504.	3.	0.	563. *	210.	22.	110.	36.	1.	40.
SALT	32420.	6.	1.	0.	0.	5.	0.	0.	2.	9.
SAND/GRAVEL	7392.	4.	0.	0.	0.	0.	0.	0.	0.	0.
SILVER ORE	10651.	4.	1.	374.	99.	14.	203.	56.	0.	45.
SULFUR	1372.	3.	0.	94.	1.	15.	90.	0.	0.	28.
TIN ORE	74554.	2.	0.	4351. *	1305. *	29.	73.	20.	0.	65. *
ZINC ORE	13376.	0.	1.	149.	34.	19.	155.	8.	0.	88. *
COTTON	556.	2.	0.	0.	0.	16.	0.	0.	1.	1.
MILK BYPRODUCTS	27.	3.	0.	0.	0.	20.	0.	0.	0.	1.
LUMBER	38490.	1.	0.	0.	0.	12.	0.	0.	11.	18.
SEA WATER	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATER	874551.	3.	0.	17.	2.	0.	3.	0.	0.	0.
MISC.	1520.	0.	0.	0.	0.	0.	0.	0.	2.	0.
STEAM	239973.	5.	1.	1.	0.	10.	0.	0.	1.	0.
LIMESTONE	71837.	3.	3.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	833807.	1.	3.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	4274689.	3.	0.	0.	0.	0.	0.	0.	0.	0.
COAL BYPRODUCT 2	370329.	1.	1.	6.	1.	6.	13.	1.	0.	10.

BULK MATERIAL REQUIREMENTS FOR HONEYWELL CONCENTRATING

SOLAR SCENARIO:
INTRODUCTION YEAR - 1985
CUMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY-PRODUCT		WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY		COST PER UNIT OUTPUT $/SM	NET PERCENT IMPORTED	
THRESHOLD LEVELS	---	50.		10. %/YR	10.	35.		15.	50.	
MATERIALS										
ALUMINUM	3569043.	0.		7.	1.	13.		7.	14.	
ASBESTOS	2000.	0.		3.	0.	40.	*	0.	90.	*
CHROMIUM	16099.	0.		3.	0.	31.		0.	100.	*
COPPER	757203.	1.		6.	0.	12.		2.	45.	
GLASS, FIBER	1325346.	0.		7.	5.	5.		1.	2.	
GLASS, SODA LIM	154000.	0.		3.	0.	5.		0.	5.	
IRON , STEEL	13718063.	1.		3.	0.	16.		9.	10.	
LEAD	392.	13.		5.	0.	11.		0.	18.	
MAGNESIUM	323.	30.		6.	0.	26.		0.	0.	
FERROMANGANESE	83382.	100.	*	2.	0.	9.		0.	99.	*
MERCURY	13.	2.		3.	0.	19.		0.	58.	*
MOLYBDENUM	640.	42.		5.	0.	16.		0.	4.	
NICKEL	10024.	7.		3.	0.	28.		0.	75.	*
PORCELAIN	65.	0.		0.	0.	10.		0.	0.	
SAND ! GRAVEL	56115.	0.		4.	0.	10.		0.	0.	
SILICON	8437.	0.		3.	0.	14.		0.	8.	
SULFUR	221.	31.		3.	0.	15.		0.	15.	
TIN	1404.	25.		2.	0.	29.		0.	65.	*
WATER	1059090.	0.		3.	0.	0.		0.	0.	
ZINC	191846.	25.		3.	0.	21.		0.	88.	*
STAINLESS STEEL	114616.	0.		3.	0.	10.		0.	15.	
ACRYLIC	84495.	0.		7.	1.	5.		0.	1.	
EPOXY RESIN	252840.	0.		7.	[illegible]	[illegible]		1.	[illegible]	
PHENOLIC RESIN	7896.	0.		7.	0.	5.		0.	1.	
PVC PLASTIC	6192.	0.		7.	0.	5.		0.	0.	
TEFLON	9804.	0.		7.	2.	5.		0.	1.	
NEOPRENE	161250.	0.		3.	4.	5.		0.	1.	
PITCH	702405.	0.		7.	3.	5.		0.	5.	
EPDM RUBBER	65.	0.		7.	0.	5.		0.	5.	

RAW MATERIAL REQUIREMENTS FOR HONEYWELL CONCENTRATING

SOLAR SCENARIO:
INTRODUCTION YEAR -1985
COMMULATIVE CAPACITY 2000 - 500. M SQ. M

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/SM OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	300.	200.	15.	50.
MATERIALS										
ASBESTOS	5.	3.	0.	539. *	28.	34.	190.	29.	0.	99. *
BAUXITE	18615.	5.	1.	2257. *	301. *	28.	14.	9.	1.	89. *
BORATE	331.	5.	1.	11.	0.	50.	10.	0.	0.	3.
CHROMITE	121.	3.	0.	3300. *	425. *	27.	17.	4.	0.	66. *
CLAYS	155.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	23654.	1.	0	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	220873.	1.	1.	6.	1.	6.	13.	1.	7.	10.
COPPER ORE	166505.	6.	0.	992. *	435. *	12.	85.	24.	1.	37.
FELDSPAR	14.	3.	0.	5.	0.	10.	12.	0.	0.	3.
FLUORSPAR	378.	5.	0.	704. *	151.	22.	200.	120.	0.	50. *
IRON ORE	79607.	5.	0.	56.	7.	11.	15.	6.	0.	35.
LEAD ORE	13.	3.	0.	77.	38.	11.	126.	13.	0.	33.
LIME	0.	3.	0.	0.	0.	31.	0.	0.	0.	2.
MANGANESE ORE	462.	3.	0.	100.	4.	24.	6.	11.	0.	100. *
MERCURY	0.	1.	0.	384.	573. *	19.	13.	36.	0.	58. *
MOLYBDENUM ORE	488.	5.	0.	44.	8.	16.	43.	13.	7.	4.
NATURAL GAS	611.	5.	0.	245.	277.	30.	93.	9.	0.	5.
NICKEL ORE	2719.	3.	0.	4445. *	5334. *	37.	54.	23.	0.	75. *
NITROGEN, FIXED	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
OXYGEN	0.	4.	0.	0.	0.	22.	0.	0.	0.	0.
PETROLEUM	879.	3.	0.	562. *	210.	22.	110.	36.	0.	40.
PROPANE	197.	1.	0.	191.	23.	10.	136.	11.	0.	5.
SALT	14771.	6.	0.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	1053.	4.	0.	0.	0.	0.	0.	0.	0.	0.
SULFUR	994.	3.	0.	94.	1.	15.	90.	0.	0.	28.
TIN ORE	14035.	2.	0.	4336. *	1301. *	29.	73.	30.	0.	65. *
ZINC ORE	3415.	0.	0.	147.	34.	19.	154.	8.	0.	88. *
MILK BYPRODUCTS	0.	3.	0.	0.	0.	20.	0.	0.	0.	1.
LUMBER	5.	1.	0.	0.	0.	12.	0.	0.	0.	18.
SEA WATER	233.	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATER	7347.	3.	0.	17.	2.	0.	3.	0.	0.	0.
MISC.	416.	0.	0.	0.	0.	0.	0.	0.	0.	0.
STEAM	109136.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	10817.	3.	1.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	128274.	1.	0.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	198225.	3.	0.	0.	0.	0.	0.	0.	0.	0.

BULK MATERIAL SUMMARY REPORT

SHACOB Mixed System Scenario: Introduction Year - 1985
Cummulative Capacity by the Year 2000 - 500 M. Sq. M.
Composed of 9 SHACOB Designs Each at 55.6 M. Sq. M.

THIS REPORT IS A SUMMARY OF THESE DESIGNS:
25 26 27 28 29 30 31 32 33

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY PRODUCT	WORLD PRODN GROWTH RATE 1976-2000	SOURCES % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	50.	10. %/YR	10.	35.	15.	50.
MATERIALS							
ALUMINUM	1847663.	0.	7.	0.	13.	5.	14.
ANTIMONY	195.	100. *	5.	0.	22.	0.	55. *
ASBESTOS	6258.	0.	3.	0.	40. *	0.	90. *
BROMINE	10823.	0.	6.	0.	10.	0.	19.
CADMIUM	502.	100. *	4.	0.	15.	0.	57. *
CARBON BLACK	46379.	100. *	2.	0.	12.	0.	0.
CEMENT	21805448.	0	3.	0	18.	2.	4.
CHROMIUM	791.	0.	3.	0.	31.	0.	100. *
COPPER	1555843.	1.	6.	1.	12.	6.	45.
GLASS, FIBER	949241.	0.	7.	4.	5.	1.	2.
GLASS, SODA LIM	6661600.	0.	3.	5.	5.	4.	5.
GYPSUM	3127.	0.	3.	0.	10.	0.	37.
IRON & STEEL	19260778.	1.	3.	0.	16.	13.	10.
LEAD	9204.	13.	5.	0.	11.	0.	18.
LITHIUM	940.	0.	7.	1.	1.	0.	1.
MAGNESIUM	706.	30.	6.	0.	26.	0.	0.
FERROMANGANESE	116361.	100. *	2.	0.	9.	0.	99. *
MERCURY	36.	2	3.	0.	19.	0.	58. *
NICKEL	829.	7.	3.	0.	28.	0.	75. *
SAND ! GRAVEL	72293480.	0.	4.	0.	10.	0.	0.
STONE	88702883.	0.	3.	0.	3.	0.	0.
SILICON	2699.	0.	3.	0.	14.	0.	8.
SILVER	717.	70. *	4.	0.	14.	0.	46.
TIN	15096.	25.	2.	1.	29.	1.	65. *
WATER	37416652.	0.	3.	0.	0.	0.	0.
ZINC	455758.	25.	3.	1.	21.	1.	88. *
STAINLESS STEEL	10719.	0.	3.	0.	10.	0.	15.
ALKYD RESIN	9725.	0.	7.	0.	5.	0.	1.
GLUE, PHENOL, FOR	16298.	0.	7.	0.	5.	0.	5.
LUMBER, SOFTWOOD	2186235.	0.	4.	0.	20.	0.	12.
PHENOLIC RESIN	26466.	0.	7.	0.	5.	0.	1.
PVC PLASTIC	25032.	0.	7.	0.	5.	0.	0.
RUBBER, SBR	51988.	0.	6.	0.	5.	0.	4.
SILICONES	64505.	0.	7.	2.	5.	1.	1.
TEFLON	16803.	0.	7.	3.	5.	0.	1.
NYLON	1606.	0.	7.	0.	5.	0.	1.
COTTON FIBERS	728.	0.	3.	0.	16.	0.	1.
KRAFT FIBERS	312.	0.	3.	0.	10.	0.	15.
URETHANE	136922.	0.	7.	1	5.	7.	5.
ASPHALT	150620.	0.	3.	0.	5.	6.	5.
NEOPRENE	113014.	0.	3.	3.	5.	1.	1.
ETHYLENE GLYCOL	246942.	0.	7.	0.	5.	1.	9.
POLYETHYLENE	488.	0.	7.	0.	5.	0.	5.
POLYVINYL FLUOR	8347.	0.	7.	2.	5.	1.	5.
EPDM RUBBER	2977.	0.	7.	0.	5.	0.	5.
PAINT THINNER	18701.	0.	3.	0.	5.	0.	5.
SODIUM DICHROMA	8447.	0.	3.	0.	5.	0.	5.
POLYCARBONATE	8347.	0.	7.	0.	5.	0.	5.
POLYPROPYLENE G	115556.	0.	7.	1.	5.	0.	5.
VITREOUS ENAMEL	38341.	0.	7.	0.	10.	0.	0.

RAW MATERIAL SUMMARY REPORT

SHACOB Mixed System Scenario: Introduction Year - 1985
Cummulative Capacity by the Year 2000 - 500 M. Sq. M.
Composed of 9 SHACOB Designs Each at 55.6 M. Sq. M.

THIS REPORT IS A SUMMARY OF THESE 9 DESIGNS:
25 26 27 28 29 30 31 32 33

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX. % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WRLD. RES. SOURCES CONSUMED BY 2000	PRESENT COSTS IN $/OR OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	300.	200.	15.	50.
MATERIALS										
ANTIMONY ORE	20.	5.	0.	1218. *	1129. *	22.	75.	64.	0.	55. *
ASBESTOS	7.	3.	0.	539. *	28.	34.	190.	129.	0.	90. *
BAUXITE	9779.	5.	1.	2235. *	298.	28.	14.	9.	0.	89. *
BORATE	237.	5.	1.	11.	0.	50.	10.	0.	0.	3.
BUTANE	59.	1.	0.	20.	2.	10.	12.	1.	0.	5.
CHROMITE	19.	3.	0.	3351. *	424. *	27.	17.	4.	0.	66. *
CLAYS	3376.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	31100.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	17666.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COPPER ORE	342711.	6.	1.	1002. *	439. *	12.	85.	25.	2.	37.
FELDSPAR	628.	3.	1.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	325.	5.	0.	704. *	151.	22.	200.	120.	0.	50. *
GYPSUM	1051.	3.	0.	175.	0.	10.	11.	0.	0.	37.
IRON ORE	112468.	5.	0.	56.	7.	11.	15.	6.	0.	35.
LEAD ORE	609.	3.	0.	77.	38.	11.	126.	13.	0.	33.
LITHIUM ORE	487.	7. *	1.	53.	19.	1.	49.	17.	0.	1.
MANGANESE ORE	657.	3.	0.	100.	4.	24.	6.	11.	0.	100. *
MERCURY	1.	1.	0.	384.	573. *	19.	13.	36.	0.	58. *
NATURAL GAS	2628.	5.	0.	245.	277.	30.	93.	9.	0.	5.
NICKEL ORE	169.	3.	0.	4431. *	5317. *	37.	54.	23.	0.	75. *
NITROGEN, FIXED	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
OXYGEN	38.	4.	0.	0.	0.	22.	0.	0.	0.	0.
PETROLEUM	1976.	3.	0.	562. *	210.	22.	110.	36.	0.	40.
SALT	11724.	6.	0.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	78555.	4.	0.	0.	0.	0.	0.	0.	0.	0.
SILVER ORE	5111.	4.	0.	373.	99.	14.	208.	56.	0.	45.
SODIUM NITRATE	1.	4.	0.	0.	0.	5.	0.	0.	0.	10.
STONE	88703.	3.	0.	0.	0.	3.	0.	0.	0.	0.
SULFUR	512.	3.	0.	93.	1.	15.	90.	0.	0.	28.
TIN ORE	150963.	2.	1.	4369. *	1311. *	29.	73.	20.	0.	65. *
ZINC ORE	8217.	0.	1.	148.	34.	19.	154.	8.	0.	88. *
COTTON	1.	2.	0.	0.	0.	16.	0.	0.	0.	1.
FLAX SEED	55.	1.	0.	0.	0.	25.	0.	0.	0.	20.
MILK BYPRODUCTS	1.	3.	0.	0.	0.	20.	0.	0.	0.	1.
LUMBER	2268.	1.	0.	0.	0.	12.	0.	0.	1.	18.
SEA WATER	173723.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SOYBEAN	28.	3.	0.	0.	0.	12.	0.	0.	0.	0.
WATER	97680.	3.	0.	17.	2.	0.	3.	0.	0.	0.
WHEAT	5.	3.	0.	0.	0.	10.	0.	0.	0.	0.
MISC.	763.	0.	0.	0.	0.	0.	0.	0.	1.	0.
STEAM	71634.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	51586.	3.	2.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	209934.	1.	1.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	1107392.	3.	0.	0.	0.	0.	0.	0.	0.	0.
COAL BYPRODUCT 2	81058.	1.	0.	6.	1.	6.	13.	1.	0.	10.
PETROLEUM BYPRO	7682.	3.	0.	563. *	210.	22.	110.	36.	0.	40.

BULK MATERIAL SUMMARY REPORT

SHACOB Mixed System Scenario: Introduction Year - 1985
Cummulative Capacity by the Year 2000 - 1000 M. Sq. M.
Composed of 9 SHACOB Designs Each at 111.1 M. Sq. M.

THIS REPORT IS A SUMMARY OF THESE 9 DESIGNS:
25 26 27 28 29 30 31 32 33

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY-PRODUCT	WORLD PRODN GROWTH RATE 1976-2000	SOLAR'S % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	50.	10. %/YR	10.	35	15.	50.
MATERIALS							
ALUMINUM	3680680.	0.	7.	1.	13.	5.	14.
ANTIMONY	389.	100. *	5.	0.	22	0.	55 *
ASBESTOS	12493.	0.	3.	0.	45. *	0.	90. *
BROMINE	21607.	0.	6.	0.	10.	0.	19.
CADMIUM	1002.	100. *	4.	0.	15	0.	57. *
CARBON BLACK	92590.	100. *	2.	0.	12.	0.	0.
CEMENT	43532450.	0.	3.	0	18.	2.	4.
CHROMIUM	1580.	0.	3.	0.	31	0.	100. *
COPPER	3106090.	1	6.	2.	12.	6.	45.
GLASS, FIBER	1895068.	0.	7.	7.	5.	1.	2.
GLASS, SODA LIM	13299237.	0.	3.	10. *	5.	4.	5.
GYPSUM	6243.	0.	3.	0.	10.	0.	37.
IRON, STEEL	38452276.	1.	3.	0.	16.	13.	10.
LEAD	18376.	13	5.	0.	11.	0.	18.
LITHIUM	1876.	0.	7.	1.	1.	0.	1.
MAGNESIUM	1409.	30.	6.	0.	26.	0.	0.
FERROMANGANESE	232303.	100. *	2.	0.	9.	0.	99. *
MERCURY	72.	2.	3.	0.	19.	0.	58. *
NICKEL	1655.	7.	3.	0.	28.	0.	75. *
SAND ! GRAVEL	144326912.	0.	4.	0.	10.	0.	0.
STONE	177086704.	0.	3.	0.	3.	0.	0.
SILICON	5388.	0.	3.	0.	14.	0.	8.
SILVER	1432.	70. *	4.	1.	14.	0.	46.
TIN	30138.	25.	2.	1.	29.	1.	65. *
WATER	74698720.	0.	3.	0.	0.	0.	0.
ZINC	909876.	25.	3.	1.	21.	1.	88. *
STAINLESS STEEL	21400.	0.	3.	0.	10.	0.	15.
ALKYD RESIN	19414.	0.	7.	0.	5.	0.	1.
GLUE, PHENOL, FOR	32538.	0.	7.	1.	5.	0.	5.
LUMBER, SOFTWOOD	4364607.	0.	4.	0.	20.	0.	12.
PHENOLIC RESIN	52838.	0.	7.	0.	5.	0.	1.
PVC PLASTIC	49973.	0.	7.	0.	5.	0.	0.
RUBBER, SBR	103789.	0.	6.	0.	5.	0.	4.
SILICONES	128779.	0.	7.	3.	5.	1.	1.
TEFLON	33545.	0.	7.	7.	5.	0.	1.
NYLON	3207.	0.	7.	0.	5.	0.	1.
COTTON FIBERS	1453.	0.	3.	0.	16.	0.	1.
KRAFT FIBERS	623.	0	3.	0.	10.	0.	15.
URETHANE	273352.	0.	7.	2.	5.	7.	5.
ASPHALT	300699.	0.	3.	0.	5.	0.	5.
NEOPRENE	225622.	0.	3.	5.	5.	1.	1.
ETHYLENE GLYCOL	492995.	0.	7.	0.	5.	1.	9.
POLYETHYLENE	974.	0.	7.	0.	5.	0.	5.
POLYVINYL FLUOR	16663.	0.	7.	5.	5.	1.	5.
EPDM RUBBER	5942.	0.	7.	0.	5.	0.	5.
PAINT THINNER	37335.	0.	3.	1.	5.	0.	5.
SODIUM DICHROMA	16863.	0.	3.	0.	5.	0.	5.
POLYCARBONATE	16663.	0.	7.	0.	5.	0.	5.
POLYPROPYLENE G	230696.	0.	7.	1.	5.	0.	5.
VITREOUS ENAMEL	76543.	0.	7.	1.	10.	0.	0.

RAW MATERIAL SUMMARY REPORT

SHACOB Mixed System Scenario: Introduction Year - 1985
Cummulative Capacity by the Year 2000 - 1000 M. Sq. M.
Composed of 9 SHACOB Designs Each at 111.1 M. Sq. M.

THIS REPORT IS A SUMMARY OF THESE 9 DESIGNS:
25 26 27 28 29 30 31 32 33

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX. % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/OR OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	300.	200.	15.	50.
MATERIALS										
ANTIMONY ORE	41.	5.	0.	1210. *	1129. *	22.	75.	64.	0.	55. *
ASBESTOS	13.	3.	0.	539. *	28.	34.	190.	129.	0.	90. *
BAUXITE	19523.	5.	1.	2259. *	301. *	28.	14.	9.	0.	89. *
BORATE	474.	5.	1.	11.	0.	50.	10.	0.	0.	3.
BUTANE	118.	1.	0.	20.	2.	10.	12.	1.	0.	5.
CHROMITE	37.	3.	0.	3352. *	424. *	27.	17.	4.	0.	66. *
CLAYS	6739.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	62089.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	35208.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COPPER ORE	604190.	6.	2.	1020. *	417. *	17.	86.	25.	2.	37.
FELDSPAR	1254.	3.	3.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	650.	5.	0.	706. *	151.	22.	201.	120.	0.	50. *
GYPSUM	2098.	3.	0.	176.	0.	10.	11.	0.	0.	37.
IRON ORE	224532.	5.	1.	56.	7.	11.	15.	6.	0.	35.
LEAD ORE	1217.	3.	0.	78.	38.	11.	126.	13.	0.	33.
LITHIUM ORE	812.	7. *	1.	53.	19.	1.	49.	17.	0.	1.
MANGANESE ORE	1311.	3.	1.	100.	4.	24.	6.	11.	0.	100. *
MERCURY	2.	1.	0.	385.	573. *	19.	13.	36.	0.	58. *
NATURAL GAS	5247.	5.	0.	245.	277.	30.	93.	9.	0.	5.
NICKEL ORE	337.	3.	0.	4432. *	5318. *	37.	54.	23.	0.	75. *
NITROGEN, FIXED	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
OXYGEN	75.	4.	0.	0.	0.	22.	0.	0.	0.	0.
PETROLEUM	3946.	3.	0.	562. *	210.	22.	110.	36.	0.	40.
SALT	23407.	6.	1.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	150828.	4.	0.	0.	0.	0.	0.	0.	0.	0.
SILVER ORE	10203.	4.	1.	374.	99.	14.	208.	36.	0.	45.
SODIUM NITRATE	2.	4.	0.	0.	0.	5.	0.	0.	0.	10.
STONE	177087.	3.	0.	0.	0.	3.	0.	0.	0.	0.
SULFUR	1022.	3.	0.	94.	1.	15.	90.	0.	0.	28.
TIN ORE	301383.	2.	1.	4405. *	1321. *	29.	73.	20.	0.	65. *
ZINC ORE	16485.	0.	1.	150.	34	19.	155.	8.	0.	68. *
COTTON	1.	2.	0.	0.	[illegible]	14.	0.	0.	0.	1.
FLAX SEED	110.	1.	1.	0.	6.	[illegible]	0.	0.	0.	20.
MILK BYPRODUCTS	2.	3.	0.	0.	0.	3.	0.	0.	0.	1.
LUMBER	4409.	1.	0.	0.	0.	12.	0.	0.	1.	18.
SEA WATER	346020.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SOYBEAN	56.	3.	0.	0.	0.	12.	0.	0.	0.	0.
WATER	195009.	3.	0.	17.	2.	0.	3.	0.	0.	0.
WHEAT	9.	3.	0.	0.	0.	10.	0.	0.	0.	0.
MISC.	1524.	0.	0.	0.	0.	0.	0.	0.	1.	0.
STEAM	143010.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	102986.	3.	4.	0.	0.	5.	0.	0.	0.	2.
COAL BY PROD	419112.	1.	1.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	2210809.	3.	0.	0.	0.	0.	0.	0.	0.	0.
COAL BYPRODUCT 2	161824.	1.	1.	6.	1.	6.	13.	1.	0.	10.
PETROLEUM BYPRO	15336.	3.	0.	563. *	210.	22.	110.	36.	0.	40.

BULK MATERIAL SUMMARY REPORT

AIPH Mixed System Scenario: Introduction Year - 1985
Cummulative Capacity by the Year 2000 - 500 M. Sq. M.
Composed of 3 AIPH Designs Each at 166.7 M. Sq. M.

THIS REPORT IS A SUMMARY OF THESE 3 DESIGNS:
40 41 42

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY PRODUCT		WORLD PRODN GROWTH RATE 1976-2000	SOURCES % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY		COST PER UNIT OUTPUT		NET PERCENT IMPORTED	
THRESHOLD LEVELS	---	50.		10. %/YR	10.	35.		15.		50.	
MATERIALS											
ALUMINUM	2926719.	0.		7.	1.	13.		6.		14.	
ASBESTOS	64441.	0.		3.	0.	40.	*	0.		90.	*
CADMIUM	913.	100.	*	4.	0.	15.		0.		57.	*
CEMENT	17224718.	0.		3.	0.	10.		4.		4.	
CHROMIUM	74517.	0.		3.	0.	31.		0.		100.	*
COPPER	715867.	1.		6.	0.	12.		2.		45.	
GLASS, FIBER	690820.	0.		7.	3.	5.		1.		2.	
GLASS, SODA LIM	3856046.	0.		3.	3.	5.		2.		5.	
IRON , STEEL	34375320.	1.		3.	0.	16.		24.	*	10.	
LEAD	1625.	13.		5.	0.	11.		0.		10.	
MAGNESIUM	108.	30.		6.	0.	26.		0.		0.	
FERROMANGANESE	208079.	100.	*	2.	0.	9.		0.		99.	*
MERCURY	4.	2.		3.	0.	19.		0.		58.	*
MOLYBDENUM	214.	42.		5.	0.	16.		0.		4.	
NICKEL	40320.	7.		3.	0.	28.		0.		75.	*
PORCELAIN	83.	0.		0.	0.	10.		0.		0.	
SAND ! GRAVEL	46754236.	0.		4.	0.	10.		0.		0.	
STONE	69350264.	0.		3.	0.	3.		1.		0.	
SILICON	7335.	0.		3.	0.	14.		0.		8.	
SILVER	507.	70.	*	4.	0.	14.		0.		46.	
SULFUR	74.	31.		3.	0.	15.		0.		15.	
TIN	3026.	25.		2.	0.	29.		0.		65.	*
WATER	31952642.	0.		3.	0.	0.		0.		0.	
ZINC	318428.	25.		3.	0.	21.		0.		88.	*
STAINLESS STEEL	38282.	0.		3.	0.	10.		0.		15.	
ACRYLIC	28221.	0.		7.	0.	5.		0.		1.	
EPOXY RESIN	84449.	0.		7.	1.	5.		0.		5.	
[illegible]	488.	0.		7.	0.	5.		0.		5.	
[illegible]	[illegible]	[illegible]		4.	0.	20.		1.		[illegible]	
PHENOLIC RESIN	268352.	0.		7.	1.	5.		1.		1.	
POLYESTER RESIN	167167.	0.		7.	1.	5.		1.		0.	
PVC PLASTIC	118535.	0.		7.	0.	5.		0.		0.	
TEFLON	3774.	0.		7.	1.	5.		0.		1.	
COTTON FIBERS	185689.	0.		3.	0.	16.		0.		1.	
KRAFT FIBERS	101074.	0.		3.	0.	10.		0.		15.	
URETHANE	222776.	0.		7.	2.	5.		5.		5.	
NEOPRENE	59924.	0.		3.	1.	5.		0.		1.	
PITCH	234603.	0.		7.	1.	5.		0.		5.	
POLYVINYL FLUOR	6404.	0.		7.	2.	5.		1.		5.	
EPDM RUBBER	79088.	0.		7.	1.	5.		0.		5.	

RAW MATERIAL SUMMARY REPORT

AIPH Mixed System Scenario: Introduction Year - 1985
Cummulative Capacity by the Year 2000 - 500 M. Sq. M.
Composed of 3 AIPH Designs Each at 166.7 M. Sq. M.

THIS REPORT IS A SUMMARY OF THESE 3 DESIGNS:
40 41 42

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/OR OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	---	7. %/YR	10.	400.	300.	60.	300.	200.	15.	50.
MATERIALS										
ASBESTOS	66.	3.	0.	539. *	28.	34.	190.	129.	0.	90. *
BAUXITE	15241.	5.	1.	2249. *	300. *	28.	14.	9.	0.	89. *
BORATE	223.	5.	0.	11.	0.	50.	10.	0.	0.	3.
CHROMITE	248.	3.	1.	3373. *	427. *	27.	17.	4.	0.	66. *
CLAYS	2868.	2.	0.	0.	0.	10.	8.	0.	0.	0.
COAL	48700.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	89248.	1.	0.	6.	1.	6.	13.	1.	3.	10.
COPPER ORE	157491.	6.	0.	992. *	435. *	12.	85.	24.	1.	37.
FELDSPAR	359.	3.	1.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	494.	5.	0.	705. *	151.	22.	201.	130.	0.	50. *
GYPSUM	827.	3.	0.	175.	0.	10.	11.	0.	0.	37.
IRON ORE	196101.	5.	1.	56.	7.	11.	15.	6.	1.	35.
LEAD ORE	54.	3.	0.	77.	38.	11.	126.	13.	0.	33.
LIME	0.	3.	0.	0.	0.	31.	0.	0.	0.	2.
MANGANESE ORE	1147.	3.	0.	100.	4.	24.	6.	11.	0.	100. *
MERCURY	0.	1.	0.	384.	572. *	19.	13.	36.	0.	58. *
MOLYBDENUM ORE	160.	5.	0.	44.	8.	16.	43.	13.	2.	4.
NATURAL GAS	2281.	5.	0.	245.	277.	30.	93.	9.	0.	5.
NICKEL ORE	4338.	3.	0.	4454. *	5345. *	37.	54.	23.	0.	75. *
NITROGEN, FIXED	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
OXYGEN	47.	4.	0.	0.	0.	22.	0.	0.	0.	0.
PETROLEUM	2211.	3.	0.	562. *	210.	22.	110.	36.	0.	40.
PROPANE	66.	1.	0.	191.	23.	10.	136.	11.	0.	5.
SALT	16137.	6.	0.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	58069.	4.	0.	0.	0.	0.	0.	0.	0.	0.
SILVER ORE	3612.	4.	0.	372.	99.	14.	208.	56.	0.	45.
STONE	69350.	3.	0.	0.	0.	3.	0.	0.	1.	0.
SULFUR	784.	3.	0.	94.	1.	15.	90.	0.	0.	28.
TIN ORE	30256.	2.	0.	4340. *	1302. *	29.	73.	20.	0.	65. *
ZINC ORE	5853.	0.	0.	147.	34.	19.	154.	8.	0.	88. *
COTTON	185.	2.	0.	0.	0.	16.	0.	0.	0.	1.
MILK BYPRODUCTS	9.	3.	0.	0.	0.	20.	0.	0.	0.	1.
LUMBER	12900.	1.	0.	0.	0.	12.	0.	0.	4.	18.
SEA WATER	79.	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATER	313480.	3.	0.	17.	2.	0.	3.	0.	0.	0.
WHEAT	0.	3.	0.	0.	0.	10.	0.	0.	0.	0.
MISC.	678.	0.	0.	0.	0.	0.	0.	0.	1.	0.
STEAM	118489.	5.	0.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	55021.	3.	2.	0.	0.	5.	0.	0.	0.	2.
COAL, BY PROD	519677.	1.	2.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	1578624.	3.	0.	0.	0.	0.	0.	0.	0.	0.
COAL BYPRODUCT 2	131883.	1.	0.	6.	1.	6.	13.	1.	0.	10.

BULK MATERIAL SUMMARY REPORT

AIPH Mixed System Scenario: Introduction Year - 1985
Cummulative Capacity by the Year 2000 - 1000 M. Sq. M.
Composed of 3 AIPH Designs Each at 333.3 M. Sq. M.

THIS REPORT IS A SUMMARY OF THESE 3 DESIGNS:
40 41 42

FACTORS	MATERIAL USAGE MT.	PERCENT SUPPLIED AS BY.PRODUCT	WORLD PRODN GROWTH RATE 1976-2000	SOURCES % OF WORLD CONSUMPTION	% FROM LARGEST COUNTRY	COST PER UNIT OUTPUT	NET PERCENT IMPORTED
THRESHOLD LEVELS	----	50.	10. %/YR	10.	35.	15.	50.
MATERIALS							
ALUMINUM	5853437.	0.	7.	1.	13.	6.	14.
ASBESTOS	128882.	0.	3.	0.	40. *	0.	90. *
CADMIUM	1826.	100. *	4.	1.	15.	0.	57. *
CEMENT	34449136.	0.	3.	0.	10.	4.	4.
CHROMIUM	140003.	0.	3.	0.	31.	0.	100. *
COPPER	1431735.	1.	6.	1.	12.	2.	45.
GLASS, FIBER	1781640.	0.	7.	6.	5.	1.	2.
GLASS, SODA LIM	7712092.	0.	3.	6.	5.	2.	5.
IRON , STEEL	60750056.	1.	3.	1.	16.	24. *	10.
LEAD	3200.	13.	5.	0.	11.	0.	10.
MAGNESIUM	215.	30.	6.	0.	26.	0.	0.
FERROMANGANESE	416158.	100. *	2.	0.	9.	0	99. *
MERCURY	9.	2.	3.	0.	19.	0.	58. *
MOLYBDENUM	420.	42.	5.	0.	16.	0.	4.
NICKEL	80039.	7.	4.	1.	28.	0.	75. *
PORCELAIN	167.	0.	0.	0.	10.	0.	0.
SAND ! GRAVEL	93508472.	0.	4.	0.	10.	0.	0.
STONE	138700528.	0.	3.	0.	3.	1.	0.
SILICON	14671.	0.	3.	0.	14.	0.	8.
SILVER	1014.	70. *	4.	1.	14.	0.	46.
SULFUR	147.	31.	3.	0.	15.	0.	15.
TIN	6051.	25.	2.	0.	29.	0.	65. *
WATER	63905284.	0.	3.	0.	0.	0.	0.
ZINC	636857.	25.	3.	1.	21.	0.	88. *
STAINLESS STEEL	76564.	0.	3.	0.	10.	0.	15.
ACRYLIC	56443.	0.	7.	0.	5.	0.	1.
EPOXY RESIN	168897.	0.	7.	2.	5.	0.	5.
GLUE, PHENOL, FOR	977.	0.	7.	0.	5.	0.	5.
LUMBER, SOFTWOOD	25386004.	0.	4.	0.	20.	1.	12.
PHENOLIC RESIN	536705.	0.	7.	2.	5.	1.	1.
POLYESTER RESIN	334334.	0.	7.	1.	5.	1.	0.
PVC PLASTIC	237069.	0.	7.	0.	5.	0.	0.
TEFLON	7547.	0.	7.	2.	5.	0.	1.
COTTON FIBERS	371377.	0.	3.	1.	16.	0.	1.
KRAFT FIBERS	282147.	0.	3.	0.	10.	0.	15.
URETHANE	445551.	0.	7.	4.	5.	5.	5.
NEOPRENE	118049.	0.	3.	3.	5.	0.	1.
PITCH	469287.	0.	7.	2.	5.	0.	5.
POLYVINYL FLUOR	12809.	0.	7.	4.	5.	1.	5.
EPDM RUBBER	159775.	0.	7.	2.	5.	0.	5.

RAW MATERIAL SUMMARY REPORT

AIPH Mixed System Scenario: Introduction Year - 1985
Cummulative Capacity by the Year 2000 - 1000 M. Sq. M.
Composed of 3 AIPH Designs Each at 333.3 M. Sq. M.

THIS REPORT IS A SUMMARY OF THESE 3 DESIGNS:
40 41 42

FACTORS	RAW MATERIAL USAGE (1000MT)	WORLD PRODUCTN GROWTH RATE	MAX. % FOR SOLAR IN ONE YEAR WORLD	% U.S. RESERVES CONSUMED BY 2000	% U.S. RESOURCES CONSUMED BY 2000	% FROM LARGEST COUNTRY NON-US	% WORLD RESERVES CONSUMED BY 2000	% WORLD RESOURCES CONSUMED BY 2000	PRESENT COSTS IN $/OR OF SOLAR	NET PERCENT IMPORTED
THRESHOLD LEVELS	- -	7. %/YR	10.	400.	300.	60.	300.	200.	15.	50.
MATERIALS										
ASBESTOS	131.	3.	0.	539. *	28.	34.	190.	129.	0.	90. *
BAUXITE	30482.	5.	2.	2287. *	305. *	28.	14.	9.	0.	89. *
BORATE	445.	5.	1.	11.	0.	50.	10.	0.	0.	3.
CHROMITE	496.	3.	1.	3396. *	430. *	27.	17.	4.	0.	66. *
CLAYS	5736.	2.	0.	0.	0.	10.	0.	0.	0.	0.
COAL	97400.	1.	0.	6.	1.	6.	13.	1.	1.	10.
COAL BITUM/LIGNT	178496.	1.	1.	6.	1.	6.	13.	1.	3.	10.
COPPER ORE	314982.	6.	1.	1000. *	438. *	12.	85.	25.	1.	37.
FELDSPAR	717.	3.	1.	5.	0.	10.	13.	0.	0.	5.
FLUORSPAR	900.	5.	0.	780. *	152.	22.	201.	220.	0.	50. *
GYPSUM	1654.	3.	0.	175.	0.	10.	11.	0.	0.	37.
IRON ORE	392203.	5.	1.	57.	8.	11.	15.	6.	1.	35.
LEAD ORE	108.	3.	0.	77.	38.	11.	126.	13.	0.	33.
LIME	0.	3.	0.	0.	0.	31.	0.	0.	0.	2.
MANGANESE ORE	2293.	3.	1.	100.	4.	24.	6.	11.	0.	100. *
MERCURY	0.	1.	0.	384.	573. *	19.	13.	36.	0.	58. *
MOLYBDENUM ORE	321.	5.	0.	44.	8.	16.	43.	13.	2.	4.
NATURAL GAS	4563.	5.	0.	245.	277.	30.	93.	9.	0.	5.
NICKEL ORE	8676.	3.	1.	4478. *	5374. *	37.	54.	23.	0.	75. *
NITROGEN, FIXED	0.	4.	0.	0.	0.	5.	0.	0.	0.	10.
OXYGEN	94.	4.	0.	0.	0.	22.	0.	0.	0.	0.
PETROLEUM	4421.	3.	0.	563. *	210.	22.	110.	36.	0.	40.
PROPANE	131.	1.	0.	191.	23.	10.	136.	11.	0.	5.
SALT	32274.	6.	1.	0.	0.	5.	0.	0.	1.	9.
SAND/GRAVEL	101738.	4.	0.	0.	0.	0.	0.	0.	0.	0.
SILVER ORE	7223.	4.	0.	373.	99.	14.	208.	56.	0.	45.
STONE	138701.	3.	0.	0.	0.	3.	0.	0.	1.	0.
SULFUR	1569.	3.	0.	94.	1.	15.	90.	0.	0.	28.
TIN ORE	60513.	2.	0.	4347. *	1304. *	29.	73.	20.	0.	65. *
ZINC ORE	11706.	0.	1.	149.	34.	19.	155.	8.	0.	88. *
COTTON	371.	2.	0.	0.	0.	16.	0.	0.	0.	1.
MILK BYPRODUCTS	18.	3.	0.	0.	0.	20.	0.	0.	0.	1.
LUMBER	25801.	1.	0.	0.	0.	12.	0.	0.	4.	18.
SEA WATER	159.	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATER	626960.	3.	0.	17.	2.	0.	3.	0.	0.	0.
WHEAT	0.	3.	0.	0.	0.	10.	0.	0.	0.	0.
MISC.	1356.	0.	0.	0.	0.	0.	0.	0.	1.	0.
STEAM	236978.	5.	1.	1.	0.	10.	0.	0.	0.	0.
LIMESTONE	110041.	3.	4.	0.	0.	5.	0.	0.	0.	2.
COAL BY PROD	10[illegible]154.	1.	3.	6.	1.	6.	13.	1.	0.	10.
ELECTRICITY	31[illegible]247.	3.	0.	0.	0.	0.	0.	0.	0.	0.
COAL BYPRODUCT 2	26[illegible]766.	1.	1.	6.	1.	6.	13.	1.	0.	10.

APPENDIX B

SOLAR SYSTEMS DESIGN CHARACTERIZATION AND MATERIAL REQUIREMENTS*

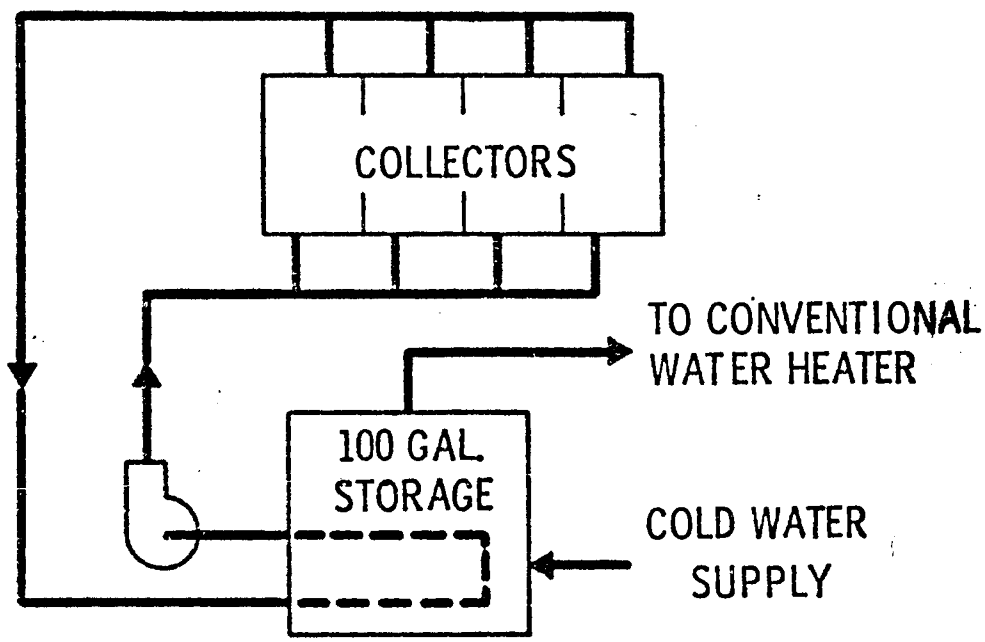
by

T. B. Correy
W. E. Gurwell
E. I. Husa
J. O. Vining

*Material Requirements are in kilograms

SHACOB and AIPH System Identifications

Design Number	Short Title	Full Title
SHACOB		
25	SUNWORKS RES HW	DOMESTIC HOT WATER-SUNWORKS COLLECTOR
26	SOLARON-RES HT	SPACE HEATING - SOLARON SYSTEM
27	SOLARON-RES HT + HW	SPACE HEATING AND DOMESTIC HOT WATER - SOLARON
28	AMER HELIOTHERMAL H + HW	SPACE HEATING AND DOMESTIC HOT WATER - AMERICAN HELIOTHERMAL
29	KTA AND ECOSOL HEAT PUMP SY	SPACE HEATING AND DOMESTIC HOT WATER - KTA AND ECOSOL HEAT PUMP SYSTEM
30	RAYPAK - HT + COOL + HW	SPACE HEATING AND COOLING AND DOMESTIC HOT WATER - RAYPAK COLLECTOR
31	TROMBE WALL CONCRETE	PASSIVE SPACE HEATING - CONCRETE TROMBE WALL
32	TROMBE WALL WATER	PASSIVE SPACE HEATING - WATER-TANK TROMBE WALL
33	DIRECT GAIN MASONRY WALL	PASSIVE SPACE HEATING - DIRECT GAIN, MASONRY WALLS
AIPH		
40	LLL SOLAR POND	PROCESS HOT WATER, URANIUM MILLING - LLL SOLAR POND
41	CHAMBERLAIN - LUMBER KILN	PROCESS HEAT, LUMBER KILN - CHAMBERLAIN COLLECTORS
42	HONEYWELL CONCENTRATING	PROCESS STEAM, TEXTILE DRYING - HONEYWELL CONCENTRATING COLLECTORS



DOMESTIC HOT WATER
SUNWORKS COLLECTORS
AT
MANHATTAN, KANSAS

THIS SYSTEM PROVIDES ABOUT 85 PERCENT OF THE DOMESTIC HOT WATER NEEDS FOR A TYPICAL FAMILY OF FOUR IN A MODERATE CLIMATE. THE 74 SQUARE FEET OF SUNWORKS COLLECTORS SUPPLY HEAT TO A 100 GALLON STORAGE TANK WHICH IN TURN SUPPLIES HOT WATER DIRECTLY TO THE HOME OR IF NECESSARY TO A CONVENTIONAL WATER HEATER.

TECHNOLOGY	SHACOB
CAPACITY	18 MJ/HOUR
APPLICATION	DOMESTIC HOT WATER
LOCATION	MANHATTAN, KANSAS
INSOLATION	6.5 GJ/SQUARE FEET-YEAR
SOLAR CONTRIBUTION	14 GJ/YEAR
SUPPLEMENT	VARIABLE
SOLAR EFFICIENCY	
COLLECTOR AREA	7.14 M*M
OPERATING TEMPERATURE	5 TO 99 DEGREES C
ENERGY TRANSPORT MEDIUM	GLYCOL AND WATER
STORAGE TYPE	WATER
STORAGE CAPACITY	300 KG

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

12.	ENERGY COLLECTOR - SUNWORKS SOLECTORS NO. 10-1711		
	12.01 MISCELLANEOUS NUTS, BOLTS, RIVETS	CARBON STEEL	2.3
	12.02 GLAZING	SODA LIME GLASS	1.4
	12.03 ABSORBER	COPPER	15.6
	12.04 ENERGY TRANSPORT	COPPER	30.8
	12.05 INSULATION	GLASS WOOL	11.0
	12.07 FRAME	ALUMINUM	65.3
	12.08 SEALS	NEOPRENE	4.5
		SILICONE	0.4
13.	ENERGY TRANSPORT		
	13.01 MISCELLANEOUS	CARBON STEEL	0.5
		50-50 SOLDER	0.5
		ANTIMONY TIN SOLDER	0.5
	13.02 PIPE AND FITTINGS	COPPER	16.3
		BRASS	0.5
		STAINLESS STEEL	0.5
	13.03 INSULATION	POLYURETHANE	9.1
	13.04 TRANSPORT FLUID	ETHYLENE GLYCOL	10.9
		WATER	7.3
	13.05 SUPPORTS	SOFTWOOD	54.4
	NAILS-	CARBON STEEL	1.4
	13.06 SEALANTS	TEFLON	0.03
	13.07 VALVES	COPPER	6.6
	13.08 PUMPS	CAST IRON	6.4
		CARBON STEEL	3.6
		RUBBER	0.9
14.	ENERGY CONVERSION		
	14.02 HEAT EXCHANGER	COPPER	3.9
		NICKEL	0.1
		CHROMIUM	0.1

15. ENERGY STORAGE

15.03 STORAGE TANK

CARBON STEEL	57.9
CONCRETE	74.4
GLASS WOOL	4.4
WATER	300.0

17. ENERGY SYSTEM CONTROLLER

17.02 METERS, SWITCHES, TERMINAL BOARDS

COPPER	1.1
60-40 SOLDER	0.23
PHENOLIC	2.3

FOOTNOTES

12.07 - Estimated 0.7 #/ft for aluminum exterior frame and cap.

12.08 - Assumed 2.25 #/collector for neoprene. Estimated use of silicone sealant.

13.01 - Estimated weight of teflon tape, pipe anchors and solder.

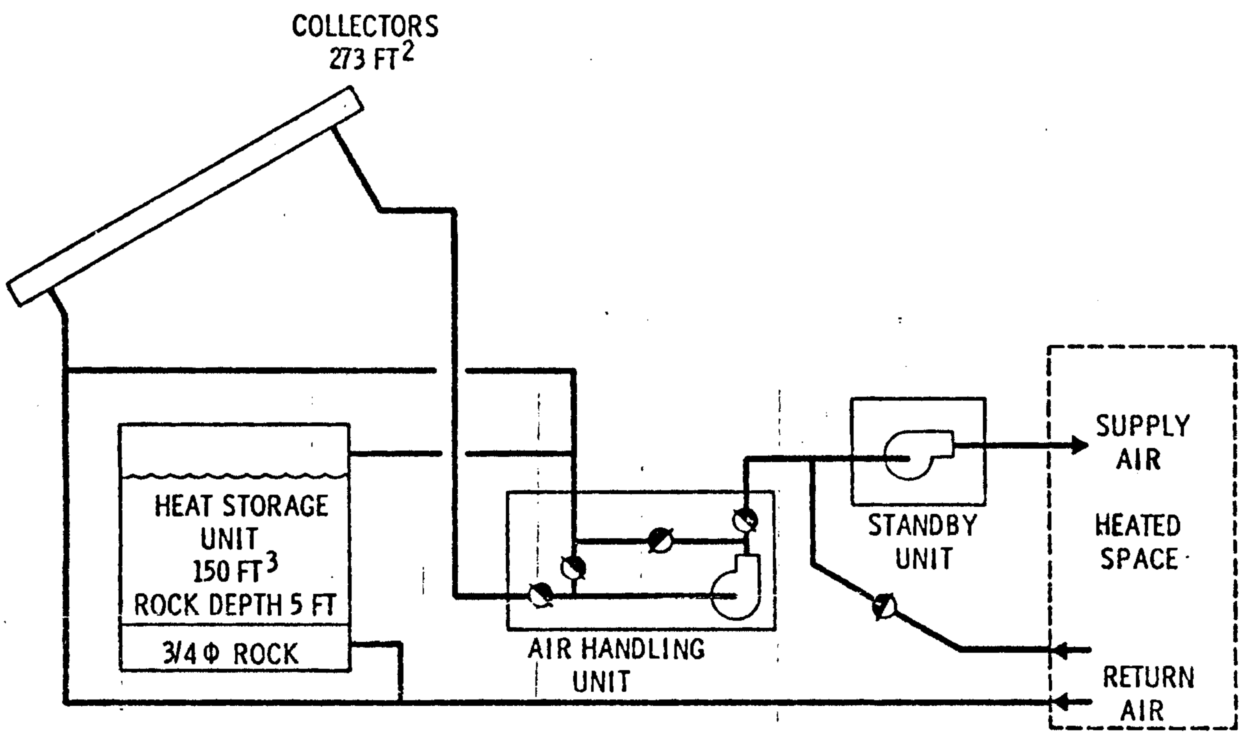
13.02 - 1/2 inch ID copper pipe 100 feet.
1 to 1/2 inch ID cu pipe adapters (8).
1/2 inch ID cu T's (12).
1/2 inch ID cu Els (12).
1/2 inch ID cu cross El (1).
1/2 inch brass unions (6).
Estimated weights of air vents, pressure gages and thermometers.

13.05 - Used 2 x 4's for base shoe top and bottom with sufficient bracing to obtain the desired tilt angle on the collectors.

13.06 - Assumed use of 1 roll of Teflon tape for pipe joints.

13.07 - Assumed all valves are 1/2 inch brass with estimated weights.

13.08 - Expansion Tanks (2 required) 14 ID x 16 long x 16 gage galvanized steel. Assumed weight.



SPACE HEATING
SOLARON SYSTEM
AT
WASHINGTON, D. C.

THIS SYSTEM PROVIDES SOLAR ASSISTED SPACE HEATING WITH ROCK BED HEAT STORAGE. THE 273 SQUARE FOOT COLLECTORS ARE SOLARON SERIES 2000, AIR TYPE, COLLECTORS. THE AIR HANDLING UNIT CONTAINS ALL OF THE AIR MOVING AND TEMPERATURE CONTROL HARDWARE

TECHNOLOGY	SHACOB
CAPACITY	48 MJ/HR.
APPLICATION	SPACE HEATING
LOCATION	WASHINGTON, D. C.
INSOLATION	5.5 GJ/M*M-YEAR
SOLAR CONTRIBUTION	27 GJ/YEAR
SUPPLEMENT	VARIABLE
SOLAR EFFICIENCY	
COLLECTOR AREA	25.4 M*M
OPERATING TEMPERATURE	
ENERGY TRANSPORT MEDIUM	AIR
STORAGE TYPE	ROCK
STORAGE CAPACITY	.6 2 MT

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

12.	ENERGY COLLECTOR - SOLARON SERIES 2000			
	12.01 MISCELANEOUS		SOFT WOOD	49.4
			CARBON STEEL	73.5
	12.02 GLAZING		SODA LIME GLASS	537.0
	12.03 ABSORBER		CARBON STEEL	70.8
			VITREOUS ENAMEL	8.7
	12.04 DUCT		CARBON STEEL	78.5
	12.05 INSULATION		GLASS WOOL	41.0
	12.07 FRAME		CARBON STEEL	186.0
	12.08 SEALS		BUTYL RUBBER	6.4
			SILICONE	6.4
13.	ENERGY TRANSPORT			
	13.02 DUCT		CARBON STEEL	441.0
			ZINC	71.0
	13.03 INSULATION		GLASS WOOL	40.0
	13.08 FANS		COPPER	5.0
			CARBON STEEL	5.0
			BRASS	0.5
			POLYCARBONATE	0.9
15.	ENERGY STORAGE			
	15.02 ROCK BED		PLYWOOD	186.0
			SOFTWOOD	115.0
			GLASS WOOL	35.0
		NAILS	CARBON STEEL	2.3
		ROCKS	SAND AND GRAVEL	6200.0
17.	ENERGY SYSTEM CONTROL			
	17.02 SWITCHES, METERS ETC.		COPPER	0.5
			POLYCARBONATE	0.5
			PHENOLIC	0.5

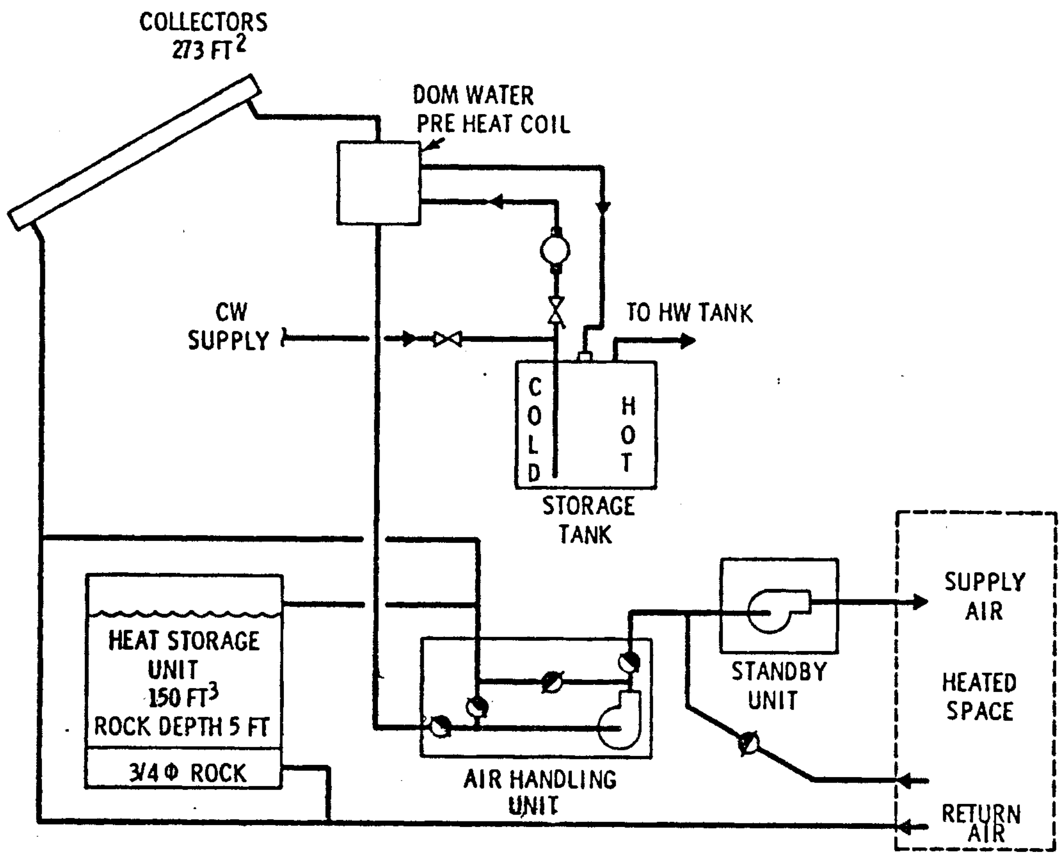
FOOTNOTES

12.01 - Wood nailer frame-assume 1-1/2 x 7 1/8 inches x 68 feet of lumber.

13.02 - Assumed 0.16 pound zinc per ft^2 of sheet metal. Sheet metal is 24 gage. Seventy-nine linear feet of 12 x 14 inch duct 13 linear feet 12 inch diameter duct. Eighteen linear feet of 14 inch diameter duct and 8 linear feet of 12 x 20 inch duct.

15.02 - Built from 2 x 4 studs with a 5/8 inch plywood inner wall and a 1/4 inch outer wall. To form the base, 2 x 6's are used. A steel screen holds rocks from falling into base.

17.02 - Assumed 3 pounds of controls in steel, copper, plastic phenolic, assorted things. Not defined now.



SPACE HEATING AND DOMESTIC HOT WATER
SOLARON
AT
WASHINGTON, D. C.

THE 273 SQUARE FOOT OF SOLARON SERIES 2000, AIR TYPE COLLECTORS, PROVIDES SOLAR ASSISTED SPACE HEATING AND DOMESTIC WATER PREHEAT. HEAT STORAGE IS IN THE ROCK BED, AND IN THE WATER STORAGE TANK. THE AIR HANDLING UNIT CONTAINS ALL OF THE AIR MOVING AND TEMPERATURE CONTROL HARDWARE.

TECHNOLOGY	SHACOB
CAPACITY	48 MJ/HOUR
APPLICATION	SPACE HEATING AND HOT WATER
LOCATION	WASHINGTON, D. C.
INSOLATION	5.5 GJ/M*M-YEAR
SOLAR CONTRIBUTION	39 GJ/YEAR
SUPPLEMENT	VARIABLE
SOLAR EFFICIENCY	
COLLECTOR AREA	25.4 M*M
OPERATING TEMPERATURE	
ENERGY TRANSPORT MEDIUM	AIR
STORAGE TYPE	ROCK AND WATER
STORAGE CAPACITY	6.2 MT ROCK

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

12.	ENERGY COLLECTOR - SOLARON SERIES 2000		
	12.01 MISCELLANEOUS	SOFTWOOD	49.4
		CARBON STEEL	73.5
	12.02 GLAZING	SODA LIME GLASS	537.0
	12.03 ABSORBER	CARBON STEEL	70.8
		VITREOUS ENAMEL	8.7
	12.04 DUCT	CARBON STEEL	78.5
	12.05 INSULATION	GLASS WOOL	41.0
	12.07 FRAME	CARBON STEEL	186.0
	12.08 SEALS	RUBBER	6.4
		SILICONE	6.4
13.	ENERGY TRANSPORT		
	13.02 DUCT	CARBON STEEL	441.0
		ZINC	71.0
	13.03 INSULATION	GLASS WOOL	40.0
	13.08 FANS	COPPER	5.0
		CARBON STEEL	5.0
		BRASS	0.5
		POLYCARBONATE	0.9
14.	ENERGY CONVERSION		
	14.01 MISCELLANEOUS	50-50 SOLDER	0.9
		GLASS WOOL	0.5
	14.02 HEAT EXCHANGER	COPPER	1.5
		ALUMINUM	1.0
		50-50 SOLDER	0.5
	14.03 PIPING	COPPER	17.7
	14.04 PUMPS	STAINLESS STEEL	0.9
		ALUMINUM	0.9
		RUBBER	0.4
		COPPER	1.4
		CARBON STEEL	0.9

15.	ENERGY STORAGE		
	15.02 ROCKBED	PLYWOOD	186.0
		SOFTWOOD	115.0
		CARBON STEEL	2.3
		GLASS WOOL	35.0
		SAND AND GRAVEL	6200.0
	15.03 HOT WATER STORAGE	CARBON STEEL	68.0
		GLASS WOOL	3.5
17.	ENERGY SYSTEM CONTROL		
	17.02 METERS ETC.	COPPER	3.0
		POLYCARBONATE	1.0
		PHENOLIC	0.5

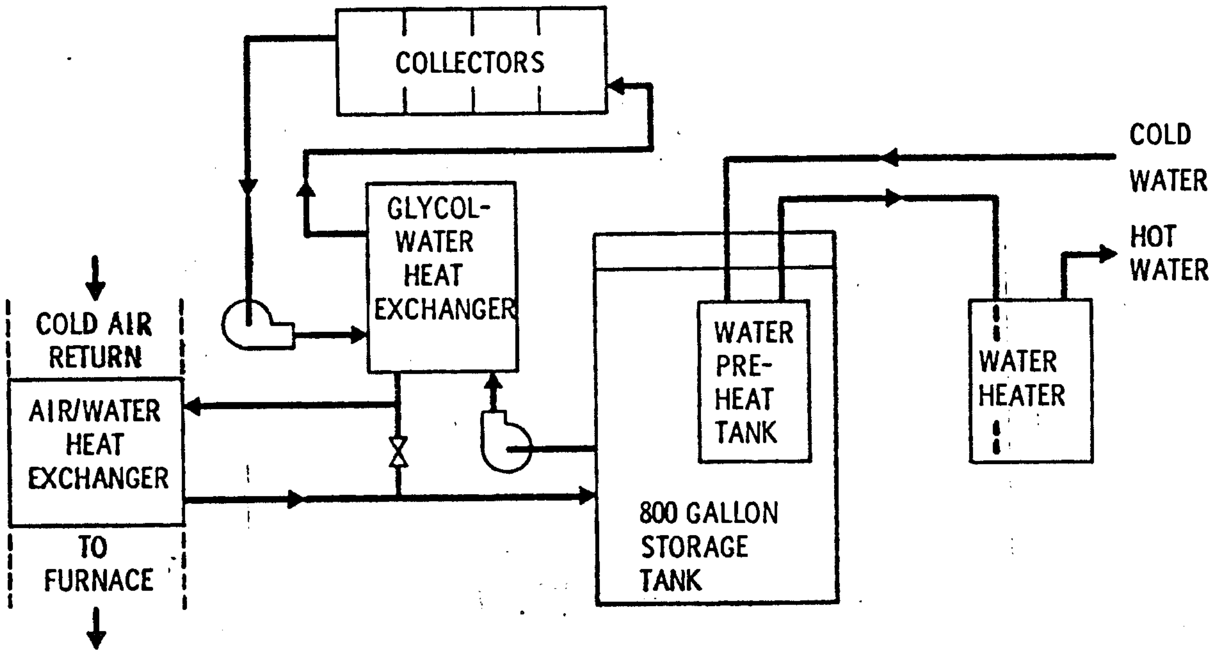
FOOTNOTES

12.01 - Wood nailer frames-assume 1-1/2 x 7-1/8 inches x 68 feet of lumber.

13.02 - Assumed 0.16 pound zinc per ft^2 of sheet metal. Sheet metal is 24 gage. Seventy-nine linear feet of 12 x 14 inch duct 13 linear feet of 12 inch diameter duct. Eighteen linear feet of 14 inch diameter duct and 8 linear feet of 12 x 20 inch duct.

15.02 - Built from 2 x 4 studs with a 5/8 inch plywood inner wall and a 1/4 inch outer wall. To form the base, 2 x 6's are used. A steel screen holds rocks from falling into the base.

17.02 - Assumed 9-1/2 pounds of controls in steel, copper, plastic phenolic, assorted things. Not defined now.



SPACE HEATING AND DOMESTIC HOT WATER
AMERICAN HELIOTHERMAL
AT
WASHINGTON, D. C.

THIS SYSTEM USES 268 SQUARE FEET OF MIROMIT FLAT PLATE COLLECTORS IN A SEPARATE FREEZE PROTECTED, GLYCOL LOOP. THE GLYCOL-WATER HEAT EXCHANGER TRANSFERS COLLECTED ENERGY TO THE WATER LOOPS WHICH PERFORM THE FUNCTIONS OF ENERGY STORAGE, SPACE HEATING, AND DOMESTIC WATER PREHEATING.

TECHNOLOGY	SHACOB
CAPACITY	65 MJ/HOUR
APPLICATION	HOT WATER AND SPACE HEATING
LOCATION	WASHINGTON, D. C.
INSOLATION	5.5 GJ/M*M-YEAR
SOLAR CONTRIBUTION	41 GJ/YEAR
SUPPLEMENT	VARIABLE
SOLAR EFFICIENCY	
COLLECTOR AREA	24.9 M*M
OPERATING TEMPERATURE	
ENERGY TRANSPORT MEDIUM	GLYCOL AND WATER MIXTURE
STORAGE TYPE	WATER
STORAGE CAPACITY	3 MT

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

12.	ENERGY COLLECTOR - MIROMIT MODEL NO. 110		
	12.01 MISCELLANEOUS	CARBON STEEL	12.2
	12.02 GLAZING	SODA LIME GLASS	286.7
	12.03 ABSORBER	CARBON STEEL	413.0
	12.04 PIPING	CARBON STEEL	292.0
	12.05 INSULATION	GLASS WOOL	38.0
	12.07 FRAME	CARBON STEEL	156.0
		ZINC	7.7
	12.08 SEALS	NEOPRENE	14.5
13.	ENERGY TRANSPORT		
	13.01 MISCELLANEOUS	TEFLON	1.0
	13.02 PIPE	CARBON STEEL	139.0
		ZINC	12.2
	13.03 INSULATION	GLASS. WOOL	5.9
	13.04 TRANSFER FLUID	PROPYLENE GLYCOL	51.7
		WATER	34.5
	13.05 SUPPORTS	SOFTWOOD	20.9
		CARBON STEEL	2.3
	13.07 VALVES	BRASS	0.9
		CARBON STEEL	0.5
		NYLON	0.2
	13.08 PUMPS	ALUMINUM	1.0
		COPPER	1.4
		CARBON STEEL	7.3
14.	ENERGY CONVERSION		
	14.02 HEAT EXCHANGERS	COPPER	15.9
		CARBON STEEL	63.0
		ZINC	2.3
		ALUMINUM	45.0

15. ENERGY STORAGE

15.02 STORAGE TANK

	CARBON STEEL	584.0
	ZINC	11.4
	VITREOUS ENAMEL	0.1
	WATER	2917.0
	GLASS WOOL	32.0

17. ENERGY SYSTEM CONTROLLER

	COPPER	1.2
	CARBON STEEL	1.4
	POLYCARBONATE	0.5
	ALUMINUM	2.5

AMERICAN HELIOTHERMAL

FOOTNOTES

12.01 - Assumed steel screws and bolts, ignored platings.

12.07 - Used dimensions of the topless box to calculateweight.

13.02 - Base the zinc weight upon difference in weight for black & galvanized pipe.

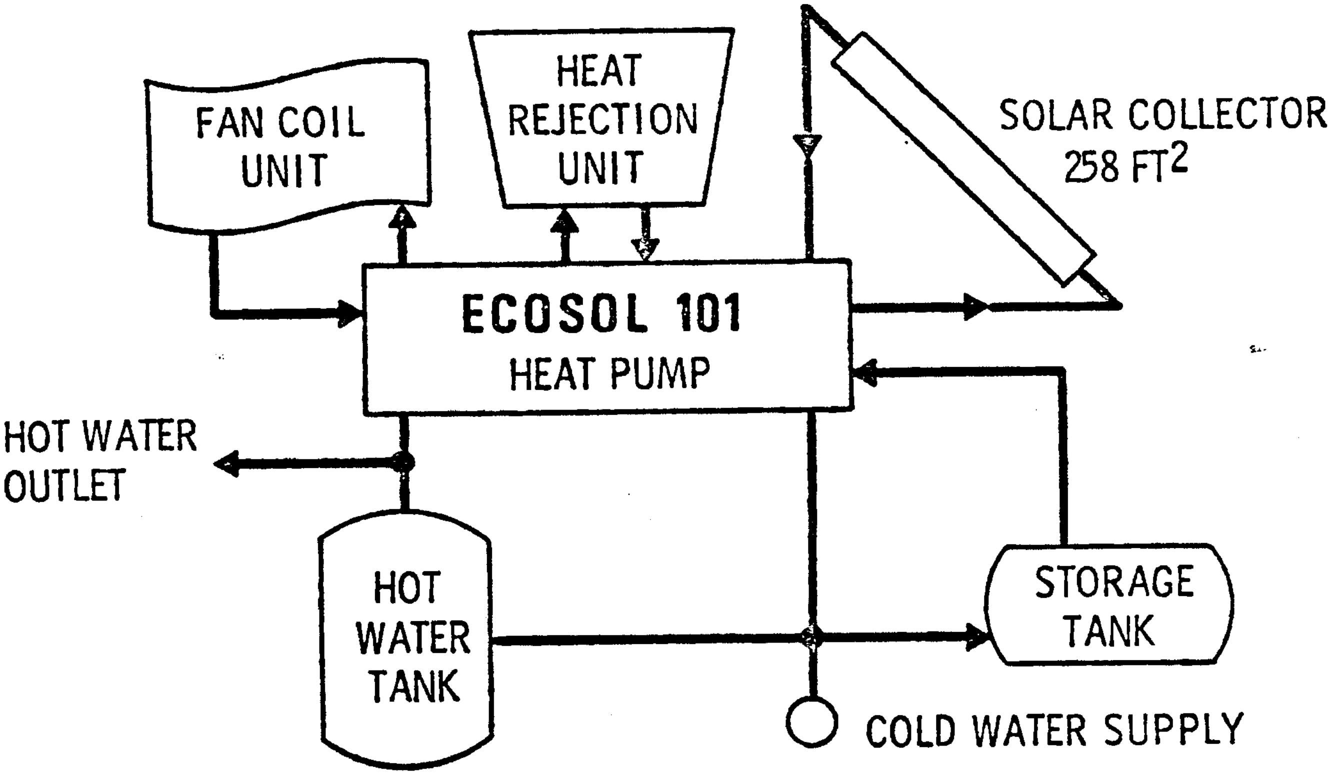
13.04 - Assumed a minimum wood frame to assemble and contain heat exchange and pumping equipment.

13.08 - Weight is given from Sunstrand "L" model pump.

14.02 - The glycol/water heat exchanger is copper tube (coiled) inside steel tube counterflow type. Seventy-two inches of steel 5" diameter tube around 72 feet of 5/8 copper tube. The water/air heat exchanger is half iron and aluminum.

15.01 - For the 800 gallon storage tank use 4' diameter, 8' tall with .250" steel wall.

15.02 - Assumed 6" insulation around the 800 gallon tank.



SPACE HEATING AND DOMESTIC HOT WATER
KTA AND ECOSOL
HEAT PUMP SYSTEM
AT
WASHINGTON, D. C.

THE SOLAR ASSISTED HEAT PUMP SYSTEM SHOWN IN THE SCHEMATICS IS A COMMON MARRIAGE BETWEEN KTA COLLECTORS AND AN ECOSOL PACKAGE WHICH INCLUDES ALL CONTROLS AND HEAT EXCHANGERS AS WELL AS A HEAT PUMP. HEAT STORAGE IS INCLUDED IN THE SYSTEM. THE SUMMER COOLING FUNCTION OF THE HEAT PUMP IS NOT SOLAR ASSISTED.

TECHNOLOGY	SHACOB
CAPACITY	58 MJ/HR SOLAR ASSIST
APPLICATION	SPACE HEATING AND DOMESTIC HOT WATER
LOCATION	WASHINGTON, D. C.
INSOLATION	5.5 GJ/M*M/YEAR
SOLAR CONTRIBUTION	52 GJ/YEAR
SUPPLEMENT	ELECTRIC
SOLAR EFFICIENCY	
COLLECTOR AREA	24 M*M
OPERATING TEMPERATURE	
ENERGY TRANSPORT MEDIUM	WATER
STORAGE TYPE	WATER
STORAGE CAPACITY	3.8 MT

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

12.	ENERGY COLLECTOR - KTA KT3-64B		
	12.01 MISCELLANEOUS	SODA LIME GLASS	38.0
		POLYVINYL FLOURIDE	3.6
	12.03 ABSORBER	COPPER	103.4
	12.04 PIPING	COPPER	27.2
	12.05 INSULATION - ISOCYANURATE	POLYURETHANE	5.4
	12.06 REFLECTOR	SILVER	0.3
	12.07 FRAME	6063 ALUMINUM	43.5
		ALUMINUM	101.4
13.	ENERGY TRANSPORT		
	13.01 MISCELLANEOUS	50-50 SOLDER	2.8
	13.02 PIPING	COPPER	15.4
	13.03 INSULATION	POLYURETHANE	0.3
	13.04 TRANSPORT FLUID	WATER	32.0
	13.07 VALVES	BRASS	15.0
14.	ENERGY CONVERSION		
	14.02 HEAT EXCHANGERS - PART OF ECOSOL PACKAGE		
15.	ENERGY STORAGE		
	15.02 TANK - 1000 GALLON	CARBON STEEL	635.0
		FLAT BLACK ALKYD PAINT	9.1
		CONCRETE	1769.0
		POLYURETHANE	9.1
		WATER	3780.0
17.	ENERGY SYSTEM CONTROLLER		
	ECOSOL PACKAGE INCLUDES SYSTEMS CONTROLS		
	ECOSOL PACKAGE - MODEL 101-24-IDC/DRC-A/H	CARBON STEEL	136.0
		COPPER	37.2
		ALUMINUM	11.3
		CAST IRON	6.0
		LEADED TIN BRONZE	5.4
		ZINC	3.6
		BRASS	3.5
		NYLON	0.5
		R-22 CHCLF2	0.0
		FLAT BLACK ALKYD PAINT	0.3
		PHENOLIC	2.3

FOOTNOTES

12. Energy Collector

12.02 - Use two concentric tubes each 0.008 inch thick, OD=1.5 & 0.5 inches, 28 tubes per collector. Include endcaps of glass. Tedlar is 0.004 inch thick.

12.04 - Use 1/2 inch copper manifold top and bottom - guess.

12.05 - Use 3 x 3 x 46 inch block top and bottom.

12.06 - Use half silver 1.5 inch diameter, 0.00004 inch thick.

13. Energy Transport

13.02 - Use 3/4 inch copper to run to collector (40 ft.), evaporator (10), condenser (10) and domestic hot water (10 ft). Use one inch copper to storage tank (20 ft). Use 1/2 inch copper between storage tank and expansion tanks (4 ft).

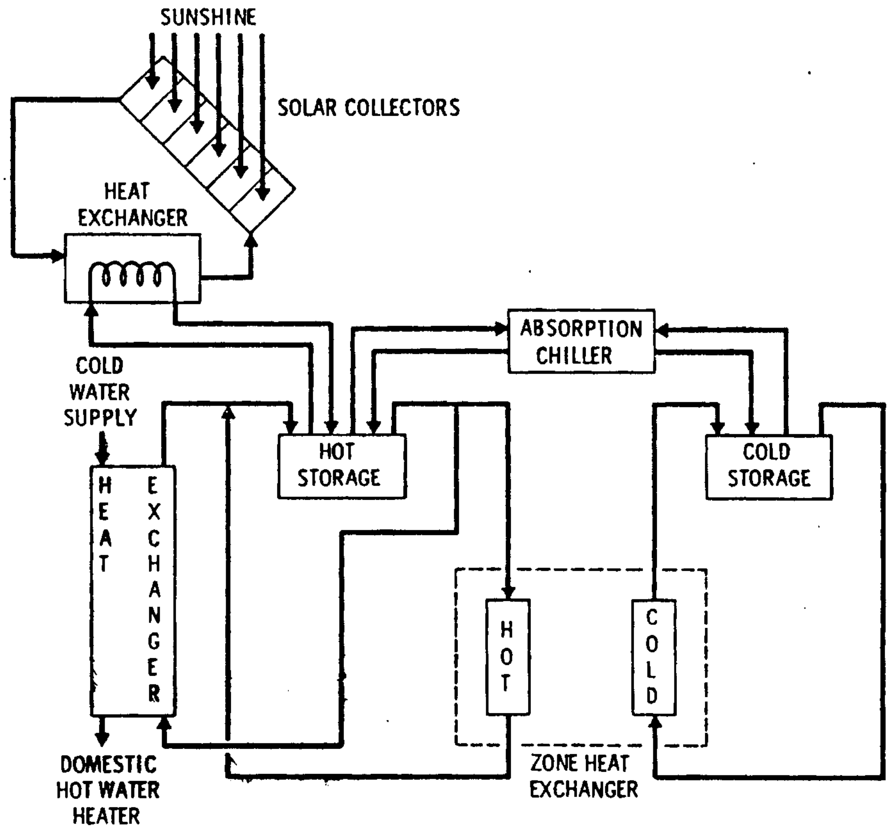
13.03 - Insulation - use 3/4 inch on all piping.

13.04 - Assumed 70 pounds water.

13.07 - Assumed 11 valves at 3 pounds brass each.

13.08 - Pumps included in ECOSOL Package.

15.02 - Assumed 6 ft. diameter, 4-12 ft. tall - 0.25 wall steel. Assumed a concrete footing 6 ft diameter - 1 ft deep.



SPACE HEATING AND COOLING AND DOMESTIC HOT WATER
RAYPAK COLLECTOR
AT
KIRKLAND AIR FORCE BASE, NEW MEXICO

THE SOLAR COLLECTOR SYSTEM CONSISTS OF 480 FLAT PLATE TUBULAR COLLECTORS TO FURNISH THE PRINCIPAL ENERGY FOR HEATING AND COOLING OF THE EXCHANGE MAIN STORE. EXCESS SOLAR HEAT IS STORED IN HOT STORAGE TANK.

THERE ARE THREE MODES OF WINTER OPERATION,

- -DIRECT HEATING WHEN THE WATER IN THE HOT STORAGE TANK IS 105 DEGREES F OR ABOVE,
- -HEAT PUMP HEATING WHEN THE HOT WATER STORAGE IS BELOW 105 DEGREES F TO SUPPLY THE HEAT TO THE HEAT PUMP, AND
- -WINTER COOLING BY HEAT PUMP WITH COLD TANK USED FOR CONDENSING WATER SERVICE.

FOR SUMMER OPERATION THE HOT WATER FROM THE HOT WATER STORAGE TANK CIRCULATES THROUGH THE ABSORPTION CHILLER TO PROVIDE BUILDING COOLING. ADDITIONAL COOLING WHEN REQUIRED IS SUPPLIED BY THE HEAT PUMP SYSTEM.

ZONE HEAT EXCHANGERS HAVE BOTH HEATING AND COOLING COILS SO THAT DURING THE IN-BETWEEN SEASONS ANY ZONE CAN AUTOMATICALLY SELECT EITHER HEATING OR COOLING.

TECHNOLOGY	SHACOB
CAPACITY	1000 MJ/HOUR
APPLICATION	HEATING AND COOLING A RETAIL STORE
LOCATION	KIRKLAND AIR FORCE BASE NEW MEXICO
INSOLATION	6800MJ/M*M-YEAR
SOLAR CONTRIBUTION	1700 MJ/YEAR
SUPPLEMENT	ELECTRIC HEAT PUMP
SOLAR EFFICIENCY	
COLLECTOR AREA	773M*M
OPERATING TEMPERATURE	
ENERGY TRANSPORT MEDIUM	ETHYLENE GLYCOL AND WATER
STORAGE TYPE	WATER
STORAGE CAPACITY	68,300 MJ

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

12.	ENERGY COLLECTOR 480 PANELS - RAYPAK DG-18P		
	12.02 GLAZING		
		SODA LIME GLASS	1.37+04
	12.03 ABSORBER		
		ALUMINUM	16[illegible]3.0
		COPPER	36[illegible]4.0
	12.05 INSULATION		
		GLASS WOOL	9[illegible]3.0
	12.07 FRAME		
		CARBON STEEL	1.36+04
		ZINC	5[illegible]4.0
		CADMIUM	7.0
		BRASS	1[illegible]3.0
		RUBBER	2[illegible]4.0
		SILICONE	1[illegible]3.0
		LUMBER	27[illegible]3.0
		GYPSUM	[illegible]3.0
	12.09 SUPPORTS		
		CARBON STEEL	2.50+04
13.	ENERGY TRANSPORT		
	13.02 PIPE		
		CARBON STEEL	1.15+04
		LEADED TIN BRONZE	1[illegible]5.0
		LEADED RED BRASS	1[illegible]9.0
		50-50 SOLDER	11.2
		COPPER	3[illegible]2.0
		MICARTA	29.0
		STAINLESS STEEL	11.0
		ZINC	3.5
	13.03 INSULATION		
		GLASS WOOL	9[illegible]0.0
		ALUMINUM	3[illegible]4.0
	13.04 TRANSPORT FLUID		
		WATER	1.55+05
		ETHYLENE GLYCOL	22[illegible]3.0
	13.05 SUPPORTS		
		CONCRETE	2013.0
	13.07 VALVES		
		CARBON STEEL	10[illegible]3.0
		STAINLESS STEEL	56.7
		EPT PLASTIC	41.5
		LEADED TIN BRONZE	1[illegible]8.0
		LEADED RED BRASS	3.7
		CAST IRON	172.0
		NEOPRENE RUBBER	5.4

	13.08 PUMPS		
		COPPER	35.0
		CARBON STEEL	3210.0
		NEOPRENE	11.3
		TEFLON	5.9
		LEADED TIN BRONZE	75.0
		LEADED RED BRASS	3.3
		SILICON STEEL	163.0
		ALUMINUM	5.4
		SILVER	0.3
	13.09 SITE DEPENDENT - SOLAR MAINS		
		CARBON STEEL	3020.0
		GLASS WOOL	50.0
		ZINC	23.0
		ALUMINUM	264.0
	13.10 EXPANSION TANKS		
		CARBON STEEL	354.0
		NEOPRENE	55.0
14.	ENERGY CONVERSION		
	14.02 HEAT EXCHANGERS		
		CARBON STEEL	1640.0
		ALUMINUM BRONZE D	363.0
		LEADED TIN BRONZE	9.1
		TRANSITE	349.0
		ZINC	35.5
		COPPER	5.9
		ALUMINUM	1.1
		PVC	349.0
		NICHROME	0.9
		POLYETHYLENE	5.8
		SILICON STEEL	0.9
	14.04 ABSORPTION CHILLER		
		CARBON STEEL	3363.0
		COPPER	591.0
		LITHIUM	13.1
		WATER	192.0
		BROMINE	158.9
15.	ENERGY STORAGE		
	15.02 PRIMARY STORAGE		
		CARBON STEEL	1.96+04
		URETHANE	443.0
		ADHESIVE SILICON	356.0
		ASPHALT	2100.0
17.	ENERGY SYSTEM CONTROLLER		
	17.02 METERS, SWITCHES, TERMINAL BOARDS		
		BRASS	1.3
		CARBON STEEL	12.0
		COPPER	7.0
		MERCURY	0.5

FOOTNOTES

13. ENERGY TRANSPORT

A number of the components of the energy transport system provide dual functions and thus cannot be assigned wholly to either the solar system or to the basic system. In order to overcome this problem, the cooling tower and its circulating pump CP2 were considered part of the solar system. Heat exchanger HE1 and pumps CP5 and CP6 were considered part of the basic system. The heat pumps F/HP1 and F/HP2, pumps CP7 and CP8 and the domestic hot water system were considered parts of the basic system.

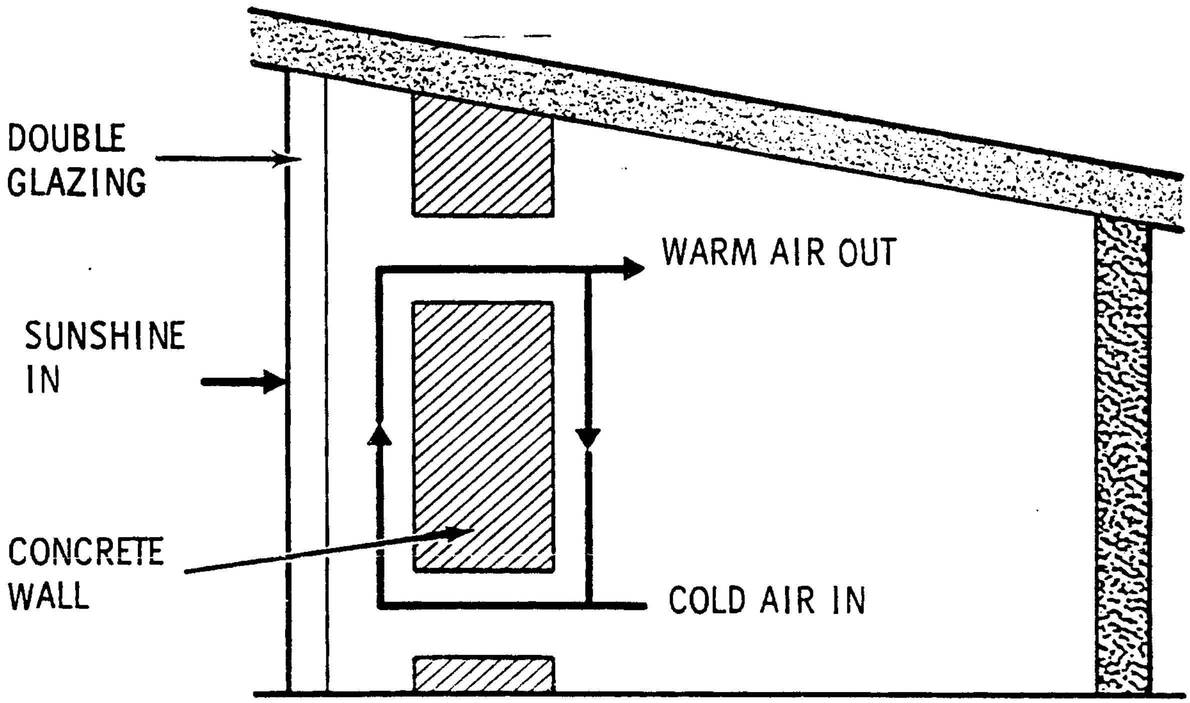
13.02 - PIPING

As a matter of economizing on materials and labor the solar panel header and piping were placed on the surface of the roof. Roof penetrations for pipe were reduced from 320 to 4.

13.04 - Ethylene glycol solution was estimated at a 50-50 volume percent.

13.07 - Weight of EPT plastic in butterfly valves was estimated.

13.08 - Weight of ethylene glycol feeder system components was estimated.



PASSIVE SPACE HEATING
CONCRETE TROMBE WALL
AT
WASHINGTON, D. C.

THIS SYSTEM CONSISTS OF A DOUBLE GLAZED, SOUTH FACING, CONCRETE WALL WHICH COMBINES THE HEAT COLLECTION AND STORAGE FUNCTIONS AS WELL AS FURNISHING THE STRUCTURAL SUPPORT FOR THE SOUTH SIDE OF THE ROOF. ROOM AIR CIRCULATES OVER THE HOT OUTER FACE BY THERMOSIPHON. LIGHTWEIGHT FLAPS ON THE TOP VENTS PREVENT REVERSE THERMOSIPHON WHEN THE OUTER WALL TEMPERATURE IS LESS THAN THE ROOM TEMPERATURE.

TECHNOLOGY	SHACOB
CAPACITY	50 MJ/HOUR
APPLICATION	SPACE HEATING
LOCATION	WASHINGTON, D. C.
INSOLATION	3.7 GJ/M*M-YEAR
SOLAR CONTRIBUTION	20 GJ/YR
SUPPLEMENT	VARIABLE
SOLAR EFFICIENCY	20-35 PERCENT
COLLECTOR AREA	47.4 M*M
OPERATING TEMPERATURE	10-60 DEGREES C
ENERGY TRANSPORT MEDIUM	AIR
STORAGE TYPE	CONCRETE
STORAGE CAPACITY	45 MT

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

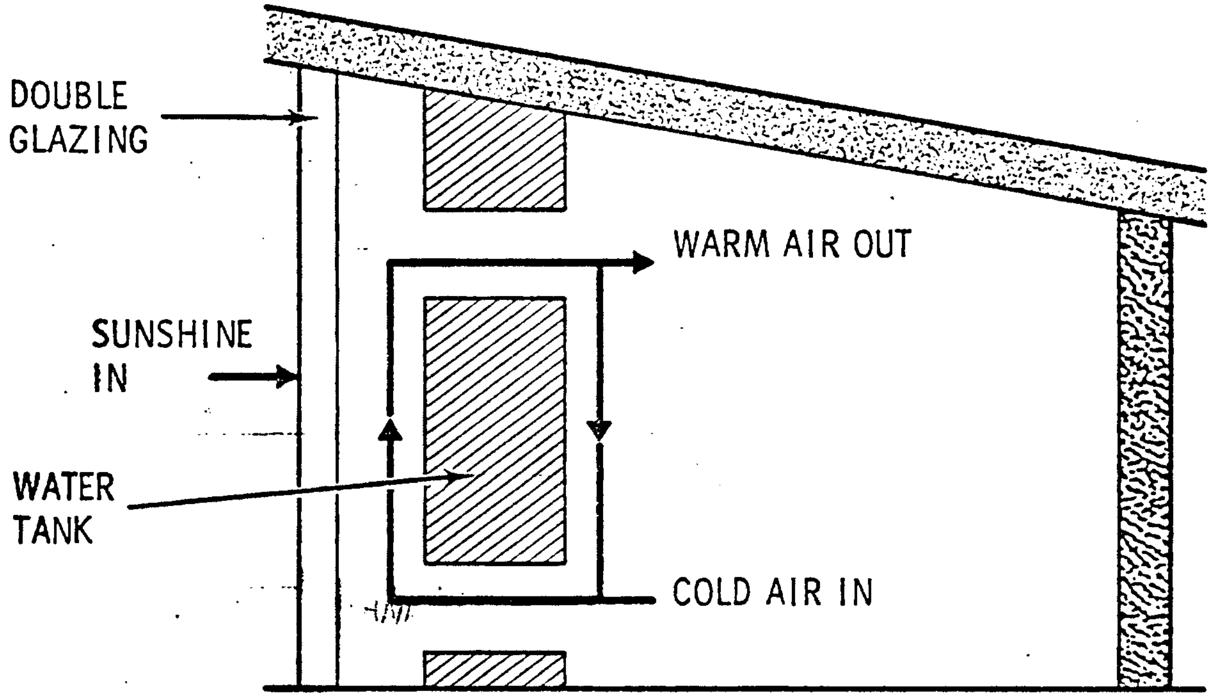
12.	ENERGY COLLECTOR - CONCRETE TROMBE WALL 510 SQ. FT. GLAZING		
12.01	MISCELLANEOUS NAILS -	CARBON STEEL	6.8
12.02	GLAZING	SODA LIME GLASS	740.0
12.03	ABSORBER WALL AND FOOTINGS	CONCRETE	4.12+04
	REINFORCING BAR	CARBON STEEL	520.0
		FLAT BLACK ALKYD PAINT	22.0
12.07	FRAME - WINDOWS	ALUMINUM	145.0
12.08	SEALS	NEOPRENE	11.3

FOOTNOTES

10. - Rules of thumb used in sizing Trombe wall: Glazed Trombe wall area equal to half of floor area, wall thickness - one foot, and double glazing. 1024 sq. ft. floor area assumed.

Solar contribution estimated from Nashville, TN data given by Balcombe et al, "Passive Solar Heating of Buildings", at Workshop on Solar Energy Applications, Associated Universities, Inc. June 27 through July 31,1977. Approximately 65% solar contribution.

12.03 - Trombe wall also supports south side of roof.



PASSIVE SPACE HEATING
WATER-TANK TROMBE WALL
AT
WASHINGTON, D. C.

THIS VARIATION OF THE TROMBE WALL USES WATER TANKS TO ACHIEVE MORE UNIFORM ROOM TEMPERATURES THAN DOES THE CONCRETE TROMBE WALL. HOWEVER, THE ROOF MUST BE SUPPORTED BY ADDING BEAMS RATHER THAN THE WATER TANKS AND CORROSION AND LEAKING OF THE WATER ARE NOTEWORTHY DISADVANTAGES. OTHERWISE THE WATER TANK AND CONCRETE TROMBE WALLS OPERATE SIMILARLY.

TECHNOLOGY	SHACOB
CAPACITY	50 MJ/HOUR
APPLICATION	SPACE HEATING
LOCATION	WASHINGTON, D. C.
INSOLATION	3.7 GJ/M*M-YEAR
SOLAR CONTRIBUTION	20 GJ/YEAR
SUPPLEMENT	VARIABLE
SOLAR EFFICIENCY	20-35 PERCENT
COLLECTOR AREA	47.4M*M
OPERATING TEMPERATURE	10-45 DEGREES C
ENERGY TRANSPORT MEDIUM	AIR
STORAGE TYPE	WATER
STORAGE CAPACITY	7.2 MT

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

12. ENERGY COLLECTOR-WATER TANK TROMBE WALL - 510 SQ. FT. GLAZING

12.01	MISCELLANEOUS		
	NAILS -	CARBON STEEL	6.8
12.02	GLAZING		
		SODA LIME GLASS	740.0
12.03	ABSORBER - WATER TANK		
		CARBON STEEL	1250.0
		FLAT BLACK ALKYD PAINT	22.0
		WATER	7210.0
		SODIUM DICHROMATE	7.2
12.07	FRAME, WINDOW		
		ALUMINUM	145.0
12.08	SEALS		
		NEOPRENE	11.3
12.09	SUPPORTS		
	FOOTING	CONCRETE	3735.0
	REINFORCING BAR	CARBON STEEL	51.2
	I BEAM	CARBON STEEL	250.0
	CHANNEL IRON	CARBON STEEL	346.0

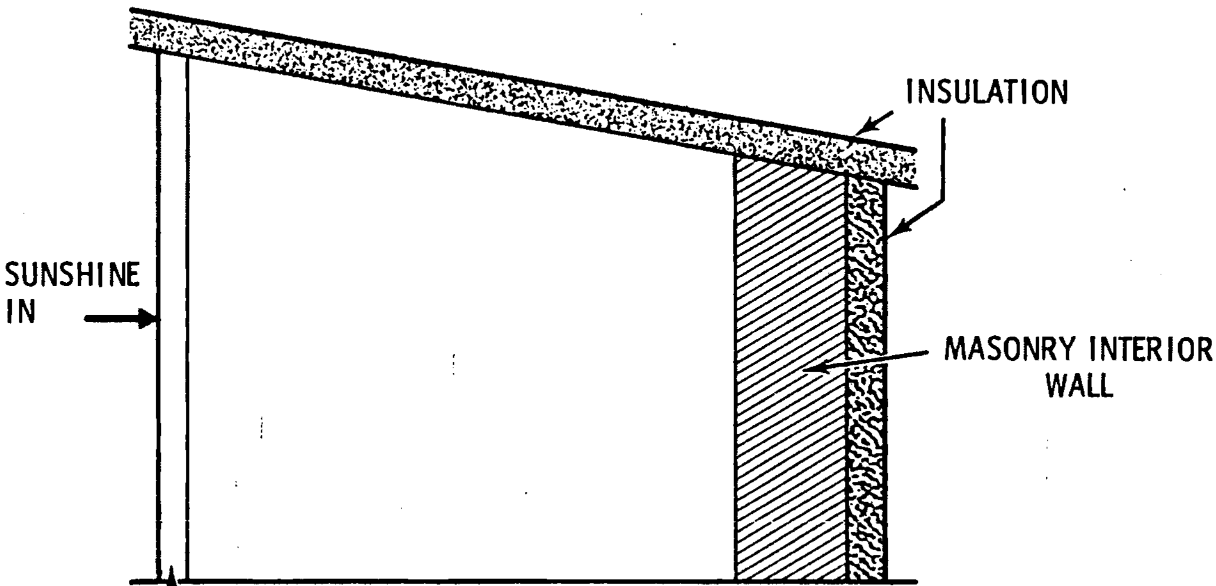
FOOTNOTES

10. - Rules of thumb used in sizing Trombe wall:; glazed Trombe wall area equal to half of floor area, six inch wall thickness, and double glazing. 1024 sq. ft. floor area assumed.

Solar contribution estimated from Nashville, TN data given by Balcomb et al, "Passive Solar Heating of Buildings", at Workshop on Solar Energy Applications, Associated Universities, Inc., June 27 through July 31, 1977. Approximately 65% solar contribution.

12.03 - Corrosion inhibitor - 0.1% sodium dichromate assumed.

12.09 - Supports required are for the south side of roof and for the water tank.



PASSIVE SPACE HEATING
DIRECT GAIN, MASONRY WALLS
AT
WASHINGTON, D. C.

THE SIMPLEST OF ALL SOLAR HEATING SYSTEMS, DIRECT GAIN UTILIZES THE HOUSE WALLS TO BOTH ABSORB AND STORE SOLAR ENERGY. IT OFFERS LESS CONTROL OVER ROOM TEMPERATURES THAN DOES THE TROMBE WALL.

TECHNOLOGY	SHACOB
CAPACITY	50 MJ/HOUR
APPLICATION	SPACE HEATING
LOCATION	WASHINGTON, D. C.
INSOLATION	3.7 GJ/M*M-YEAR
SOLAR CONTRIBUTION	20 GJ/YEAR
SUPPLEMENT	VARIABLE
SOLAR EFFICIENCY	50 - 60 PERCENT
COLLECTOR AREA	23.8 M*M (GLAZING)
OPERATING TEMPERATURE	15-30 DEGREES C
ENERGY TRANSPORT MEDIUM	AIR
STORAGE TYPE	MASONRY
STORAGE CAPACITY	42 MT

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

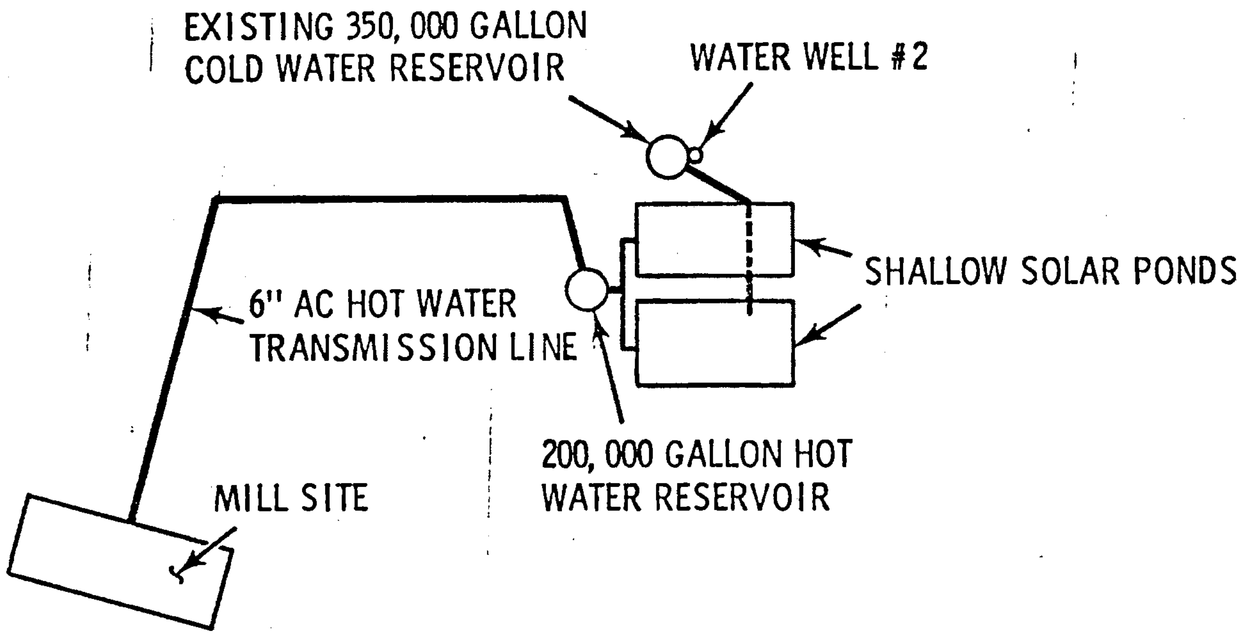
12. ENERGY COLLECTOR-HOUSEWALLS
256 SQ. FT. GLAZING

12.01	MISCELLANEOUS NAILS	CARBON STEEL	5.4
12.02	GLAZING	SODA LIME GLASS	372.0
12.03	ABSORBER - HOUSE WALLS		
	MASONRY WALLS	CONCRETE	4.20+04
	REINFORCING BAR	CARBON STEEL	341.0
12.07	FRAME, WINDOW	ALUMINUM	73.0
12.08	SEALS	NEOPRENE	5.9

FOOTNOTES

10. Rules of thumb used in sizing direct gain: glazing area equal to one-fourth of floor area, four inch wall thickness, absorbing wall area equal to six times glazing area. 1024 sq. ft. floor area assumed.

    Solar contribution equivalent to Trombe wall with twice the glazed area. Contribution estimated from Nashville, TN data given by Balcomb et al, "Passive Solar Heating of Buildings," at Workshop on Solar Energy Applications Associated Universities, Inc. June 27 through July 31, 1977. Approximately 65% solar contribution.



PROCESS HOT WATER
U MILLING
LLL SOLAR PONDS
AT
GRANTS, NEW MEXICO

THIS SYSTEM DESIGNED BY LAWRENCE LIVERMORE LABORATORY CONSISTS OF 15,400 M*M OF SHALLOW SOLAR PONDS, A HOT WATER STORAGE RESERVOIR AND THE NECESSARY PUMPS, PIPING, AND INSTRUMENTATION. THE SYSTEM IS SIZED TO PROVIDE 50 PERCENT OF THE HOT WATER REQUIRED FOR THE URANIUM MINING AND MELTING FACILITY. THE HOT WATER IS USED TO ACCELERATE THE CHEMICAL LEACHING PROCESS BY WHICH URANIUM ORE IS CONCENTRATED.

TECHNOLOGY	AIPH
CAPACITY	27,500 MJ/YEAR
APPLICATION	CHEMICAL LEACHING OF URANIUM ORES
LOCATION	GRANTS, NEW MEXICO
INSOLATION	7,150 MJ/M*M-YEAR
SOLAR CONTRIBUTION	50+06 MJ/YR
SUPPLEMENT	OIL
SOLAR EFFICIENCY	48 PERCENT
COLLECTOR AREA	15,390 M*M
OPERATING TEMPERATURE	60 DEGREES C
ENERGY TRANSPORT	WATER
STORAGE TYPE	WATER
STORAGE CAPACITY	750,000 KG

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

12.	ENERGY COLLECTOR - SHALLOW SOLAR PONDS		
	12.02 GLAZING		
		POLYVINYL FLUORIDE	590.0
		FRP POLYESTER	2.20+04
	12.03 ABSORBER		
		PVC	1083.0
	12.05 INSULATION		
		SODA LIME GLASS	3.96+04
		KRAFT PAPER	1980.0
		GLUE, PHENOLIC FORM	45.0
	12.07 FRAME		
	GLAZING HARDWARE	CARBON STEEL	6.88+04
		ZINC	1190.0
		CADMIUM	5.3
	CURB	CONCRETE	1.12+07
		CARBON STEEL	3440.0
	12.08 SEALS		
		URETHANE	15.0
	12.09 SUPPORTS		
		SAND	9.91+05
13.	ENERGY TRANSPORT		
	13.02 PIPE AND FITTINGS		
		CAST IRON	9050.0
		CARBON STEEL	24.0
		PVC	113.0
	13.04 TRANSPORT FLUID		
		WATER	1.63+06
	13.07 VALVES		
		CAST IRON	1280.0
		LEADED TIN BRONZE	87.0
		COPPER	68.0
		CARBON STEEL	8.6
		ZINC	0.5
	13.08 PUMPS		
		CAST IRON	740.0
		LEADED TIN BRONZE	15.4
		COPPER	109.0
		CARBON STEEL	39.0
	13.09 SITE DEPENDENT PIPE		
		TRANSITE	2.35+04
	13.10 FOUNDATIONS		
		CONCRETE	8260.0
		CARBON STEEL	95.0
15.	ENERGY STORAGE		
	15.02 STORAGE TANKS		
		CARBON STEEL	3.19+04
		LEADED TIN BRONZE	0.1
		NEOPRENE	475.0
		URETHANE	1260.0
	15.04 SUPPORTS		
		SAND	6.40+04
	15.05 FOUNDATIONS		
		CONCRETE	136.0

17. ENERGY SYSTEM CONTROLLER

17.01 MISCELLANEOUS

COPPER	1884.0
CARBON STEEL	198.0
PVC	7.9
PORCELAIN	5.7
ZINC	11.3
SILVER	0.7
ALUMINUM	39.0

FOOTNOTES

12. Energy Collector

All material items have been adjusted for the 16 ft x 210 ft pond dimensions and the number of ponds reduced from 36 to 26.

Asphalt paving was eliminated. Unistreet anchor street in curbing was replaced with 1/2 in. machine bolts put in the concrete curbing.

Glazing bows were estimated on the new pond dimensions.

12.08 - Density of foam rubber was estimated.

13.02 - Height of pipe stands was estimated from description.

13.07 - The amount of bronze in cast iron valves was estimated on information obtained from valve manufacturers.

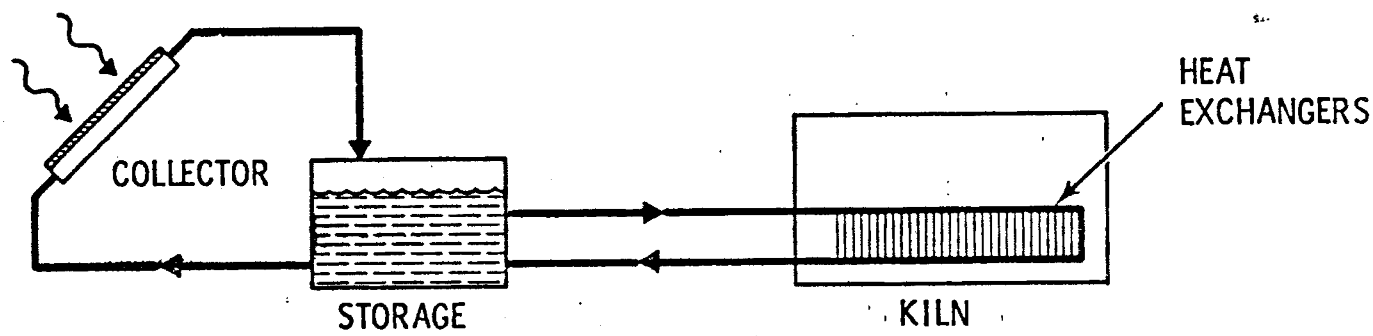
The amount of copper in the valve actuators was estimated on information obtained from the manufacturer.

13.08 - The amount of copper, bronze and steel in pumps and motors was estimated on information obtained from the manufacturers.

13.10 - The amount of concrete and steel in the pumping station foundation was estimated.

17. Energy System Controllers

The amount of each material was estimated on information obtained from measuring and weighing similar existing equipment.



PROCESS HEAT
LUMBER KILN
CHAMBERLAIN COLLECTORS
AT
CANTON, MISSISSIPPI

THIS SYSTEM DESIGNED BY LOCKHEED MISSILES AND SPACE CO. USES 2520 SQUARED FEET OF CHAMBERLAIN CORPORATION FLAT PLATE COLLECTORS IN A SAWTOOTH ARRANGEMENT WITH REFLECTORS. THE HEAT TRANSPORT MEDIUM IS WATER WITH 40,000 LB. OF STORAGE CAPACITY. HEAT IS TRANSFERED TO THE KILN AIR THROUGH FIN PIPE HEAT EXCHANGERS IN THE KILN. TEMPERATURE INSTRUMENTATION AND CONTROL ARE INTEGRATED INTO THE PRESENT COMPUTERIZED DRYING SYSTEM.

TECHNOLOGY	AIPH
CAPACITY	1080 MJ/HOUR
APPLICATION	KILN DRYING HARDWOOD
LOCATION	CANTON, MISSISSIPPI
INSOLATION	7900 MJ/M*M-YEAR, 19 PERCENT REFLECTED
SOLAR CONTRIBUTION	918,000 MJ/YEAR
SUPPLEMENT	NATURAL GAS
SOLAR EFFICIENCY	50 PERCENT
COLLECTOR AREA	234M*M
OPERATING TEMPERATURE	49-93 DEGREES C
ENERGY TRANSPORT MEDIUM	WATER
STORAGE TYPE	WATER
STORAGE CAPACITY	18,200 KG

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

12.	ENERGY COLLECTOR - CHAMBERLAIN	DOUBLE GLAZE BLACK CHROME NO. 44-6267	
	12.01 MISCELLANEOUS	CARBON STEEL	14.0
	12.02 GLAZING	SODA LIME GLASS	4732.0
	12.03 ABSORBER	CARBON STEEL	1.67+04
		CHROMIUM	97.0
		NICKEL	48.0
	12.05 INSULATION		528.0
	12.07 FRAME	ALUMINUM	218.0
		CARBON STEEL	7325.0
		ZINC	328.0
	12.08 SEALS	EPDM RUBBER	112.0
	12.09 SUPPORTS	SOFT WOOD	1.78+04
		CARBON STEEL	6478.0
		ALUMINUM	2213.0
		CADMIUM	1.2
		MASONITE	744.0
13.	ENERGY TRANSPORT		
	13.01 MISCELLANEOUS	50-50 SOLDER	2.7
		CARBON STEEL	2.3
		ZINC	7.1
	13.02 PIPE AND FITTINGS	COPPER	572.0
		BRASS	0.1
		PVC	138.0
		CARBON STEEL	85.0
	13.03 INSULATION	URETHANE	212.0
	13.04 TRANSPORT FLUID	WATER	1.95+04
	13.07 VALVES	LEADED TIN BRONZE	28.0
		CARBON STEEL	27.0
	13.08 PUMPS	CARBON STEEL	28.0
		TEFLON	0.7
		ALUMINUM	0.5
		CAST IRON	84.0

14.	ENERGY CONVERSION		
	14.01 MISCELLANEOUS STRAPS AND HANGERS	CARBON STEEL	10.0
		ZINC	1.4
	14.02 HEAT EXCHANGER	CARBON STEEL	7354.0
15.	ENERGY STORAGE		
	15.01 MISCELLANEOUS FOAMED INSULATION	URETHANE	81.0
	15.02 STORAGE TANK	CARBON STEEL	2113.0
17.	ENERGY SYSTEM CONTROLLER		
	17.02 METERS, SWITCHES, TERMINAL BOARDS	CAST IRON	0.9
		LEADED TIN BRONZE	7.7
		SODA LIME GLASS	0.2
		CARBON STEEL	67.0
		PHENOLIC	1.0
		SILVER	0.7
		NICKEL	0.1
		ALUMINUM	0.5
		PVC	7.0
		COPPER	12.0

FOOTNOTES

10. Estimates based upon document by S.J. Robertson and P.O. Mc Cormick, Solar Industrial Process Heat for Kiln Drying Lumber, Final Report - Phase I, LMSC-HREC TR D497234, March 30, 1977.

13. ENERGY COLLECTOR

12.03 - Used Plating Thickness from Handbook

12.09 - Cadmium plate estimated on basis of 1/2 in^2/fastener coated 0.0025 in. thick.

13. ENERGY TRANSPORT

All items taken from bill of material.

13.01 - Assumed 6' - 0" spacing.

13.01 - Assumed 2 in. wire solder used per average joint.

13.02 - Handbook weights used on all pipe, tubing and fittings.

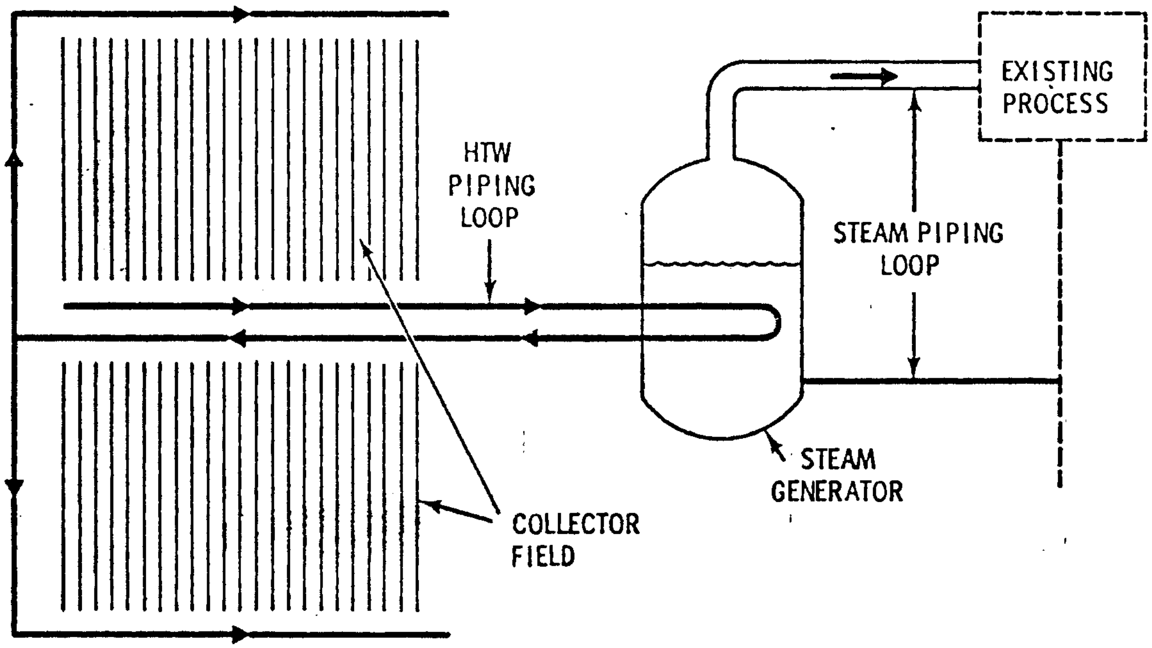
13.08 - Material weights estimated on basis of motor and pump unit weight.

14. ENERGY CONVERSION

14.01 - Estimated.

17. ENERGY SYSTEM CONTROLLER

17.02 - Materials estimated from component parts.



PROCESS STEAM
TEXTILE DRYING
HONEYWELL CONCENTRATING COLLECTORS
AT
FAIRFAX, ALABAMA

THIS SYSTEM DESIGNED BY HONEYWELL INCORPORATED FOR THE WESTPOINT PEPPERELL MILL IN FAIRFAX, ALABAMA. PROCESS STEAM IS USED THERE TO DRY TEXTILES IN CYLINDRICAL CAN DRYERS. OVER 50 PERCENT OF ALL WOVEN GOODS ARE DRIED ON CYLINDRICAL CAN DRYERS.

THE SOLAR COLLECTOR SUBSYSTEM CONSISTS OF 48 PARABOLIC-TROUGH SINGLE-AXIS-TRACKING, CONCENTRATING COLLECTORS WHICH HEAT WATER IN A HIGH TEMPERATURE WATER (HTW) LOOP TO 198 DEGREES C AT 230 PSI (AT TWO OCLOCK P.M. ON SEPTEMBER 21). THE HOT WATER FROM THE COLLECTORS FUELS A STEAM GENERATOR WHICH PROVIDES 544 KG/HOUR OF PROCESS STEAM TO THE CYLINDRICAL CAN DRYERS. THE BALANCE OF THE PROCESS STEAM REQUIREMENTS ARE GENERATED BY FUEL-OIL-FIRED BOILERS. CONDENSATE IS COLLECTED IN AN EXISTING CONDENSATE RECEIVER AND PUMPED BACK TO THE SOLAR HTW-FIRED STEAM GENERATOR.

TECHNOLOGY	AIPH
CAPACITY	1140 MJ/HOUR
APPLICATION	DRYING OF TEXTILE YARN
LOCATION	FAIRFAX ALABAMA
INSOLATION	4230 MJ/M*M-YEAR
SOLAR CONTRIBUTION	1.3+06 MJ/YEAR
SUPPLEMENT	FUEL OIL
SOLAR EFFICIENCY	40 PERCENT
COLLECTOR AREA	773M*M
OPERATING TEMPERATURE	198 DEGREES C
ENERGY TRANSPORT MEDIUM	WATER AND STEAM
STORAGE TYPE	NONE
STORAGE CAPACITY	NONE

MATERIAL REQUIREMENTS
BY
FUNCTIONAL COMPONENTS

12.	ENERGY COLLECTOR - HONEYWELL HSCC-1		
12. 01	MISCELLANEOUS		
	DRIVE ASSEMBLY	CAST IRON	55. 3
		COPPER	2. 7
		CARBON STEEL	28. 1
		TIN BRONZE	3. 2
	SUN TRACKING CONTROL		
		CARBON STEEL	5. 4
		COPPER	1. 6
		PVC	0. 5
		PHENOLIC	1. 0
		BRASS	0. 5
		MERCURY	0. 02
		PORCELAIN	0. 1
		SILICON	0. 05
		SILICON STEEL	0. 9
12. 03	ABSORBER		
	ABSORBERS AND ABSORBER SUPPORT ASSEMBLIES		
		ALUMINUM	1060. 0
		COPPER	894. 0
		GLASS WOOL	196. 0
		REFRACTORY SILICA	87. 0
		CHROMIUM	13. 0
		SODA LIME GLASS	240. 0
		CARBON STEEL	1175. 0
12. 04	ENERGY TRANSPORT		
	FLEXIBLE HOSE AND SWIVELS		
		TEFLON	15. 2
		LEADED TIN BRONZE	23. 9
		CARBON STEEL	26. 1
		BRASS	4. 4
12. 06	REFLECTORS		
		ALUMINUM	2530. 0
		ACRYLIC	131. 0
		EPOXY	392. 0
12. 07	FRAME		
	TORQUE TUBE ASSEMBLY		
		ALUMINUM	1570. 0
		CARBON STEEL	2005. 0
12. 09	SUPPORTS		
		CARBON STEEL	8255. 0
		ZINC	283. 0
		PITCH	1089. 0
13.	ENERGY TRANSPORT		
13. 01	MISCELLANEOUS		
	IMMERSION HEATERS		
		MAGNESIUM	0. 5
		NICHROME	1. 4
		BRASS	2. 3
	AIR SEPARATORS	304 STAINLESS STEEL	1. 8
		ASBESTOS	0. 2
		CAST IRON	7. 3
		STAINLESS STEEL	0. 5
13. 02	PIPE		
		CARBON STEEL	4944. 0
13. 03	INSULATION	GLASS WOOL	1818. 0
		ALUMUNUM	293. 0
		PVC	9. 1

	13.04 TRANSPORT FLUID		
		WATER	1642.0
	13.05 SUPPORTS		
		CARBON STEEL	2195.0
		CAST IRON	318.0
	13.07 VALVES		
		ALUMINUM	0.4
		ASBESTOS	2.9
		LEADED TIN BRONZE	6.5
		CAST IRON	72.6
		416 STAINLESS STEEL	17.1
		316 STAINLESS STEEL	33.1
		CARBON STEEL	312.0
		BRASS	19.1
		STAINLESS STEEL	3.2
		EPT RUBBER	0.1
	13.08 PUMPS		
		STAINLESS STEEL	137.0
		CAST IRON	65.8
		COPPER	11.3
		CARBON STEEL	3.2
	13.10 EXPANSION TANKS		
		CARBON STEEL	227.0
		NEOPRENE	250.0
14.	ENERGY CONVERSION		
	14.05 STEAM GENERATOR		
		COPPER NICKEL 10 PERCENT	227.0
		CARBON STEEL	953.0
		GLASS WOOL	40.8
		ZINC	4.5
17.	ENERGY SYSTEM CONTROLLER		
	17.02 METERS, SWITCHES, RELAYS, TERMINAL BOARDS, ETC.		
		COPPER	15.0
		CARBON STEEL	25.0
		PHENOLIC	10.0
		STAINLESS STEEL	32.0
	17.03 SUPPORTS - CABINETS		
		ALUMINUM	80.0
		STAINLESS STEEL	5.0
		CARBON STEEL	700.0
22.	PLANT UTILITIES		
	22.01 BUILDING - BOILER AND CONTROLS		
		CARBON STEEL	1996.0
		FIBERGLASS	798.0
		PLYWOOD - SOFTWOOD	447.0
	22.02 EMERGENCY GENERATOR 12 KW DIESEL POWERED		
		COPPER	45.4
		ALUMINUM	4.5
		CAST IRON	240.0
		CARBON STEEL	31.8

FOOTNOTES

10. Data are based on report ORO/5124-77/1, March, 1977.

12.04 - Teflon hose assumed.

12.06 - Epoxy adhesive assumed.

17. Energy system control requirements assumed to be 1/2 of the MIT-LL and UNL photovoltaic system at Mead, Nebraska.

ENERGY CONTRIBUTION CALCULATIONS

The details of all energy contribution calculations are given in Tables B.1, B.2, B.3, and B.4 which follow.

TABLE B.1. Details of Energy Contribution Calculations

System	Location	Collector Tilt	Energy Contribution Calculation Method	Insolation Calculation Method	Location Selection Method
Sunworks - HW	Manhattan, KS (38° Lattitude)	38°	"f"-Chart[1-4] (85% Solar)	"f"-Chart	Weighted Average[a]
Solaron-H	Washington, D.C. (38° Lattitude)	48°	"f"-Chart (50% Solar)	↓	↓
Solaron - H&HW	↓	↓	↓	↓	↓
American Helio. - H&HW	↓	↓	↓	↓	↓
KTA-Ecosol - H&HW	↓	↓	Estimated From Balcomb[5]	↓	↓
Direct Gain - H	↓	↓	↓	↓	↓
Concrete Trombe - H	↓	↓	↓	↓	↓
Water Trombe - H	↓	↓	↓	↓	↓
RayPak - H,C, & HW	Site selection and all calculations completed by system designers.				
LLL Solar Pond					
Chamber. Lumber Kiln					
Honeywell Textile Dry					

(a) See Tables B.2 and B.3

(1-4) References 1, 2, 3, and 4. Hot water or space heating load varied to arrive at percentage solar contribution shown (which is near the economic optimum in most cases. See reference 6).

(5) Reference 5.

TABLE B.2. Calculation of Weighted Average Solar Contribution From 6.9 m^2 Sunworks DHW System[(a)]

State and Representative City[(6)(b)]	Projected New Homes Using Electric DHW 1977-1985[(6)] (1000)	Assumed Number of Homes With Solar DHW (1000)	Solar Contribution per Home[(1-4)] (At 85% Solar DHW) (GJ/yr)	State Yearly Solar Contribution From Solar DHW (10^3 GJ)
CA-Los Angeles	200+	250	18.5	4626
FL-Miami	200+	250	19.0	4750
NY-Ithaca	100-199	150	8.42	1263
NJ- New York City	100-199	150	9.85	1478
AZ-Phoenix	50-99	75	23.9	1794
MD-Washington, DC	50-99	75	11.5	859
NV-Las Vegas	1-49	25	23.1	578
DL-Washington, DC	1-49	25	11.5	286
TOTAL		1,000		15,634

(a) Weighted Average Contribution = $\frac{15,634}{1,000}$ = 15.63 GJ/yr.

Representative Location Selected-Manhattan, KS = 14.38 GJ/yr
(15.63-14.38=1.25 GJ or 8% Allowance for System Thermal Losses)

(b) States listed are those where solar DHW is economically feasible in competition with electric resistance on a 10-yr life cycle cost basis without government incentives. Oil and gas are more economical on 10-yr life cycle basis without government incentives. Some states were represented by cities, outside of the state that have similar weather conditions.

TABLE B.3. Calculation of Weighted Average Solar Contribution From 25.4 m^2 Solaron Space Heating System(a)

State and Representative City(6)(b)	Projected New Homes Using Electric Space 1977-1985)(6) (1000)	Assumed Number of Homes With Solar Heating (1000)	Solar Contribution Per Home(1-4) (At 50% Solar) (GJ/yr)	State Yearly Solar Contribution From Solar Space Heat (-10^3 GJ)
NY-Ithaca	100-199	150	22.9	3437
MD-Washington, DC	100-199	150	27.4	4108
MA-Boston	50-99	75	26.4	1978
NJ-New York City	50-99	75	22.7	1701
CT-Boston	1-49	25	26.4	659
RI-Newport	1-49	25	35.7	893
VT-Mt. Weather	1-49	25	35.3	881
NH-Mt. Weather	1-49	25	35.3	881
ME-Portland	1-49	25	41.7	1043
WI-Madison	1-49	25	35.0	876
MN-St. Cloud	1-49	25	41.9	1047
ND-Bismark	1-49	25	46.38	1159
SD-Rapid City	1-49	25	53.7	1343
CO-Boulder	1-49	25	48.1	1203
NM-Albuquerque	1-49	25	56.7	1417
TOTAL		725		22,626

(a)Weighted Average Contribution = $\frac{22,626}{725}$ = 31.2 GJ/yr.

Representative Location - Washington DC = 27.4 GJ/yr.
(31.2-27.4 = 3.8 GJ or 11% allowance for system thermal losses)

(b)Cities where solar space heat economically competitive with electric resistance on 20-yr life cycle cost basis without government incentives. Oil and gas are more economical on 10-yr life cycle basis without government incentives. Some states were represented by cities, outside of the state that have similar weather conditions.

TABLE B.4. Solar Contribution From 500 Million m^2 of Collector

SHACOB Systems	Solar Contribution Quads
Sunworks Res HW	0.9
Solaron - Res HT	0.5
Solaron - Res HT + HW	0.7
Amer Heliothermal H+HW	0.8
KTA and ECOSOL Heat Pump System	1.0
RayPak - HT+COOL+HW	1.0
Trombe Wall Concrete	0.2
Trombe Wall Water	0.2
Direct Gain Masonry Wall	0.4
Mixed Case (Equal Portions of all 9 SHACOB Systems)	0.64
AIPH Systems	
LLL Solar Pond	1.5
Chamberlain - Lumber Kiln	1.9
Honeywell Concentrating	0.8
Mixed Case (Equal Portions of all 3 AIPH Systems)	1.4

APPENDIX B: REFERENCES

1. Solar Collector System Engineering, Program ACSE 1. Scotch Programs Box 430734, Miami, FL.

2. S. A. Klein, W. A. Beckman, and J. A. Duffie, "A Design Procedure for Solar Heating Systems." Solar Energy, 18:113, 1976.

3. W. A. Beckman, J. A. Duffie, and S. A. Klein, "Applications of Solar Energy for Heating and Cooling a Building," Simulation of Solar Heating Systems. Chapter 9, ASHRAE, NY, 1976.

4. S. A. Klein, W. A. Beckman, and J. A. Duffie, A Design Procedure for Solar Air Heating Systems. 1976 ISES American Sect. Conf., Winnipeg, Manitoba, August 15-20, 1976.

5. J. D. Balcomb, J. C. Hedstrom, R.D. McFarland, "Passive Solar Heating of Buildings," Workshop on Solar Energy Applications. Associated Universities, Inc., June 27-July 31, 1977.

6. F. Roach, et al., Prospects for Solar Energy: The Impact of the National Energy Plan. LA-7064-MS, Los Alamos Scientific Laboratory, Los Alamos, NM, December 1977.

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