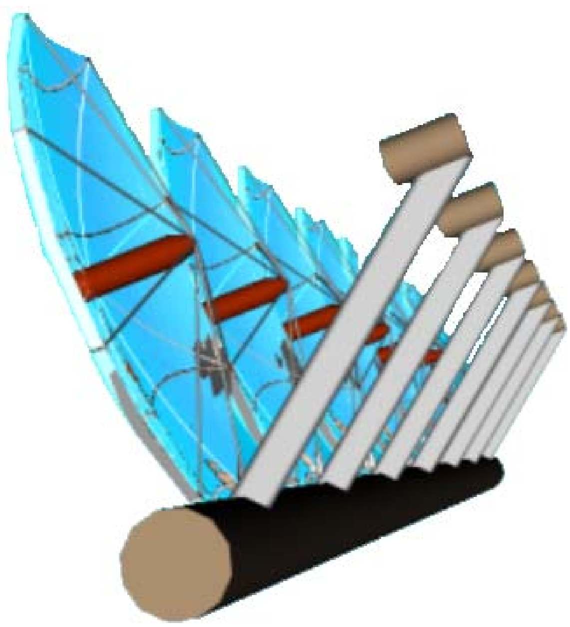
Feasibility Study

Applying CENICOM^{TM} Solar Energy Systems in China



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Executive Summary

This feasibility study was undertaken to ascertain the application effectiveness of the CENICOM™ Solar Energy collection system in China. The study was started in late 2004 and the final report will be available in May 2005. China Power Engineering Consulting Group Corporation (CPECC) and Southwest Electric Power Design Institute (SWEPDI) were selected to contribute to the study. Deputy Chief of Export Committee, Director Tang Yun Lin of CPECC provided guidance and counsel as to the content and scope of the study.

Mr. Yang Qiang, Mechanical Department Vice Chief Engineer, Miss Liu Yan, Mechanical Department Engineer and others under the direction of Mr. Yuan Qi, Chief Engineer of the Institute were authors of study from SWEPDI. Mr. Wang Zhong Hui, Mechanical Department Engineer, from CPECC was also an author. Mr. Ronald Derby, President, Mr. Samuel Lazzara, Chief Technical Officer William Dampier, Chief Operations Officer of CENICOM Solar Energy LLC also contributed to the study.

The study reviewed the solar resources available in China and described the areas of the country where good sunlight is available. These areas are mainly in the northwest, northeast and west. There are some other areas in the south that are also adequate.

The study then compares the various methods of creating electricity with solar energy. There are some power plants that using line-focusing solar troughs to produce electricity that are augmented by natural gas. In times past these were approaching commercial status, but with the current increase in natural gas prices, they may not be viewed as favorably. Solar cell arrays have gained popularity because of the apparent simplicity of their use. When all aspects of using solar cell arrays are considered, the fact that they convert directly to electricity means that for small systems they have to use batteries that wear out. For large systems they have to use the grid for storage. This type of power generation is sporadic and generally means that the grid has to have on standby, conventional power to take over when the sun disappears behind clouds or fog or the sun sets. This reduces the beneficial aspects of this power source. This is also true of wind power and Stirling engine systems. The review of dish systems included the CENICOM™ and the single concentrator using the Stirling engine. The CENICOM™ system provides thermal storage permitting continuous generation that allows it to be used in both grid independent and grid connected applications. The CENICOM™ cost per peak kilowatt is attractive when compared to other solar to electricity systems. The solar-to-electricity efficiency of the CENICOM™ system is also favorable.

The CENICOM™ system uses point focusing 3 meter diameter mirrors to concentrate the sun's energy. There are 88 of these mirrors on a rotating platform for a total of 650 square

meters of collecting area. The mirrors are hinged and ganged together to tilt to face the sun directly. The azimuth sun tracking is accomplished by turning the rotating platform to face the sun and the elevation tracking is done tilting the mirrors to face the sun. This precise focusing and close dish spacing allows the system to create high temperatures in the air used as the energy transfer medium. High temperatures are desirable for high density energy storage, and for the eventual conversion of heat into electricity. The air temperature created is controlled to be 1100°C. The hot air is piped to a storage vault where the heat is transferred to a solid inert long-lived storage medium. This allows the collection of energy to be separated from the delivery of electrical energy. This aspect of the system allows it to be used in stand-alone or in grid connected applications. In stand-alone applications the storage allows electricity to be delivered on a 24 hour 7 day a week basis. In grid attached systems the system can deliver the electricity when it is most needed. This is especially good when the peak load is during evening or night when the sun is not shining. The storage vault can be sized to closely match the application. CENICOM™ projects can be small with one or several modules connected to the Prime mover or in Clusters of one or more 36 CENICOM™ modules that will be used for larger projects.

Air is used as a transport medium. It is safer and much less expensive than molten salts used in solar towers or the mineral oils used in the solar trough systems. It also allows higher temperatures to be achieved. Trough system uses natural gas to boost the temperatures achieved by solar energy to temperatures that allow steam turbines generator sets to run at reasonable efficiencies. The tower systems use fossil fueled heaters to keep the molten salts from freezing in the system. The CENICOM™ process is entirely combustion-free.

The CENICOM™ electrical power generation is accomplished by using steam turbines. These are in general use and have been reliably employed for power generation for many decades. They are available in sizes that support CENICOM™ power plants in the various sizes that can be constructed. They are available in China. The other dish concentrator system investigated uses a single concentrating mirror to supply heat to a Stirling engine located at the focus. Stirling engines are still in the investigation phase. Currently available engines have evidenced reliability problems. The engines require external starting so the plan for using these devices attaches them directly to the grid so that the generator can drive the engine during short sun outages. This synchronizing the small systems with the grid is one of the startup problems being addressed by scientists.

The land area used by the CENICOM™ systems to collect solar energy is less that the other systems. The reason is its very good solar to electricity efficiency. Efficiencies allowed by high temperatures help this system compared to other solar thermal approaches. The CENICOM™ systems are built upon towers or upon the roofs of buildings. When installed on the ground on the towers, 93% of the space underneath the array is available up to a height of 7.34 meters.

Though the peak efficiencies of Photo Voltaic Solar Cell Arrays (PVs) are projected to approach the efficiency of the CENICOM™ system, the average efficiency is lower than the average efficiency of the CENICOM™. This is due to the efficiency of PVs being negatively related to the magnitude of the sunlight intercepted. This means that a PV with a peak efficiency at 1 KiloWatt per square meter of natural sunlight, has a much lower efficiency at 300 watts per square meter of atmospherically attenuated natural sunlight, whereas the efficiency of point focus dish systems like CENICOM™ remain the same. There are only a small number of hours per year where the maximum sunlight intensity hits the PV array, most of the sunlight hours are less than that. This is because the PV array is fixed and does not face the sun much of the time.

The CENICOM™ system project cost and power tariff is quite low compared to other systems that are or are projected to be used to generate electricity from sunlight. All of the mirrors and other parts of the system will be built in China. The equipment for power generation is available in China and projects undertaken will use Chinese engineering companies to do project design, equipment procurement, installation and commissioning, and provide help to train personnel in maintenance and operation.

CENICOM™ plans to continue refining the design in order to optimize some critical elements of the system. Several areas of design have been identified. One of the areas is the air transport, with its piping material, expansion joints and the rotary joints required to allow the system to track the sun. Another area is in working with turbine companies to achieve an efficient small turbine for less than cluster size power plants.

The study includes two areas of case study.

Case One.

Case One is a 6 MW dispatchable power plant in Lhasa, Tibet. A one cluster system was designed to be a peaking power plant that would collect solar energy in the storage vault and dispatch it during the peak load period. The system was deemed a “starter system” because of the mismatch between the collection system and the generation system. A starter system would be completed later by adding 2 additional Clusters to match the generation system. The system would only run if it could produce output for at least a 4 hour period. The analysis was done for a one hour minimum where it was discovered that 4 hours would be a better choice. Because CENICOM™ uses thermal energy storage, this interval can be adjusted over a wide range of times. The annual capacity factor was 0.2546. The project cost for this system was 136,020,732 RMB. It was noted that the match between a CENICOM™ cluster and the 6MW power generation plant was not optimum. A second version of the Lhasa case was designed to be a peaking power plant using the same 6MW power generation plant but collecting energy with three CENICOM™ Clusters. The minimum run time was 8 hours per day. There were many days that the unit ran 24 hours per day. If there were not at least 8 hours of energy available in storage then the system did not run that day, but collected only. The project cost for this system was 291,042,196 RMBI. After the case study was completed, it was discovered that Lhasa was in the second-most sunny area of the world falling just behind the Sahara Desert. With the updated sunshine factor the annual Capacity Factor for the plant was 0.764. Using the loan interest rate for Tibet projects, a special income tax profile for Tibet, a Clean Development Mechanism (CDM) and a bonus tariff the tariff for case 1B is 634 RMBI per KWHr.

A PV solar cell array system that would give the same annual output as the one cluster system would require 61,854 square meters of collecting area as compared to the CENICOM™'s 23,412 square meters. The project cost without considering installation or mounting platforms would be 288,809,152 RMBI. This is 2.91 times the cost of an equivalent CENICOM™ system. It does not have storage to allow it to cover the nighttime peaks. The CENICOM™ system has a life of 25 years while PV solar cell arrays have a somewhat shorter life.

Case Two

Case Two was a study to determine the number of dwellings that could be supplied from a roof-top installation of 3 CENICOM™ modules. The emphasis was to be on heating and cooling. The annual load profile was given for heating, cooling and electricity. The seasonal heating load is highest when the sun's resources are the least. The case study indicated that the amount of space that could be heated from solar sources during the winter was modest. However, the CENICOM™ system could easily provide the energy for cooling during the summer months. In addition there was excess energy during parts of the year that could be used to generate electricity to be supplied to the grid. A review of the economics in this case if thermal energy and energy for cooling were given appropriate weights is that the cost per effective KWHr was in the 0.8 RMBI range. Cost for the heat supplied was 0.21RMBI per KWHr – thermal. This can be contrasted with a cost of 0.28RMBI per KWHr – thermal for flat plate collectors with the same sun intensity profile for the winter months.

A single CENICOM™ system was also part of the study. This system was to produce electricity for delivery to the grid at peak load times. It also was programmed to reserve thermal storage capacity for use as an emergency back up generating system. The system produced 314,000 KWHrs per year. During the months of May, June, July, August, and September (the months of the Summer Olympic Games) it was producing at the rate of 370,000 KWHrs per year. Its cost was 3.27 million RMB. The cost for a PV system with the same annual output would be 8.825 million RMBI.

Conclusion:

The CENICOM™ system is a non-polluting, high peak and high average efficiency system that provides storage that allows time separation of solar energy collection and electric power generation. This makes it a versatile system that can be used with its own local grid or attached to a regional grid. Its comparatively low cost will make this system a viable village sized system in the sunny areas of China. The system costs will decrease as production rates increase. See the Sensitivity Analysis in Appendix B. Systems could be manufactured and installed in a reasonably short time.

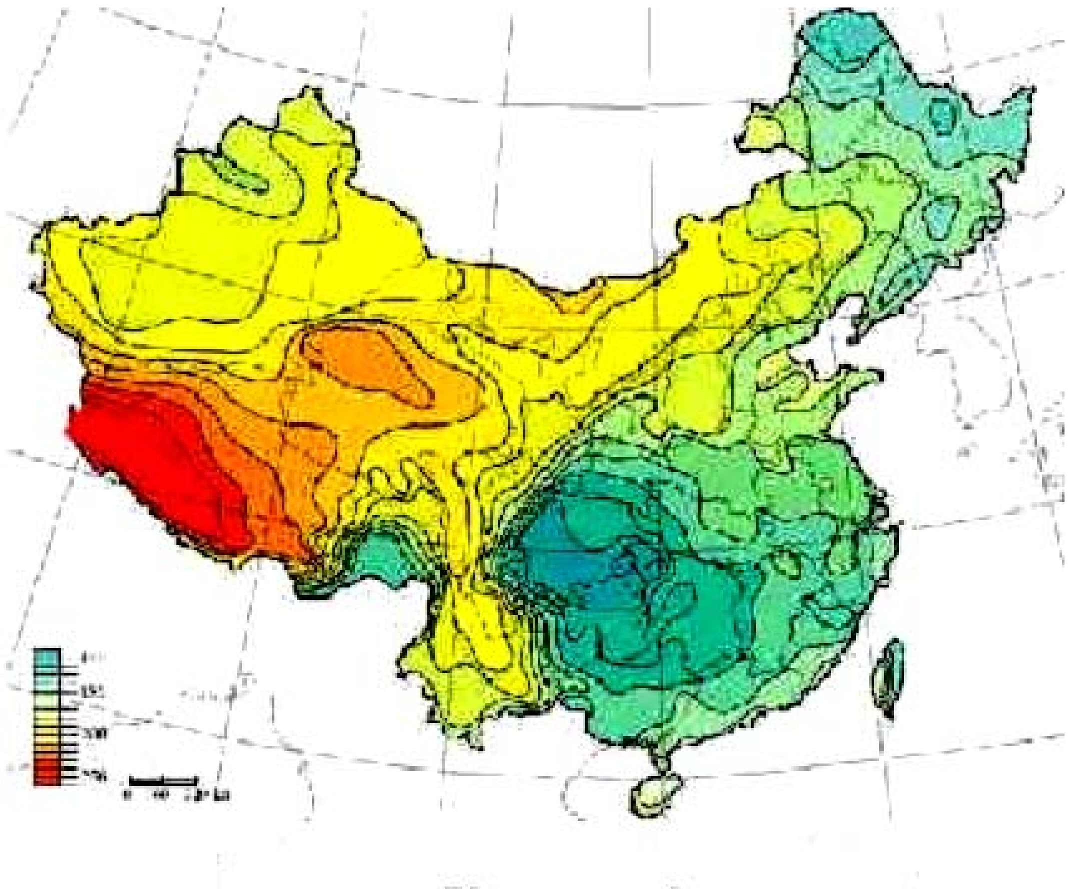
1 The Market Study Of Solar Electricity In China

1.1. Solar Resources Distribution In China

China is a very large country, and is blessed with abundant solar resources. It is estimated that Chinese firm ground surface can accept solar radiation power about $50x10^{18}$kJ/yr, and can totally accept solar radiation power up to $50x10^{18}$kJ/cm^2/year all over the country, averaging 586kJ/cm^2 annually. As the solar resources distribution around our country stands, including, Qinghai, Xinjiang, southern Inner Mongolia, Sanxi, northern Shanxi, Hebei, Shandong, Liaoling, western Jilin, middle and southwestern Yunlan, southeast Guangdong, southeast Fujian, eastern and western Hailan Island, and southwestern Taiwan. Other immense regions are rich in sunlight radiant energy, especially the Qingzang Plateau region with the largest total solar radiation. The region's average altitude above seal level is above 4000 meters, the corridor is very thin and clean, good transparency clarity, low latitude, and long sunlight time. For example Lhasa, called the "sunlight city", averages about 108.5 sunshine days per year, 98.8 cloudy days, 4.8 average cloudy quantity per year, and has 816 kJ/cm^2/yr. The total solar energy radiation is better than other provinces in the same latitude region. In the western region, the desert region area of 10,000 square kilometers can supply 5.5 of the three gorges power. Our country's solar resources have more than 1400 times wind resources and 3300 times hydraulic resources.

The major features of solar resources distribution in our country are: 1) high and low numerical value center of solar energy are all placed in the northern latitudes 22°~35°. In this part, Qingzang plateau is a high numerical value center and Sichuan basin is a low numerical value center. 2) The radiation for the year in the western region is higher than eastern region, important for Tibet and Xinjiang autonomous regions. 3) Radiation for the year in the southern region is lower than northern region because most southern regions have many mist clouds and rainy days. In latitudes 30°~40° northern region, solar energy distribution is different than normal because solar energy fluctuates according to latitude degree. In this region solar energy does not decrease along with latitude degree increase, but increases along with latitude degree increase.

Chinese solar energy resource distribution is shown in the following diagram:



Color	Radiation degree	Annual radiation quantity (MJ/ m^2)	Daily radiation quantity (KWh/m^2)
red	best	≥ 6680	≥ 5.1
Orange red	better	5850~6680	4.5 – 5.1
yellow	average	5000~5850	3.8 – 4.5
Cambridge blue	Worse	4200~5000	3.2 – 3.8
Dark blue	Worst	< 4200	< 3.2

According to accepted solar energy radiation size, entire nation can roughly be divided into five regions:

The first type region: whole year sunshine hours is 3200~3300 hours, radiation is 670~837 $x10^4kJs/cm^2/yr$. The energy is equivalent to calories that 225~285 kg standard coal sends out when burning. Area primarily includes the Qingzang plateau, northern Gansu, northern Ningxia, and southern Xinjiang etc. region. This is the most abundant region of solar energy resources in our country and equals solar energy resources in India and northern Pakistan. Especially Tibet, the geography is high, sunlight transparency clarity is also good, and the most total solar radiation is up to 921 kJs/cm^2/yr, only lower than Sahara Desert, is the second all over the world, among them Lhasa is the world famous sunlight city.

The second type region: whole year sunshine hours is 3000~3200 hours, radiation is 586 ~670 x104kJs/ cm^2/yr. The energy is equivalent to calories that 200~225 kg standard coal sends out when burning. Area primarily includes northwest Hebei, northern Shanxi, southern Inner Mongolia, southern Ningxia, central Gansu, southeast Qinghai, southeast Tibet, and southern Xinjiang etc. region. This zone has most plentiful solar energy resources in our country.

The third type region: whole year sunshine hours is 2200~3000 hours, radiation is 502~586 x104kJs/cm^2/yr. The energy is equivalent to calories that 170~200 kg standard coal sends out when burning Area primarily includes Shamdong, Henan, southeast Hebei, southern Shanxi, northern Ningxia, Jilin, Liaolin, Yunnan, northern Shanxi, southeast Gansu, southern Guangdong, southern Fujian, northern Jiangshu and northern Anhui, etc. region.

The fourth type region: whole year sunshine hours is 1400~2200 hours, radiation is 419~502 x104kJs/cm^2/yr. The energy is equivalent to calories that 140~170 kg standard coal sends out when burning. Area primarily includes Yangtze River inside downstream, Fujian, Zhejiang, and part region of Guangdong. All of these areas have many clouds and rainy days in Spring and Summer with good solar energy resources in Fall and Winter.

The fifth type region: whole year sunshine hours is 1000~1400 hours, radiation is 335 ~419 x104kJs/cm^2/yr. The energy is equivalent to calories that 115~140kg standard coal sends out when burning. Area primarily includes the two provinces of Sichuan and Guizhou. This is a zone that has fewest solar energy resources in our country.

The first, second, and third type regions have larger annual sunshine amount than 2200 hours, higher total radiation than 586 kJs/cm^2/yr. These regions have the most plentiful or abundant solar energy resources in our country. The area is very large, roughly land above 2/3 area of the national total and have potential for making good use of solar energy. Fourth and fifth regions have poor solar energy resources, but have certain exploitation value. The solar energy resources and distribution in China are summarized in the table:

Table 1 Solar Energy Resources and Distribution in China

Type	Region	Annual Sunshine Number hours	Annual Total Radiation ($kJ/cm^2 \cdot a$)
1	Southern Tibet, southeast Xinjiang, western Qinghai, western Gansu	2800~3300	672~840
2	Southeast Tibet, southern Xinjiang, eastern Qinghai, southern Lingxia, central Gansu, Inner Mongolia, northern Shanxi, northwest Hebei	3000~3200	586~672
3	Northern Xinjiang, southeast Gansu, southern Shanxin, northern Shanxin, southeast Hebei, Shandong, Henan, Jilin, Liaoling, Yunnan, southern Guangdong southern Fujian, northern Jiangsu, northern Anhui	2200~3000	502~586
4	Hunan, Guangxi, Jiangxi, Zhejiang, Hubei, northern Fujin, northern Guangdong, southern Shanxi, southern Anhui, Heilongjiang	1400~2200	420~502
5	Sichuan, Guizhou	1000~1400	335~420

1.2. The Region of Maybe Developing Solar Power Generation in China

Suitable for condition of development solar energy power generation the region, primarily have: 1). solar energy resources are plentiful but bare or expensive fossil energy; 2). Combine solar energy generating electricity with other renewable energy together, such as supply with water power resources or wind power resources each other, then increase the adjustable electricity deal; 3). region ecosystem system is weak, and environmental protection mission is heavy, so can not develop region well that generate electricity with fossil fuel; 4). wide ground but few person, and electricity grid is difficult to cover region.

From above solar energy resources distribution in China, we can see, first, second, and third type regions which have plentiful solar energy resources or more plentiful main concentration in Tibet, Xinjiang, Inner Mongolia, Qinghai, Ningxia and Gansu, these belong to China's western region, and the economy is opposite and drop behind, and the energy is limited, particularly Tibet, Qinghai, ecosystem environment is weak, environmental protection mission is heavy, unsuitable for developing standard power plant. At the same time, our country is being put into practice in development of the west region, have the certain policy support. Therefore, these regions are the most region that can probably develop the solar energy generate electricity. At the same time, also not rule out built handful demonstrate grid power plant in advanced economical cities, these regions technique level is higher, financial power support is easily solved, can gain in experience quickly from the demonstrate engineering.

Brief introduction as follows for probable regions development of solar energy generate electricity

1. Tibet region:

Briefing of the national economy: whole region population is 2,700,000 in 2003, the area has the smallest population density. Gross product is 18.46,000,000 RMB in whole region in 2003, the average is 6838 RMB/year.

Situation of power resources: water energy and solar energy resources are abundant, and have certain geothermal resources, but lack fossil fuel resources, coal, oil and gas etc., whole region coal yield is only 22 thousand tons in 2003.The native region power supply is main water power, at the end of 2003 year, total power is 380 MW, among them water power is 296 MW, geothermal power station is 30.2 MW, rest is fuel station, and annual use electricity is 711 million kWh, per-capita using electricity is 254.13 kWh/ year. Whole region did not switch on electricity is 40 country, and switch on electricity rate is 80.95%; did not switch on electricity is 716 village, and switch on electricity rate is 58.68%; did not switch on electricity families is 60 thousand families, switch on electricity rate is 70.55%.

Electric power exists key problem The power station equipments are old, efficiency is low; power supply grid radius is large, carrying density is low, network investment is large; power grid construction is weak, and power supply depends is low; Did not become the whole region of unify electricity grid provide and manage.

2.Qinghai region:

Briefing of the national economy: whole region population is 5,340,000 in 2003,expect for eastern region has a larger population density, other region has wide ground but few person. Gross product is 39.02,000,000 RMB in whole region in 2003, the average is 7,307 RMB/year.

Situation of power resources: in 2003, total power is 4250 MW, among them water power is 15.016 million kWh, per-capita using electricity is 2812.03kWh/ year. But use electricity primarily is the high expenditure energy industry (because the proportion of water and electricity is higher, and the level of electric price is lower)

Electro life is still very low. In 2003, the country which did not switch on electricity is 29, the rate of switching on electricity is 93%; the village which did not switch on electricity is 626, the rate of switching on electricity is 84.74%; door which was switched on electricity is reach 80 thousand doors, the rate of switching on electricity is 88.78%.

3.Southern Xingjiang region:

Briefing of the national economy: whole region population is 1,934,000 in 2003, gross product is 18.498,000,000 RMB in whole region in 2003, the average is 9,565 RMB/year. The population and industry of north region is more advance in whole region, south region has immense dakelamagan great desert, has scarce population, has abundance in coal resource, petroleum, and natural gas resources.

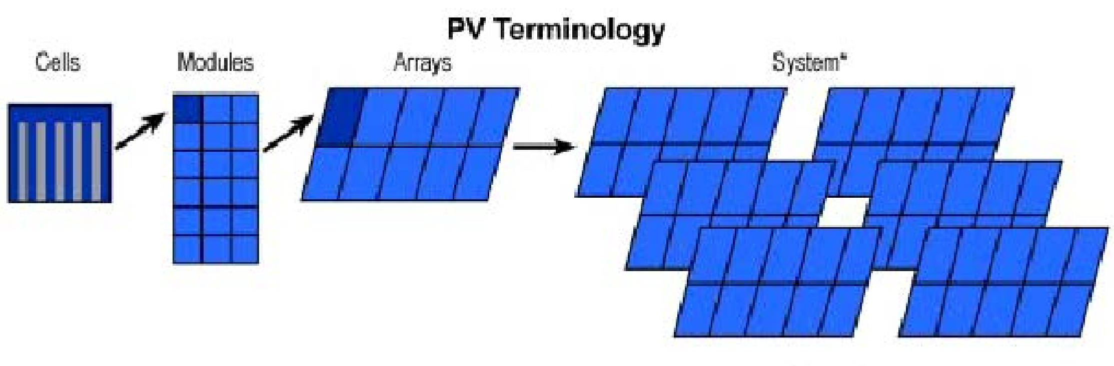
2 The Development and Status of Solar Energy System Worldwide

Solar energy generate electricity have some kinds, mainly by heat process "concentrating solar power (CSP)", including tower generate electricity, line concentrating parabolic (trough) generate electricity, point concentrating parabolic (dish) generate electricity, solar power chimney generate electricity, thermion generate electricity, solar photovoltaic generate electricity, difference in temperature generate electricity etc, and other kinds of generate electricity which without heat process, such as "photovoltaic generate electricity (SPV)", photo-induction generate electricity, photochemistry generate electricity and photobiology generate electricity etc. But for the moment only two styles are applied in deed: photovoltaic generate electricity and solar thermal generate electricity. SPV transfer solar energy to electric energy directly, solar energy/electric energy; solar thermal generate electricity use solar energy heat working medium, the working medium acted in the turbine generator produce electric energy.

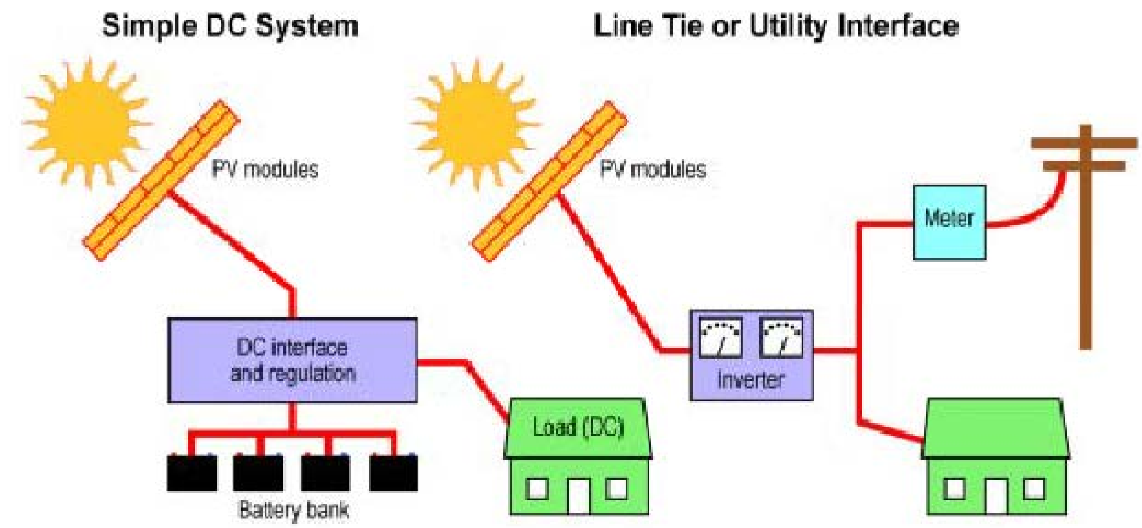
2.1. Solar Photovoltaic (SPV)

SPV makes use of "photovoltage effect", is one of the most conventional technologies of solar energy generate electricity.

The system of SPV consists of two parts: solar cell and the match system. The solar cell system consists of solar cell array, solar cell array consists of the photovoltage groupware (solar cell groupware) in series and parallel connection. Complemented system include control, power inverter etc.



The system of SPV can be separated in two great sorts, the independent system of SPV and the combination system of SPV. The independent system of SPV is the system which only depended on solar cell array battery to supply power, or can complement by the other electrical source in the necessary time. The combination system of SPV is the system that uses the DC generated by solar cell array to commutated to AC by the power inverter first, and then be used with the AC of electrical network.

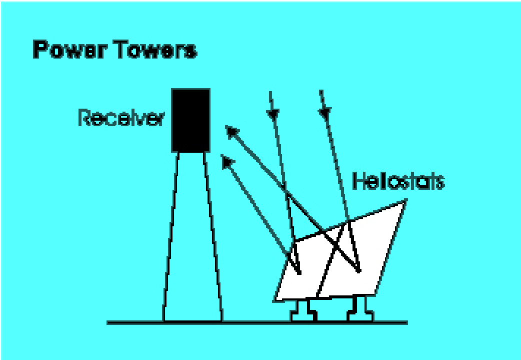


In the system of SPV, the key part is solar cell array, the characteristic of solar cell array is decide the characteristic of SPV. The main excellence is: 1) simple framework, small bulk and light; 2) easy to fix and transport, the short cycle of building; 3) easy to startup, simple maintenance; 4) clean, safe, without noise; but the shortcoming is in evidence, energy is disperse, the area is large, system cost is high resulting in high costs per kwhr., battery storage has short life and is expensive, intermittence is great.

2.2. Concentrating Solar Power (CSP)

The system of generating electricity by solar thermal included five styles: power tower system, trough system, dish system, basin system, and heat airflow system.

2.2.1. Power Tower System



The power tower system is called the concentrated solar heat generate electricity system. It uses hundreds to thousands of plane reflector arrays to reflect the solar radiation onto the receiver which is placed on the top of the high tower, the working material is heated to produce superheated steam, and to drive turbine to generate electricity, thereby transforming the solar energy to electricity energy. The power tower generate electricity system includes four parts: the setting of collecting light, the setting of collecting heat, the setting of storing heat, and turbine.

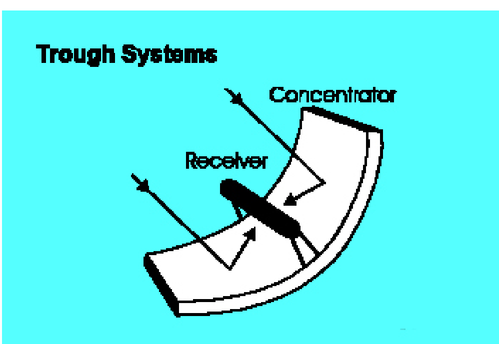
It can be seen in the list 2.1-1 which have the power tower generate electricity system in 10 places in the world, in the main is the two large demonstrate project in USA: "Solar One" and "Solar Two", the two projects' capacity are 10MW."Solar One", which operated from 1982 to

1988, aggregately produced 38,000MWh.”Solar Two” is the redesign of “Solar One”, which was put into production in 1996, it used molten-salt to be the material which transmitted heat and stored the heat energy, can continuously generate electricity in the cloudy and night days. For ”Solar Two” succeeding run, arose better interest all over the world, in particular Spain, Egypt, Morocco, and Italy. There is a 40MW capacity’s power tower system which was in the process of layout, using thermodynamic storage, can drive a 15MW turbine in the 24 hours one day. On the desert of southwest USA, it is planning to build a 30~50MW power tower plant. The investment of the first power tower plant is about one hundred million dollars, the price of the electricity is 15 cents/KWh, after taking into account scale effect and advancement of technique, maybe drop to 7 cents/KWh. Systems using molten nitrate as the heat transfer fluid and storage medium require fossil-fueled heaters to prevent the nitrate from solidifying.

Table 2.1-1 Power Tower System in the world

Project	Country	Power Output(MWe)	Heat Transfer Fluid	Storage Medium	Operation
SSPS	Spain	0.5	Liquid sodium	sodium	1981
EURELIOS	Italy	1	steam	Nitrate Salt/water	1981
SUNSHINE	Japan	1	steam	Nitrate Salt/water	1981
Solar One	USA	10	steam	Oil/Rock	1982
CESA-1	Spain	1	steam	Nitrate Salt	1983
MSEE/Cat B	USA	1	Molten Nitrate	Nitrate Salt	1984
THEMIS	France	2.5	HI-Tec Slat	HI-Tec Slat	1984
SPP-5	Russia	5	steam	Water/Steam	1986
TSA	Spain	1	Air	Ceramic	1993
Solar Two	USA	10	Molten Nitrate	Nitrate Salt	1996

2.2.2. Parabolic Trough System



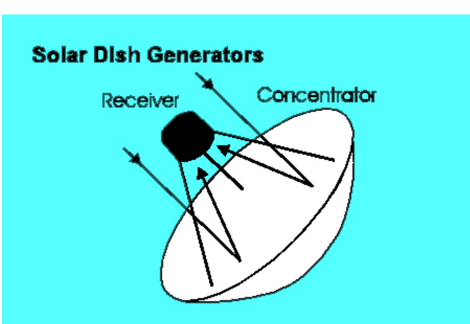
The system of solar power trough generate electricity, is also named as the parabolic trough solar power generated electricity system, is called the distributed system of solar power heat generate electricity. It arranges legions of line concentrating parabolic (troughs) setting which is used to collect light and collect heat by series-parallel connection, thereby can collect more higher temperature heat energy, heating working material, produce superheated steam, additional heat from an auxiliary fossil fueled boiler is added to drive the turbine to generate electricity. The system of solar power trough generated electricity include four parts: the setting of collecting light and heat, the setting of auxiliary energy, the setting of storing heat, and turbine generate equipment.

Over the period from 1985 to 1994, in the California desert of the USA, there have been nine solar power trough plants built. Their total capacity is 354 MW. They all supplement collected solar energy with 25% natural gas in order to boost the solar-alone steam temperature to a level needed for efficient turbine operation. The low temperature steam generated by the parabolic trough concentrators is to low for low-cost electrical generation. For example, SEGS IX solar-to-grid efficiency is 19% when it uses the fossil turbine shown in the below table, but the efficiency is only 12.9% when the solar-alone turbine is used. But because of ten years' experience of operation and continuous technical improvement, along with operation and maintenance cost reductions, in the near future, one should expect lower generation cost. Table 2.1-2 lists some USA system characteristics of SEGS 1 through 9

Table 2.1-2

SEGS Plant	1st year of operation	Net output (MW_e)	Solar Field Outlet Temp(°C/°F)	Solar Field Area(m^2)	Solar Turbine Eff. (%)	Fossil Turbine Eff. (%)	Annual Output (MWh)	Solar-alone to Gridoverall efficiency
I	1985	13.8	307/585	82,960	31.5		30,100	
II	1986	30	316/601	190,338	29.4	37.3	80,500	
III & IV	1987	30	349/660	230,300	30.6	37.4	92,780	
V	1988	30	349/660	250,500	30.6	37.4	91,820	
VI	1989	30	390/734	188,000	37.5	39.5	90,850	
VII	1989	30	390/734	194,280	37.5	39.5	92,646	
VIII	1990	80	390/734	464,340	37.6	37.6	252,750	
IX	1991	80	390/734	483,960	37.6	37.6	256,125	12.9%

2.2.3. Dish System



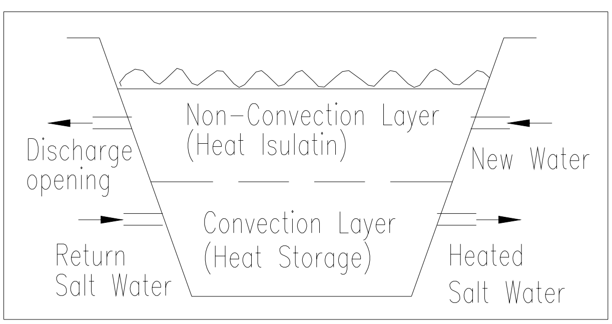
A type of solar dish system of solar energy generation of electricity, is based on the use of a single parabolic concentrating dish with a piston Stirling engine generator located at the prime focus. The power output of each dish is small, but each unit can be disbursed separately. A system is made up of the following parts. They are: 1) the parabolic dish concentrating mirror to focus the incident sunshine to one point namely the prime focus; 2) At the focus point is placed the sunlight receiver where it heats the working material (typically hydrogen or helium) to a high temperature; 3) the Sterling engine; 4) the generator.

The characteristic of this type dish system is high efficiency. In 1980, eight dish systems with capacities of 25KW and using Stirling engines were developed by MDA with plans to go into production in America. But at the present time, this system is being studied for improvements of the sterling motor and to the use of the thermal pipe to the receiver.

During the decade of 1970, direct generation of electricity from equipment located at the prime focus of a parabolic dish such as the sterling dish was shown to not be able to generate electricity continuously during days when there are occasional clouds because they were not able to store energy. This problem would eliminate these types of systems from being considered for location anywhere except in a desert and connected to a much larger grid.

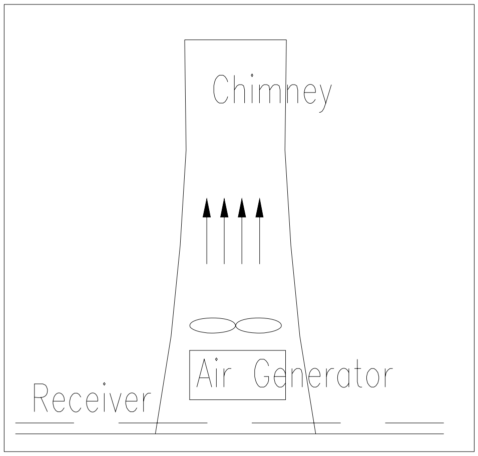
During this same period, another parabolic dish technology was developed that did recognize this need for very high temperature thermal storage-buffered electrical generation using steam Rankine processes. This system technology developed in the USA during the 1970's, was evaluated by Jet Propulsion Laboratory's desert test site in early 1979 with U.S. Department of Energy funding. These developments led to the configuration of fully dispatchable solar electric power generating plants with capacities of 6 MW and greater that are able to be located even in regions where the daily sunlight is sporadic.

2.2.4. Solar Basin System



The solar pool is a salt pool which have a PH indicator salt, the water in the salt pool have a definite salt grades in the vertical direction, fresh water upside, more heavy salt water downside, sunshine permeate the water upside to downside, heat the salt water on the bottom, afterwards under the condition that don't disturb the main body of the water in solar pool, maintain the necessary density grads, draw out the heated salt water from the bottom of pool, after changed the heat via the heat changer get back to the bottom of pool. The solar pool generate electricity namely is the characteristic of solar pool, build solar pool with nature salt lake, it namely is a huge flat solar heat collection, use it to absorb solar energy, heating the low boiling point working material to be superheat steam by heat changer, to drive the turbine to generate electricity. Israel built the first solar pool power plant in the world beside the dead sea, the capacity is 150KW in 1975, built a solar pool power plant beside the dead sea in1983, its capacity is 5MW.

2.2.5. Solar heat Airflow System



The generating electricity of solar heat airflow build a huge erect chimney in the center of huge folding floor solar air heat collection, under the bottom of chimney open the suction opening under the air heat collection's cover board, fix wind wheel over it, the floor air heat collection bases the temperature effect to generate heat air, from the suction opening to chimney, form the heat air flow, drive the wind wheel fixed in the chimney to drive the generator to generate electricity. Spain built a solar energy heat air flow demonstrated power plant whose capacity is 50KW, its chimney height is 194.6m; Australia is planning to build a 1000m chimney, it contain 8 mil^2, this solar energy heat air flow power plant's investment is 7 hundred million dollar which its capacity is 200MW.

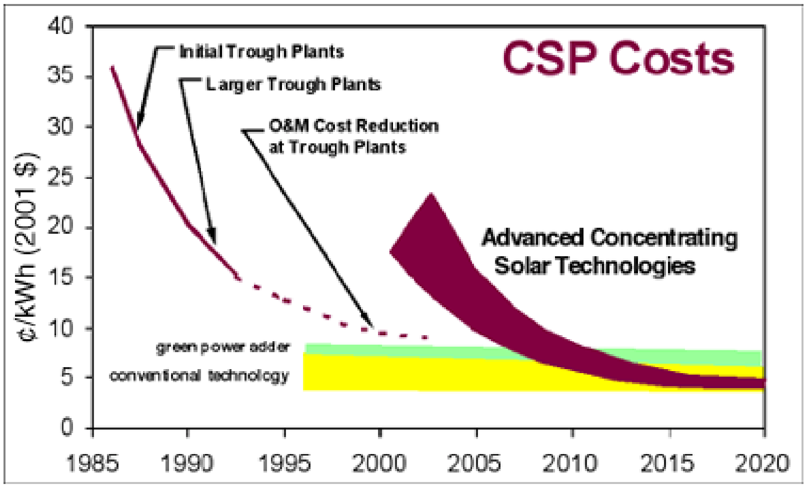
2.3. The Comparison of Concentrating Solar Power Technique

Above six systems can divide to two styles in the solar collect mode: one is the system of solar power generation which concentrate light, also it is high temperature solar power generation system, tower system, trough system and two dish systems belong to this style; second is the system of solar power generation that does not concentrate light, also it is low temperature solar power generation system, solar pool and heat airflow system belong to this style.

Based on the learning of the solar energy heat generate electricity technique both here and abroad, the compare of the capability and technique characteristic of these 6 systems of solar energy heat generate electricity as follow:

Type	The mode of Gather light and heat	WorkTemperature (°C)	Suitable for commercial plant capacity(MW)	annual average plant efficiency(%)	Units invest (dollar/kW)	technology feature estimate	Application range
Tower generate electric	Gather light high temperature	560	10～200 *	7～20 *	4400～2500 *	1 track is complex, difficulty is big 2. .the cost for energy collection is high 3.already come into middle test stage	Big capacity net generate electricity
Trough Generate electric	Gather light middle temperature	400 with fossil fuel boost	30～320 *	11～16*	4000～2700 *	1.track is more simple 2.the cost for energy collection is lower 3.already come into commercial generate electricity stage	Middle capacity net generate electricity
Multiple Dish Rankine System	Light Gathering Very high temperature	1150	132KW ~ 75MW*	19 ~ 27*	2000 ~ 1050*	1. simple ganged array tracking 2.cost for energy collection is low 3.energy storage for low lifecycle cost 4. ready for demonstration	Small to large capacity net generate electricity with significant long life energy storage
Dish Stirling System	Gather light high temperature	650	5～25 kW*	12～25*	12600～ 1300*	1.track is complex 2. .the cost for energy collection is high 3. trial stage	Small capacity generate electricity, no energy storage and requires large grid connection
Solar Basin System	Non-gather light low temperature	80	300～1000			1.have no use for tracking 2.the cost for energy collection is low 3. large-scale development of wreath sea 4.empolder and make use is limitin cilme 5.be placed in development of the demonstrate applied stage	Big capacity net generate electricity
Solar Heat Airflow System	Non-gather light low temperature	50	5～20			1. have no use for tracking 2. the cost for energy collection is low 3.technique is more simple 4.be placed in the principle to experiment the stage	Middle and small capacity net generate electricity

Note: “*”points number for the period of 1997~2030.



The cost of the solar energy heat generate electricity will continue to drop with the advancement of power plant and improvement of technique. At present this is about 9~12 cents/KWh. Along with combination solar generate electricity with fossil fuel, its electrovalence can be dropped to 8 cents/KWh. After the technique be improved and high efficiency store energy setting be developed. The electrovalence will drop to 4~5 cents/KWh in the decades after now. See on the figure.

2.4. The Foreground of Concentrating Solar Power Technique

The solar energy heat generate electricity technique is same as the other solar energy technique, continue to consummate and develop, but its commercialized degree does not achieve the level of SPV. From 1980~1985, Luz Corporation built commercialized slot line focusing trough generate electricity systems whose capacity is 354MW. Since the 1990 years, the energy source department of America check and analyze this system that passed “Heat generate electricity plan”, make sure the optimization e project of system running and maintain, analyze subsystem automation, alignment of heat collection device and cleanse, reliability, the efficiency of sub-system. The analysis and check prove that the cost of running, maintaining will drop 30%. But since ten years, this system was not been enlarged and extended to consider it a larger commercial system.

The energy source department of America established the “solar energy heat generate electricity plan” to actively promote the commercial course of heat generate electricity. This plan included:1) Advancement of the solar energy heat generate electricity systems and components; 2). Cooperation with the solar energy electric power industry to explore techniques that are the same with heat generate electricity now and tomorrow; 3) Develop education to inform user and make them cognizant of meaning of this technique. The key of plan is helping solar energy industrial community to explore commercialized manufacture, evaluate technique in store to let it enter into market in the near future. The other content of “heat generate electricity plan” is industrial developed plan, to promote cost reduction of heat generate electricity.

Europe established the solar energy generate electricity plan, the content include:1) development to be provided with cost efficiency of the parabolic trough system and tower receiver system whose capacity is 100~200MW; establish solar energy/fuel combination dish system; 2) development to optimize design of solar energy heat power plant; establish the demonstrated setting in the south of Europe and north of Africa; 4) establish the plan of system and component to be explored, including component and system optimized design; 5) the examination and development of new system; 6) explore 30MW level industrial system; 7) explore market.

Looking at the range of world, the technique of solar energy use and industry has gone to developing age from development stage. From the heat generate electricity actuality and plan, we can find that these industrial developed countries are in the solar energy heat generate electricity commercial eve, government and industrial community actively promote the commercial course. For example: international energy agency (IEA) based solar and chemical energy association (solarPACES) is a framework that aims at specially developed heat collection solar energy technique. Current attending members are America, England, Sweden, Spain, South Africa, Mexico, Israel, Germany, France, Egypt, Brazil, Australia, and Algeria. In 2002, the market development plan of heat collected solar energy was established. In the ten years aftertime, this plan will establish the setting of heat collecting generate electricity whose capacity is 5GW. At present in Europe, there is ”Europe solar energy heat electricity industry association (ESTIA)”, supports the country plus mid of Europe and north of Africa to develop solar energy heat electricity. In America there is “solar energy generate electricity industry associate (SEIA)”, to support America and Mexico to develop solar energy heat electricity; Germany regeneration bank (kfw) lend its aid to India Mathania solar energy heat electricity project; UN industry develop organize (UNIDO) and Global Environment Administration (GEF) lend its aid to four commercial solar energy power plant projects in Egypt, India, Mexico, Morocco.

The goal in “The Solar Thermal Power Stratagem Programming” made by U.S Department of Energy in 1996 year is as follow:

Time	**Worldwide**	**Tower**	**Dish**	**Trough**	**USA Capacity**
2005 year	2GW	35%	30%	35%	0.8GW
2010 year	5GW	30%	40%	30%	1GW
2015year	10GW	30%	50%	20%	2GW
2020 year	20GW	35%	50%	15%	4GW

In Germany and UK, they established “renewable energy electric power supply law” in 2002 to be favorable to power price in the network, and prescribe definite scale of renewable generate electricity capacity. Expect at least, following with development of national economy, sustainable development programming is carried into execution and environmental protection is recognized day after day, it will enter into a developed period of using solar energy to generate electricity.

3 CENICOM™ Features

3.1. Overview

The CENICOM™ concept for collecting solar energy for convenient storage and delivery as electricity on demand has been refined to produce a design that is the smallest module for efficient steam Rankine cycle conversion of thermal energy to electrical power. One CENICOM™ consists of 88 three (3) meter diameter concentrating mirrors to collect solar energy, transport it to a common high-temperature storage material where it is accumulated for conversion to electricity when there is a need for electrical energy. The annual energy generation is nearly 371,000 KWH-e (kilowatt-hours electrical) in areas with excellent direct sunlight. Thermal energy storage is done at very high temperature which makes possible the generation of very high quality steam. This allows a single CENICOM™ to run a suitable Steam Rankine cycle prime mover to generate electricity (suitable meaning high efficiency). No fossil fuels or combustion processes are used in any way in the CENICOM™ process

Most electrical power applications are much larger. CENICOM™'s can be clustered to match many of these larger applications. We have defined a cluster as 36 CENICOM™ collection arrays, 36 thermal storage vaults, and 36 steam boilers whose output steam lines have been aggregated to power a single large centralized turbine-generator. A cluster would collect and deliver 13,380,000 KWH-e. per year in areas of excellent direct sunlight. Single or multiple cluster applications generally drive a pair of turbine generators. Two turbines are needed because one provides base load generation and the other provides the means of generating power from the excess solar energy available during the summer. Two turbines provide redundancy that allows for continuous operation while doing maintenance or repair on one of the turbine generator systems.

Multiple cluster power plants are achievable and practical. The losses from the necessary increased steam line runs are more than off-set by the gain in efficiency of the larger turbine-generator. If the clusters are arranged in a North-South line, there is no adjacent cluster shading. The power generating equipment would be housed near the center of the line of clusters to minimize losses in the steam piping. There is no theoretical limit to the number of clusters that can be connected to a pair of turbine-generator sets. Practical consideration such as piping and site preparation may limit power plants to something on the order of 12or 14 clusters.

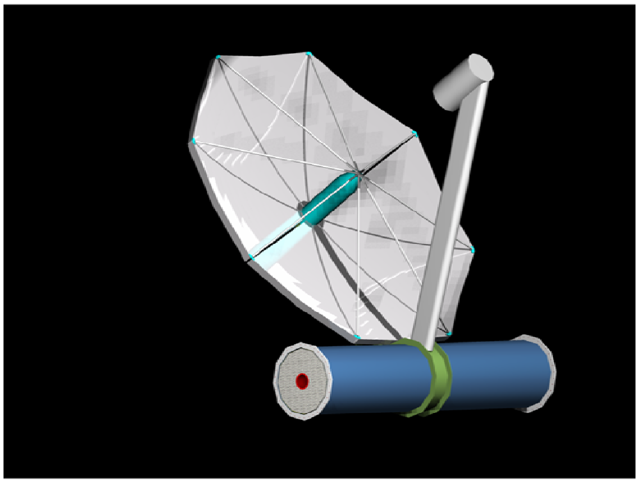
A single CENICOM™ would require 2,469 square meters of land area. The base only takes up 105 square meters. There are 2,364 square meters of useable space up to a height of 7.34 meters under each CENICOM™.

In all of these configurations, the CENICOM™ concept is set apart from all other large-scale alternative energy processes being considered such as Photovoltaic arrays, Tower's of Power, Line-Focus parabolic trough systems, and Sterling Engine concentrators in several ways. First and foremost, it collects, transports, and stores energy at temperatures up to 2,000 degrees F (1,093°C) in an inert solid material. At these temperatures, very high enthalpy steam can be generated. PV arrays and Stirling dishes store no energy, line focus troughs are limited to 600 degrees F (316°C), and the tower of power is limited to 1,100 degrees F (593°C) and uses a salt as its working fluid. Both the tower and trough use fossil fuel to supplement their solar processes. CENICOM™ is the only process that delivers electrical energy to its user community on-demand and at high efficiency without the use of supplemental combustible fuels.

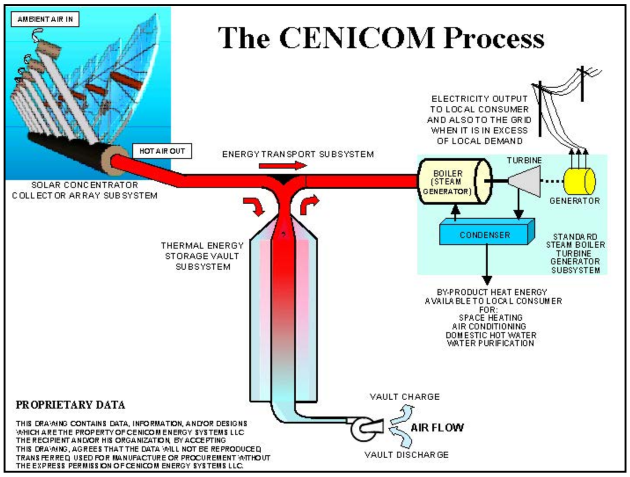
In areas of excellent direct solar radiation the following table would apply:

Power Plant Size	Power Produced per Year KWHrs/Year	Ground Area Required Square Meters	Ground Area Available for other uses up to 7.34 meters above ground Square Meters	Solar Radiation Collection Area Square Meters
1 CENICOM™	371,000	2,469	2,364	650
6 CENICOM™s	2,230,000	14,815	14,183	3,900
1 Cluster	13,380,000	91,362	85,098	23,400
2 Clusters	26,760,000	182,724	170,196	46,800
6 Clusters	80,280,000	548,171	510,589	140,400
8 Clusters	107,040,000	730,894	680,785	187,200

3.2. CENICOM™ Description

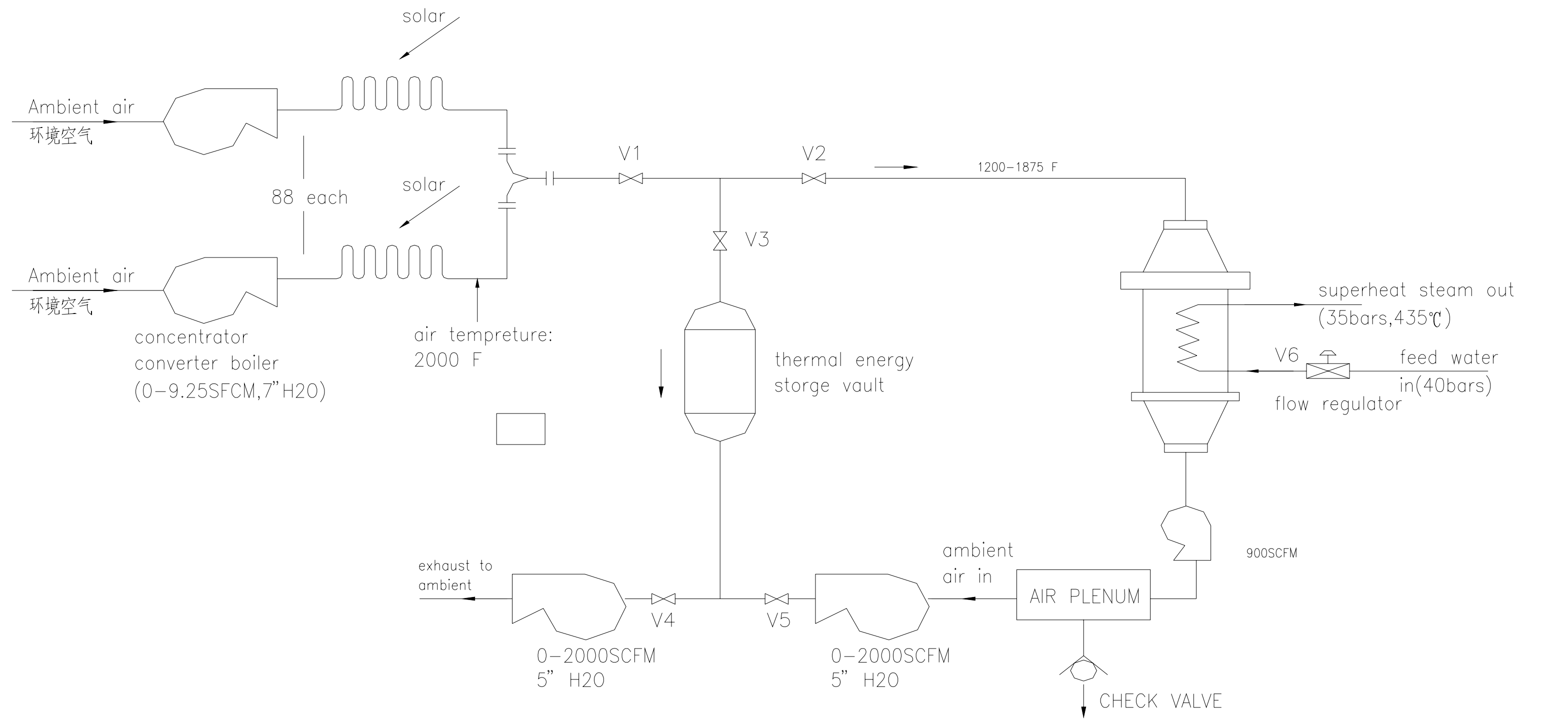


CENICOM™ intercepts and concentrates solar energy using parabolic mirrors to focus the radiated energy to a point. The diameter of the focused spot between ½ power points is 6.31 cm. The peak flux density of the focused spot is 217 W/cm^2 when incident solar radiation on the mirror is 0.10W/cm^2. This allows the system to create thermal energy at high temperatures higher than 2,500^{0}F (1371^{o}C). Ambient air injected into the focal plane components is servo regulated to maintain a set temperature of hot air leaving the focal plane components at 2,000°F (1093°C). Inlet ambient air at 15.70 standard cubic meters per hour (9.25 SCFM) is the maximum flow rate required for a solar intensity of 1,000 W/m^2. There is very little loss as the energy is converted from concentrated solar radiation to heated air inside a cavity with a small entrance opening. The cavity is insulated to limit heat loss due to radiation, convection and conduction. All losses related to the converter total up to 3.56%.



CENICOM™ employs 88 parabolic mirrors (concentrators) closely coupled and mounted on a common base carousel to collect solar energy convert it to 2,000 °F (1093°C) air and is transported to a storage vault where it is accumulated and held for later use. Thermal energy is transported by hot air through a series of insulated pipes and rotary joints in such a way as to aggregate the energy from each of the concentrators into one line entering the thermal energy storage vault. The collection system is heavily insulated to minimize energy loss during energy transport. As the heated air is passed into the storage vault, it exchanges its thermal energy with the inert energy storage material in the vault. Energy is extracted from the vault when needed to create electrical power using a Steam Rankine cycle turbine- generator. The collection and storage process is completely independent from the electrical generation and delivery process. As the demand for electricity requires, air is used to take the thermal energy from the vault to the boiler.

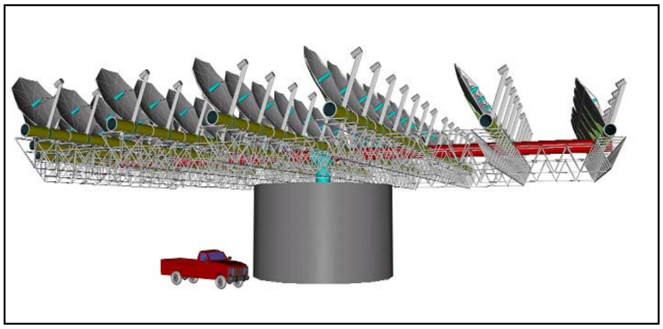
The air flow diagram for one CENICOM™ depicts this process. The status of each valve is indicated for each of the various operating conditions of the system. The boiler is a conventional single pass steam boiler originally designed for use in exhaust gas cogeneration systems. Energy is taken from the vault by heating air (exchanging from the vault material to the air) that has been injected into the cool end of the storage vault. This air will take the heat energy to the boiler. Air, a very safe transport medium, is used to take the thermal energy to the vault and to remove the energy from the vault. Air, even at high temperatures, is not combustible or very corrosive, therefore it is quite safe.



	during sunlight	V1	V2	V3	V4	V5	V6
1	No demand for steam/ electric	open	close	open	open	close	close
2	medium demand	open	partial open	partial open	close	open	partial open
3	high demand	open	open	open	close	open	open
	during no-sun periods						
1	No demand	close	close	close	close	close	close
2	demand	close	open	open	close	open	open

scfm=0.0283 m^3/h
=standard cubic foot per minute 标准立方英尺/分钟

AIR FLOW DIAGRAM



The CENICOM™ System points its 88 mirrors directly at the sun with azimuth and elevation angle pointing control. The azimuth angle pointing is accomplished by rotating the large carousel holding all of the mirrors on a common base. For elevation tracking, the mirrors are pointed by tilting the rows in unison using one mechanism and one drive motor for the entire array.

The array is able to point over an azimuth angle of over 300 degrees, and an elevation angle of –10 to +100 degrees.

This close-coupled design on a common base is a direct result of our use of air as the energy transport medium. Air, because of its low density unlike steam, cannot be conducted long distances without high thermal losses.

For a single CENICOM™, the central tower contains the thermal storage vault, the boiler, turbine-generator, grid interface, and control room. For clusters, the turbine generator, grid interface, and control room are centralized.

CENICOM™ and clusters of CENICOM™s can be applied in many ways by sizing the vault storage capacity and the output turbine to match the application requirements, as summarized in the table below.

Application	Grid	Storage Requirements	During Periods of Minimum Sun	During Periods of Maximum Sun	Size Range
24/7 Power (Local Grid Priority Mode)	Own Local	3 – 4 Summer sunny days	Requires no power from other sources	Significant extra Power for: - Seasonal Industry - Water Purification - Ice Manufacturing - Off-Load to Another Grid	1 CENICOM™ to 1 cluster
Energy Neutral	Own Local & Another Grid	2 – 4 Summer sunny days	Receives ≈ 10% of Power from Other Grid	Delivers ≈ 10% of Power to Other Grid	1 CENICOM™ to 6 clusters
Peaking (Regional Grid Priority Mode)	Local or Regional Grid	2 – 3 Summer sunny days	Delivers all energy stored at near peak load time on demand	Delivers all energy received and stored at near peak load	1 cluster to 14 clusters

3.3. Why CENICOM™

The need for Non-polluting Power.

Environmental concerns have brought focus to the need for non-polluting power. Collecting energy from sunlight allows the generation of power without creating any type of air, water, or earth pollution. This is the primary factor for selecting solar-thermal steam electric power production.

The need for a system that does not require fossil fuel in any respect.

Several hybrid systems are being used that use fossil fuel to upgrade the quality of the produced steam. Fuel up to 25% of the output is being used as in the case for parabolic trough line focus power plants. This produces pollution and green house gases. Other systems use fossil fuel to keep the energy transport medium (salt) in a molten state during periods without sun. This heating requirement also produces pollution and green house gases. The tower of power system at Daggett California has this problem.

The need for high temperatures and its relationship to high concentration ratios.

When considering thermal cycles that can be used for power generation, the efficiencies of such cycles are related to the temperature differences inherent in the cycle. Therefore it is desirable to achieve high temperatures. Parabolas of revolution can focus direct sunlight so that temperatures at the practical limit for efficient storage and electrical generation can be achieved.

The need for separating energy collection from generation can only be done if storage is possible.

The need to separate energy collection from power production is key to providing continuous uninterrupted useable energy especially from renewable resources. It is also true of power production from expendable resources. For example, coal is mined and transported (energy collection) and then power is generated when needed by combustion of the coal at a later time.

Separating energy collection from power generation is accomplished by a thermal storage vault that stores thermal energy until needed for power generation. Wind and photovoltaic systems are generally referred to as sporadic power sources because they supply power at the same time they collect the power whether it is needed or not.

The need for clean power versus intermittent power and the problems of intermittent power on grid control.

The hidden costs of keeping standby power in place in case the wind stops or the sun does not shine has not been considered. In fact, if a large portion of power comes from wind or other intermittent power generations sources it becomes very hard to keep the grid from galloping out of control as it did in the country of Denmark, if there is not an equivalent amount of dispatchable power on standby.

The need for reasonable power tariffs from solar power.

Costs of the plant are the dominant portion of the tariff calculation. Plant costs for delivering power from Photovoltaic arrays is very high for a given annual output. Since the fuel cost is zero for solar power plants that do not use auxiliary energy from fossil fuel, the other cost that is included in the tariff calculation is maintenance and repair. For a location with excellent direct sunshine, such as Lhasa, Tibet, the annual electrical power supplied by one CENICOM™ cluster is 12,300,000 KWHrs. electrical per year.

3.4. Scaling Risks for CENICOM™ Solar Power Plants

Collecting solar energy is easily scaleable. The acquisition of more energy requires the increase of the collecting area. There is some small advantage of scale in turbines, generators and other equipment but this is small in relation to the scaling of the collecting area. The scaling of Solar Power Plants is essentially linear. If four times the electrical power in KwHrs is desired, the plant must have four times the collecting area. There is essentially no risk in increasing the size of a Solar Power Plant.

3.5. Practical Experiences in the Application of CENICOM™

History provides sufficient evidence to doubt the economic success of any solar scheme. We believe that solar energy has its place in society. Making practical use of both successes and failures provide the necessary steps to avoid the pitfalls of the past. This allows the goals for both performance and economic success of the next generation renewable energy to exceed expectations with reasonable risks.

The co-founders of CENICOM™ Solar Energy LLC have been directly involved with solar thermal technology using point-focusing parabolic dish concentrators since 1973. The principals are sole owners of patents and trade secrets created as partners in a partnership called OMNIUM-G. At OMNIUM-G in the mid 1970's, they developed, manufactured, and delivered single-collector solar powered electrical generating systems worldwide to customers in private industry, universities, government agencies, and individual consumers.

In-house development of a wide range of manufacturing technologies assured a strong proprietary knowledge base. A thorough understanding of these fabrication processes produced a level of error-free product design specifications unobtainable with manufacturing outsourcing. A staff of 40 specialists working in a 16,000 square foot manufacturing facility (plus 8,000 sq ft test area) located in Anaheim, California produced early single-collector systems at the rate of one system per month.

During this period, both the business and its customers were funded or motivated by government sponsored solar initiatives[1]. The business ceased operations in 1982 when such initiatives were no longer available, both domestically and internationally. Of course, all units have gone through the basic research for which intended and have long since been dismantled. A summary of experience is included in Appendix A.

In the intervening period the principals have come to realize that solar energy harvesting had to be at a scale much larger than single collector systems. In 1989, the task of designing a system of practical size was started. The engineering task, including trade-off analyses and design to the piece-part level, was accomplished. A considerable amount of manufacturing

[1] Grant money, Small Business Association loans, or consumer tax credits

engineering was also accomplished. The result is a refined design of an optimally sized on-demand solar electrical generating system, called CENICOM™ (**C**oncept for an **E**nergy-**N**eutral **I**ndustrial **COM**plex.

A thorough understanding of the refined design is based on finely tuned "lessons learned" methods validated in the mid-1970's for single-collector systems. An archive of documentation is included in Appendix A. This substantial historical experience points to the means of producing critical components that will be difficult for any competitor to match. These methods have led to a product that will endure a 30-year life. For a competing company or technology to attract market share, they will have to undergo a similar investment in manpower to equivalently compete with the extraordinary physical specifications of the process (manufacturability, transportability, reliability and maintainability). Its introduction to the market will secure its market position and dominance for years to come.

All system design engineering and component manufacture design have been done to establish the best procedures for manufacturing, testing, packaging, shipping and on-site assembly. Remaining design definition is primarily devoted to updating drawings, procedures, and material selection to current market choices, costs, and availability.

4 Case Studies

There are a variety of other CENICOM™ configuration variations that, in some cases, are unique. Stand-by power plants for critical industrial operations and hospitals, the ballasting of inexpensive nighttime electrical power to valuable daytime peak-demand period power, and the storage-when-available and delivery-on-demand of wind-generated electrical power are all practical variants using the same developed components. The heating of air to very high temperature without any fossil fuel can also be used in a variety of ways to complement fuel cell technology and other industrial processes.

In addition, heating of air to very high temperatures, coupled with the versatility built into CENICOM™**,** enable the creation of unique process conditions which open up new environmentally-safe and ecologically-clean application possibilities, only a few of which have been thus far identified**.** For example, the system can be used in a variety of ways to complement fuel cell hydrogen generation, enhanced oil recovery, waste detoxification, soil purification, desalination, and hybrid-vehicle refueling stations.

Presented in this report are four case studies for applying the CENICOM™ system to two projects in the two specified locations of Lhasa, Tibet and Beijing, China. A summary of these case studies is shown in the table below. The extraordinary advantages of the versatility of CENICOM™ are illustrated in these case studies. One is that it can be configured in clusters to produce facilities for large-scale energy systems, either electricity or steam energy applications.

Each cluster consists of thirty-six (36) CENICOM™ systems connected by steam supply lines to centralized power generation equipment. Case 1A is configured to have one cluster (36 CENICOM™'s) powering a centralized 6 MW turbine generator. This power plant can be expanded in stages by adding up to two more clusters to the collecting field supplying steam to the same turbine with the result of improving the annual capacity factor from 0.2546 to 0.764. The 3-cluster size is analyzed as case 1B.

CASE NO.	LOCATION	PRIORITY USE	SIZE		ANNUAL CAPACITY FACTOR	PROGRAM-ABLE	ANNUAL THERMAL OUTPUT (kWh)	ANNUAL ELECTRIC OUTPUT (MWhrs)
			CENICOM™	CLUSTER				
1A	Lhasa, Tibet	Electric	36	1	0.2546	Time of Day	0	13,380
1B	Lhasa, Tibet	Electric	108	3	0.764	Time of Day	0	40,151
2A	Beijing, China	Heating / Cooling	3	0	N/A	Seasonal	1,110,000	0.708
2B	Beijing, China	Electric grid plus Emergency Backup	1	0	0.29	Fixed	N/A	0.312

4.1. CASE 1a: 1-CENICOM™ Cluster Dispatchable Power Plant In Lhasa, Tibet

The performance of a CENICOM™ Cluster power plant was evaluated using a computer simulation of the operation of the power plant hour by hour for an entire year using actual measured hourly data of direct sunlight. The plant is assumed to be located in Lhasa, Tibet. No hourly data exists for this location, so a site was chosen which had similar conditions to Lhasa where data was available. Initially, Flagstaff, Arizona data was selected to be used because of its similar latitude, and altitude. Both cities have more than 3,000 hours of sun per year. Later it was decided that Daggett, California was a better representation. The power plant is intended to operate in its "Dispatchable Power" mode. In this mode of operation, the arrays of concentrating collectors collect energy from sunlight, convert the energy to thermal energy at up to 2,000 degrees F (1093 ^{o}C), transports this energy to centralized thermal storage media, and holds it there until there is a demand for the energy, usually during the daily peak demand period of the early evening hours. At that time, the stored thermal energy is extracted and used to generate steam at 435 degrees C and 35 bars pressure, and at an aggregate rate of

28,619 kilograms per hour (92,961 Lbs/Hr) to power a 6,000 kW turbine-generator. The generator continues to run at full power until the end of the peak demand period or until the thermal storage has been used. For this analysis, the peak demand period was programmed to be from the beginning of hour 17 until the end of hour 24. Since this cycle is repeated every day, the size of the thermal storage vault was fixed at 2 bright sunny days of energy. Up to 5 days of storage is practical. However, for this application, 2 days was determined to be sufficient for maximum annual production.

The following table summarizes the important results of the simulation. To visualize what happens hour by hour, refer to the figure "CENICOM™ Cluster Power plant Performance during One Sunny Day". This is an example of the hourly status of the sun, the turbine, and the storage vault for one day. The two charts that follow show this activity for 60 other days of the year. Notice the build-up and decay of the storage vault status during periods of no-sun and good sun.

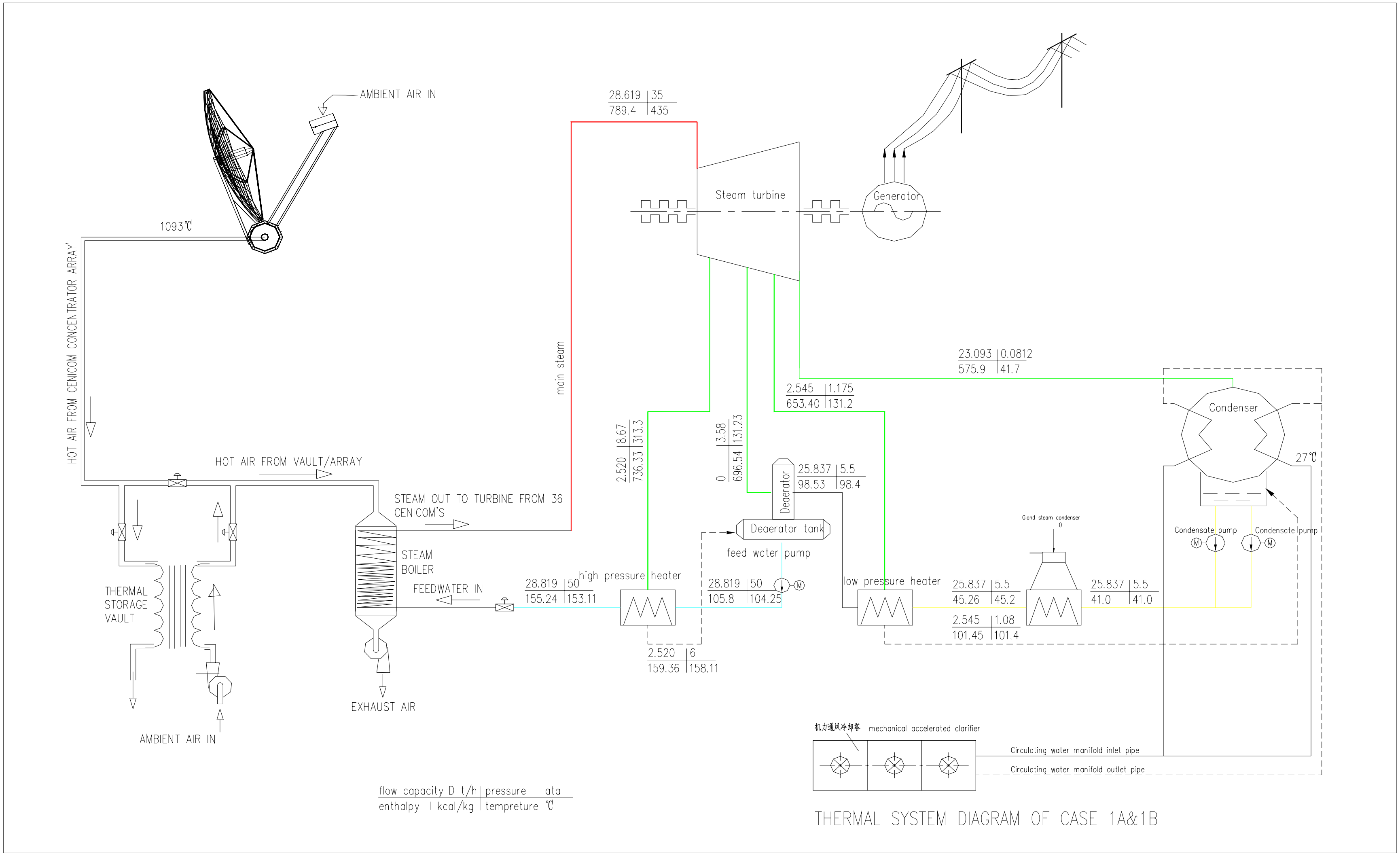
Finally, the last chart summarizes the number of days during the year that the turbine operated for 1,2,3---through 8 hours each day. A review of these results indicates that a small improvement in performance can be made by prohibiting the turbine from operating for a period of time shorter than 2 or 3 hours. The thermal storage vault makes it possible for "minimum run time" to be set to any interval between 1 and 8 hours starting at any selectable hour of the day.

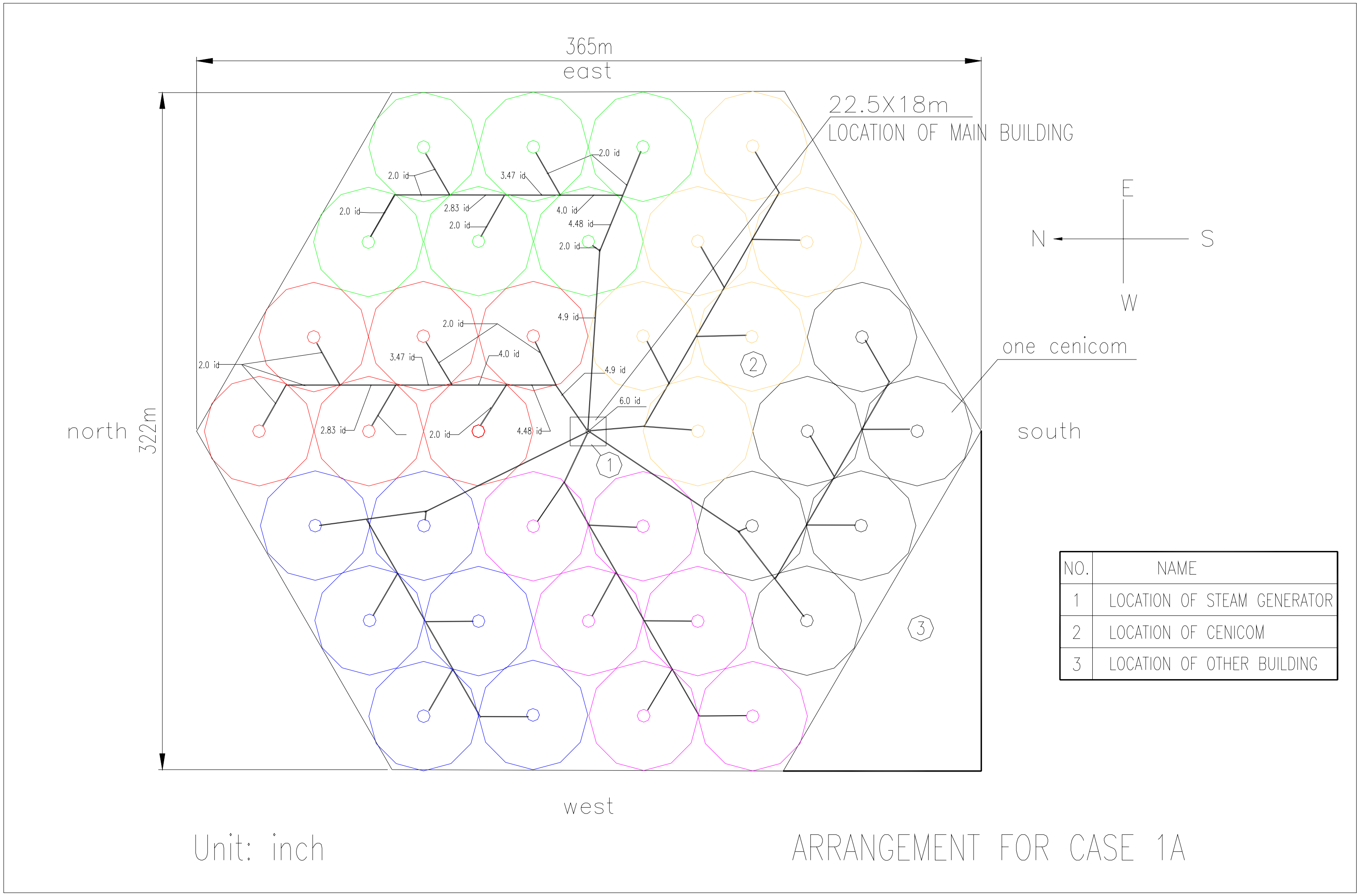
A review of the analysis of this power plant configuration consisting of one cluster (36 CENICOM™'s) teamed with a 6 MW turbine-generator indicates its value as a dispatchable power plant with an annual capacity factor of 0.2546. An extension of this configuration leads to the grouping together of 3 clusters (108 CENICOM™'s) generating steam for the same 6 MW Turbine-generator thus raising the power plant annual capacity factor to 0.764

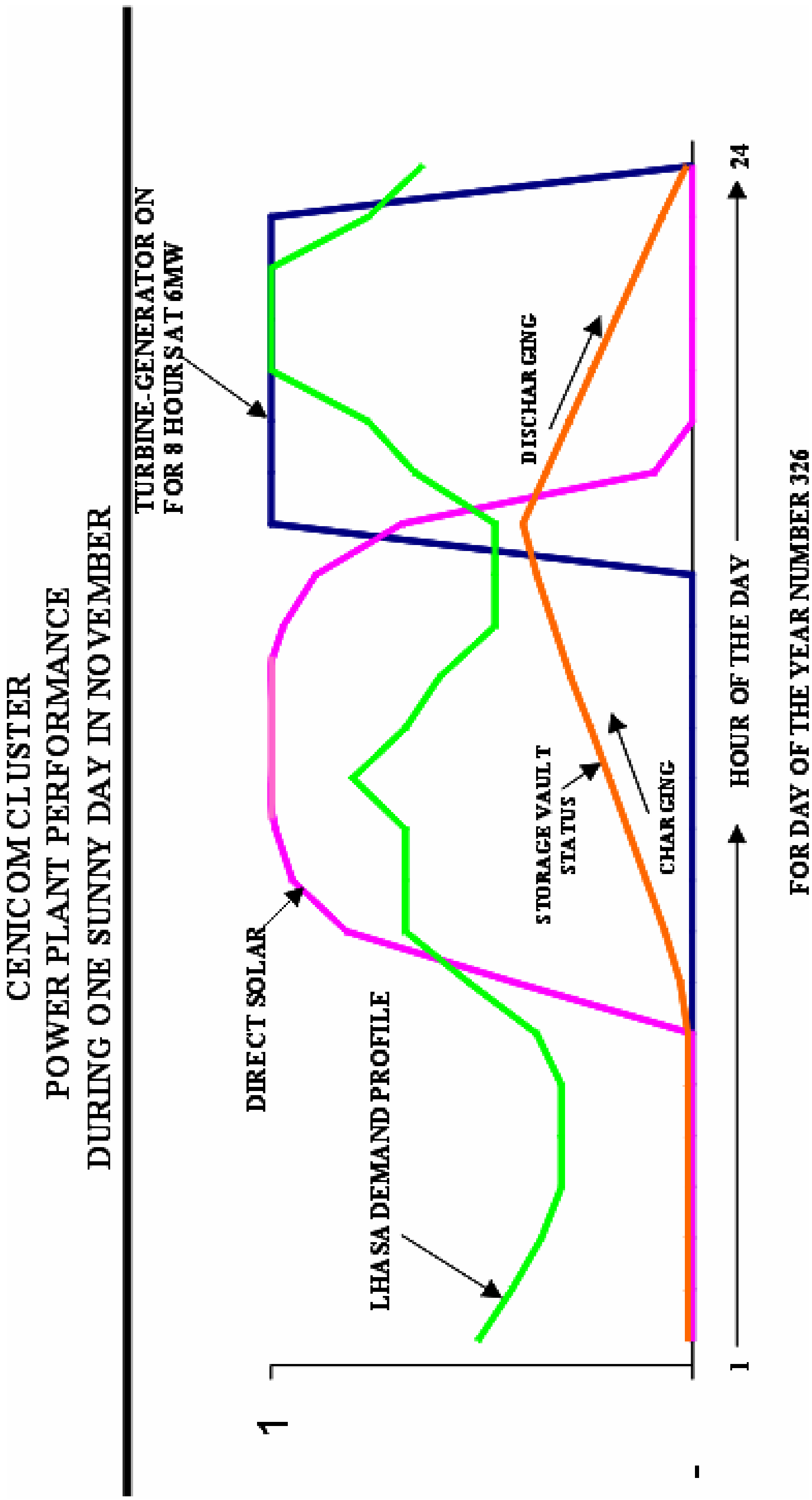
1- Cluster Power Plant
Table of Characteristics, Efficiencies, and Losses:

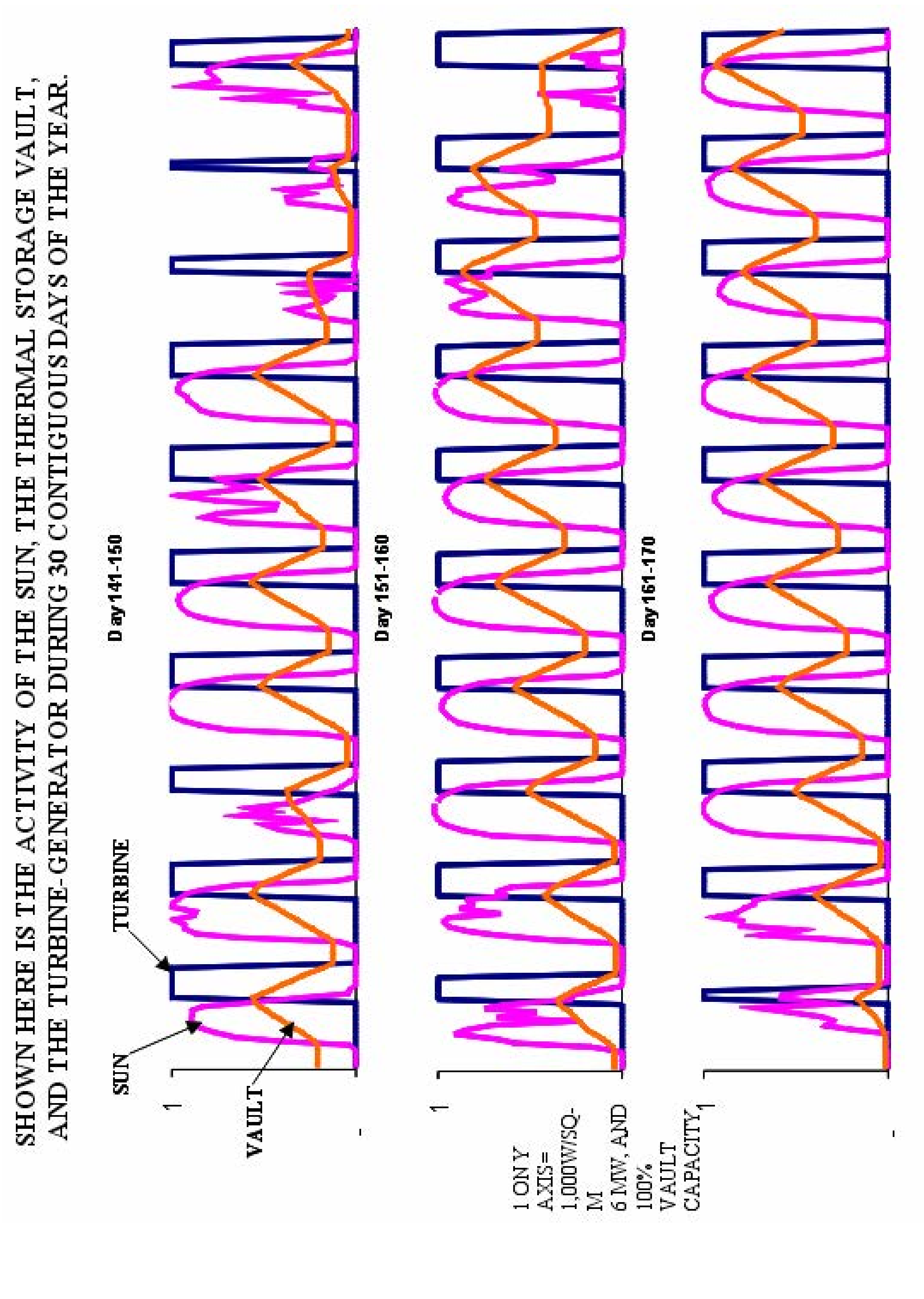
Original analysis using Flagstaff Data with new data annual output is 12,300 MWHrs/yr.

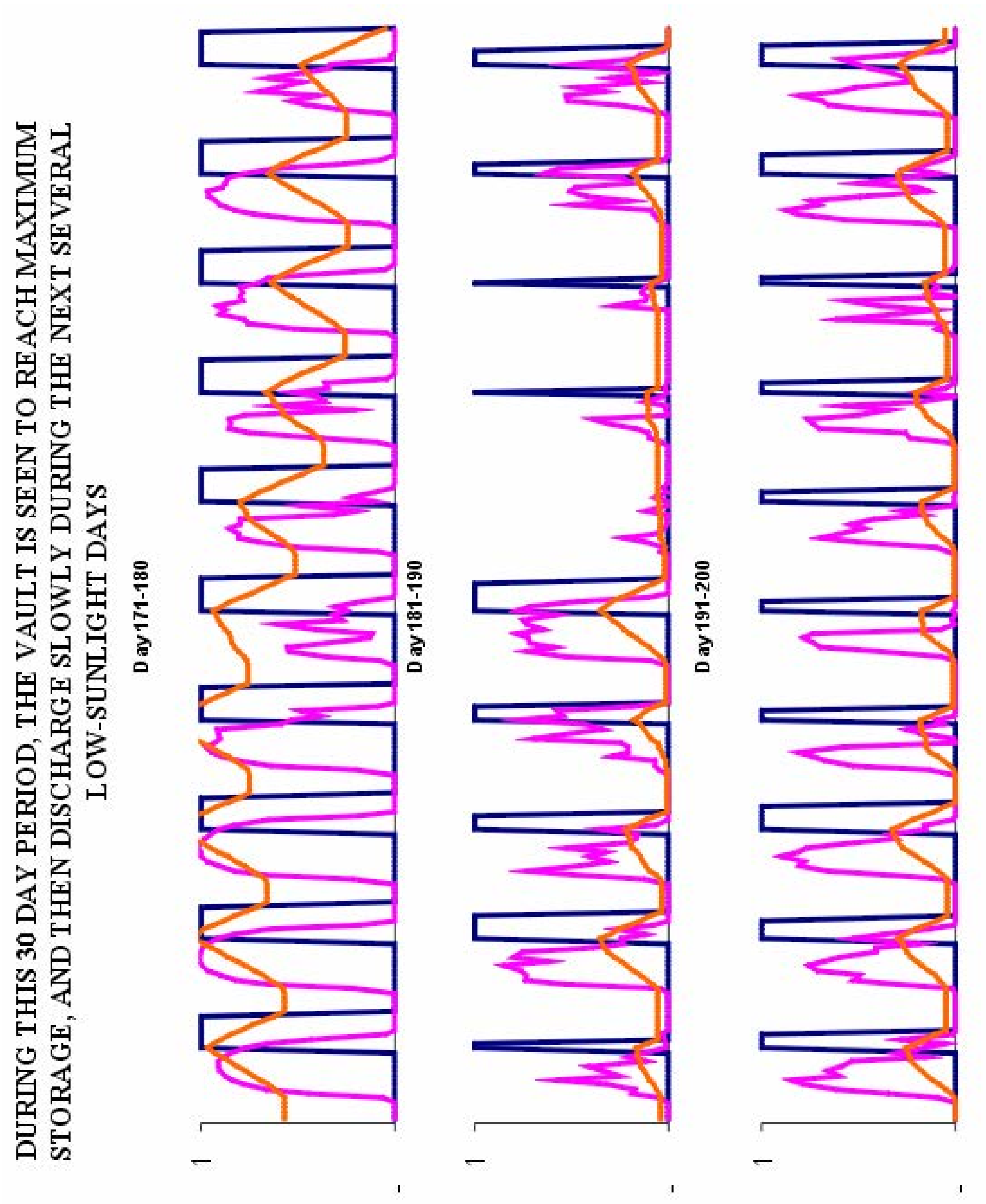
Item	Value	Unit
ANNUAL DIRECT SUNLIGHT	2,798	KWH/SQ-M
COLLECTOR ARRAY TOTAL INTERCEPT AREA	23,412	SQ-M
ROW-TO-ROW SHADOW LOSS	0-5.5%	DEPENDS ON SITE
ANNUAL INTERCEPTED DIRECT SUNLIGHT	65,504,239	KWH
MIRROR SPECULAR REFLECTIVITY	91.0%	
CONVERTER APERTURE WINDOW TRANSMISSION	98.5%	
CONVERTER GEOMETRIC CAPTURE	99%	
CONVERTER THERMAL EFFICIENCY	98.9	
CONVERTER EXIT AIR SET TEMPERATURE	1,093	DEG. C
DOWNCOMMER LOSS	4.73%	
BRANCH AND TRUNK LINE LOSS	8.42	
THERMAL STORAGE VAULT THERMAL	99.88%	
STEAM BOILER EFFICIENCY	95%	
STEAM LINES FROM BOILERS TO TURBINE	98.8%	
BOILERS OUTPUT STEAM PRESSURE	35	BARS
BOILERS OUTPUT STEAM TEMPERATURE	435	DEG. C
TURBINE-GENERATOR SIZE	6,000	KW
INPUT STEAM RATE	28,619	T/H
PARASITIC POWER REQUIRED	2.19%	
OVERALL SOLAR-TO-TURBINE INPUT EFFICIENCY	70.21%	
ANNUAL ELECTRIC ENERGY GENERATED	13,380,000	KWH-e
TURBINE-GENERATOR TOTAL OPERATING TIME	2,231	HOURS/YEAR
ANNUAL CAPACITY OF Turbine-Generator (T-G)	0.2546	
T-G PROGRAMMED START TIME	17:00	
T-G PROGRAMMED STOP TIME	24:00	
ANNUAL SUNLIGHT-TO-GRID EFFICIENCY	20.43%	
CONTIGUOUS LAND USE FOR CLUSTER	91,362	SQ-M
SINGLE CENICOM™ STORAGE VAULT SIZE	3,000	KWH-electric equivalent

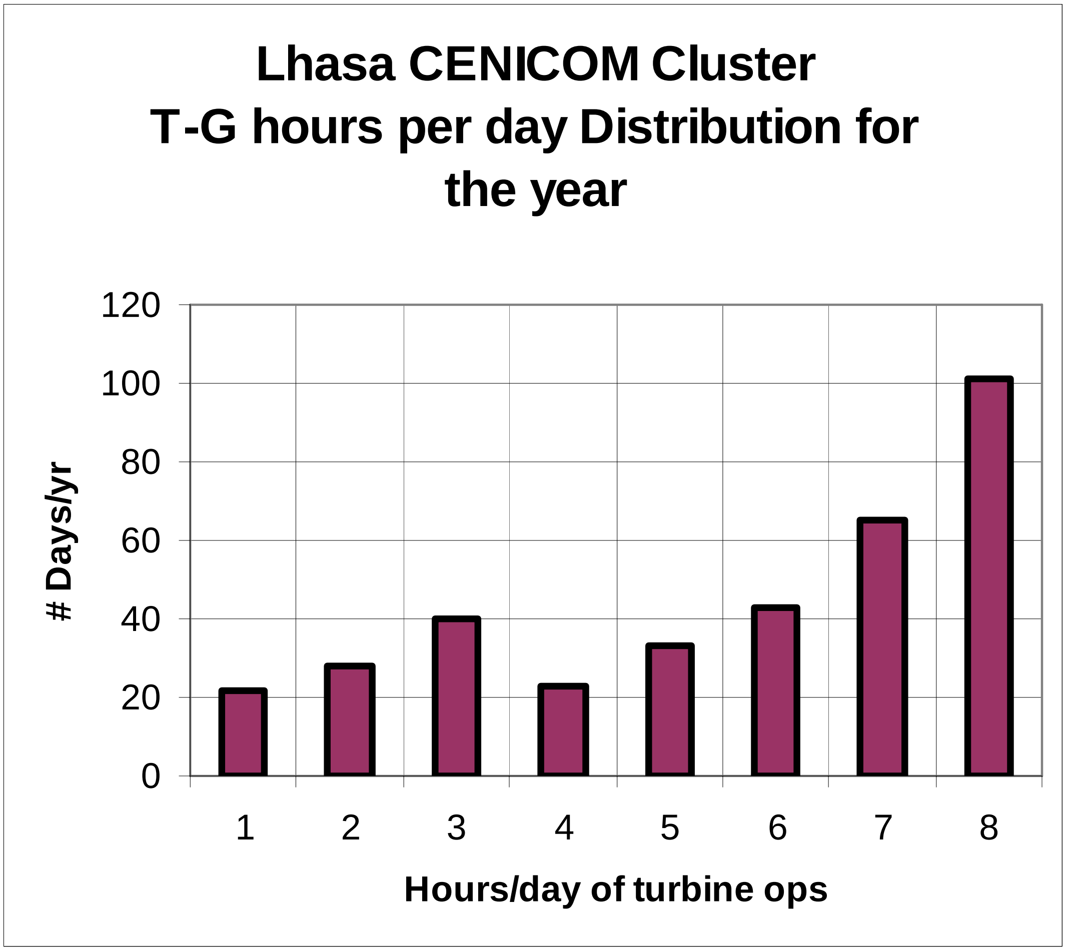

AMBIENT AIR IN
1093℃
HOT AIR FROM CENICOM CONCENTRATOR ARRAY'
HOT AIR FROM VAULT/ARRAY
THERMAL STORAGE VAULT
AMBIENT AIR IN
STEAM OUT TO TURBINE FROM 36 CENICOM'S
STEAM BOILER
FEEDWATER IN
EXHAUST AIR
main steam
28.619 35
789.4 435
Steam turbine
Generator
23.093 0.0812
575.9 41.7
2.545 1.175
653.40 131.2
Condenser
27℃
2.520 8.67
736.33 313.3
0 3.58
696.54 131.23
Deaerator
25.837 5.5
98.53 98.4
Deaerator tank
feed water pump
Gland steam condenser
Condensate pump
Condensate pump
28.819 50
155.24 153.11
high pressure heater
28.819 50
105.8 104.25
low pressure heater
25.837 5.5
45.26 45.2
25.837 5.5
41.0 41.0
2.545 1.08
101.45 101.4
2.520 6
159.36 158.11
机力通风冷却塔 mechanical accelerated clarifier
Circulating water manifold inlet pipe
Circulating water manifold outlet pipe
flow capacity D t/h pressure ata
enthalpy I kcal/kg tempreture ℃
THERMAL SYSTEM DIAGRAM OF CASE 1A&1B


365m
east
22.5X18m
LOCATION OF MAIN BUILDING
E
N
S
W
one cenicom
north
322m
south
west
Unit: inch
ARRANGEMENT FOR CASE 1A
NO.
NAME
1
LOCATION OF STEAM GENERATOR
2
LOCATION OF CENICOM
3
LOCATION OF OTHER BUILDING


CENICOM CLUSTER
POWER PLANT PERFORMANCE
DURING ONE SUNNY DAY IN NOVEMBER
TURBINE-GENERATOR ON
FOR 8 HOURS AT 6MW
DIRECT SOLAR
LHASA DEMAND PROFILE
DISCHARGING
STORAGE VAULT
STATUS
CHARGING
1
HOUR OF THE DAY
24
FOR DAY OF THE YEAR NUMBER 326


SHOWN HERE IS THE ACTIVITY OF THE SUN, THE THERMAL STORAGE VAULT, AND THE TURBINE-GENERATOR DURING 30 CONTIGUOUS DAYS OF THE YEAR.
SUN
TURBINE
VAULT
Day 141-150
Day 151-160
Day 161-170
1 ON Y AXIS= 1,000W/SQ-M 6 MW, AND 100% VAULT CAPACITY
1


DURING THIS 30 DAY PERIOD, THE VAULT IS SEEN TO REACH MAXIMUM STORAGE, AND THEN DISCHARGE SLOWLY DURING THE NEXT SEVERAL LOW-SUNLIGHT DAYS
Day171-180
Day181-190
Day191-200


Lhasa CENICOM Cluster
T-G hours per day Distribution for the year
Days/yr
0
20
40
60
80
100
120
1
2
3
4
5
6
7
8
Hours/day of turbine ops

4.2. CASE 1b: 3-CENICOM™ Cluster Dispatchable Power Plant in Lhasa, Tibet

The performance of the power plant configuration consisting of 3 clusters (108 CENICOM™'s) coupled with the same 6 MW Turbine-generator used in case 1A produced results that scaled linearly in annual output, and capacity factor. This is because the slight increase in steam line losses of the larger field of collectors was off-set by the slight improvement in turbine overhead loss reduction. The increase in annual capacity factor from 0.234 to 0.703 resulted in longer daily run-times and therefore less overhead loss (e.g. start-up and shut-down energy).

The matching of 3 clusters to a 6 MW turbine generator is an appropriate for combination based on the seasonal variation in available sunlight. The CENICOM™ thermal energy storage vault provides the day-to-day and even week-to-week buffering of energy for uninterrupted delivery, but it cannot ballast energy from season-to-season. Therefore, the solar driven power plant prime mover must be sized to handle the available energy during the summer months. It is unlikely that any solar driven power plant can ever achieve an annual capacity factor of 1.00 because of this variation without solving the season-to-season storage problem.

The following table includes only the items that have changed from case 1a.

3-Cluster Power Plant

Table of Characteristics, efficiencies, and Losses_

Original analysis using Flagstaff Data with new data annual output is 36,900 MWHrs/yr.

Item	Value	Unit	Remarks
PLANT POWER CAPACITY	6	MW	
COLLECTOR ARRAY TOTAL INTERCEPT AREA	70,234	SQ-M	
ANNUAL INTERCEPTED SUNLIGHT	196,512	MWH	
ANNUAL ELECTRIC GENERATION	40,151	MWH-E	PLUS 118 MWH-E RESERVE IN VAULT AT YEAR-END
TURBINE-GENERATOR TOTAL OPERATING TIME	6,691	HOURS/YR	(ALL AT 6 MW)
ANNUAL CAPACITY FACTOR	0.764		
T-G RUN TIME	8 HRS	MINIMUM	24 HOURS MAX
ANNUAL SUNLIGHT-TO-GRID EFFICIENCY	20.5%		
CONTIGUOUS LAND USE	274,086	SQ-M	
PARASITIC POWER	2.0%		

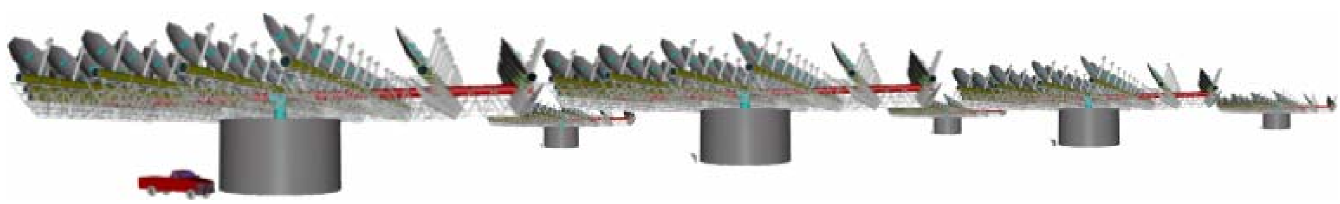
The 3-cluster site is shown in the drawing on page 41. The overall north-south dimension of the field is 967 meters. Note that this orientation minimizes the sunrise-sunset shadow losses. The power conversion equipment is located in a building at the center of the middle cluster. As a reminder, each circle represents 1 CENICOM™ with its own thermal storage vault and steam generator (boiler). Also shown are the interconnected steam lines.

Each CENICOM™ operates mostly under its own control along with a few executive commands related to steam conditions. Air path temperature, vault control, array pointing, and fault monitoring are all done at each unit. This independence makes it possible for any CENICOM™ in the field of 108 to shut down for maintenance if necessary at any time without interruption of the aggregate steam rate requirement at the turbine input. The entire field produces 191,496 metric tons of steam per year at 435°C and 35 bars pressure.

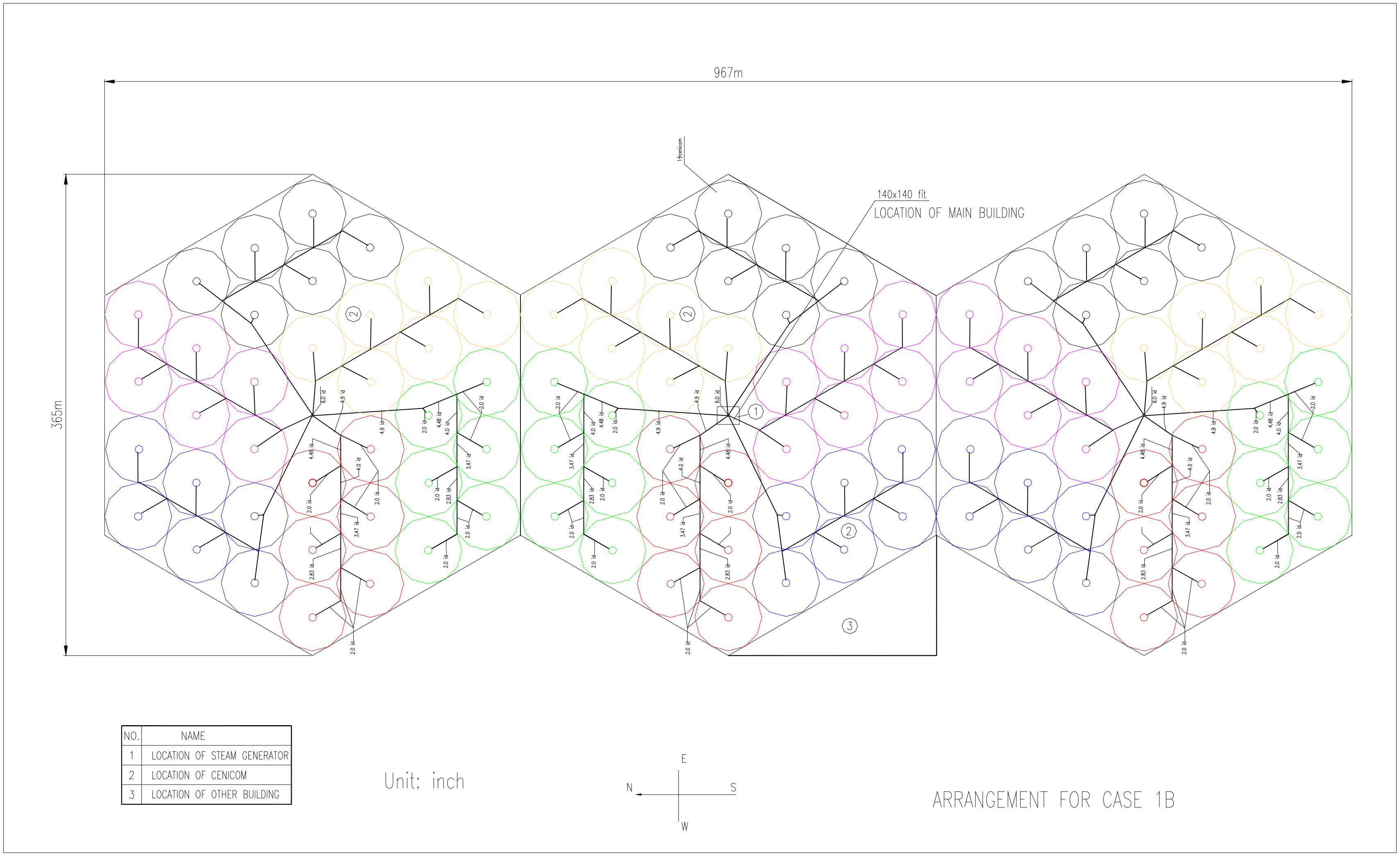
Although the entire field occupies 274,086 m^2, most of the area under each array is useable for other purposes. The view of several units as seen from ground level is shown in the picture below illustrating this feature.

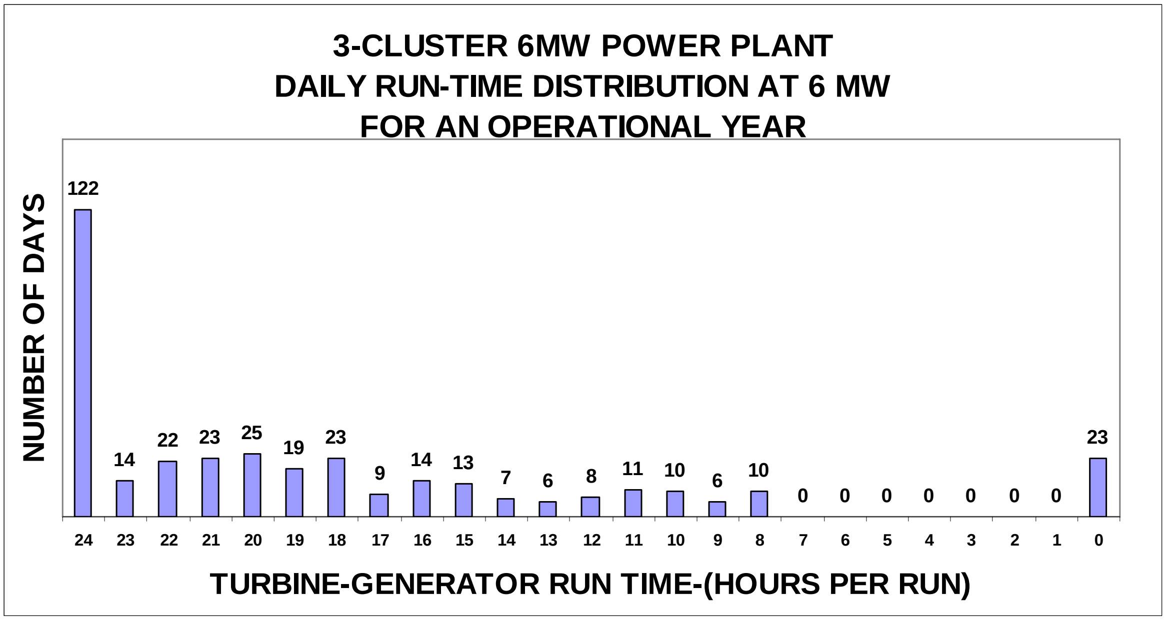
VIEW OF A PART OF A CLUSTER FIELD

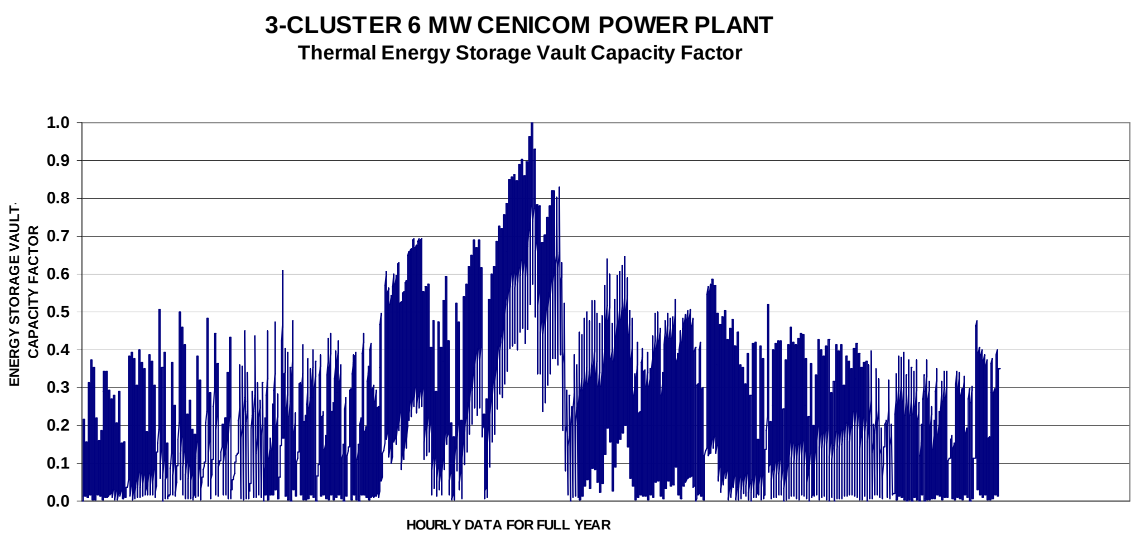
SHOWING SPACE UNDER THE ARRAYS



The performance of the 3 cluster power plant was evaluated using the same hourly direct solar data and simulation used to evaluate case 1a. In this simulation, the turbine minimum run-time was set at 8 hours. The results for the year are tabulated in the chart below. For 122 days of the year (mostly during the summer) the turbine ran continuously for 24 hours each of those days. There were only 10 days that the turbine ran for the minimum 8 hours suggesting that the minimum run time can be increased.


967m
365m
140x140 fit
LOCATION OF MAIN BUILDING
NO. NAME
1 LOCATION OF STEAM GENERATOR
2 LOCATION OF CENICOM
3 LOCATION OF OTHER BUILDING
Unit: inch
E
N
S
W
ARRANGEMENT FOR CASE 1B


3-CLUSTER 6MW POWER PLANT
DAILY RUN-TIME DISTRIBUTION AT 6 MW
FOR AN OPERATIONAL YEAR
NUMBER OF DAYS
122
14
22
23
25
19
23
9
14
13
7
6
8
11
10
6
10
0
0
0
0
0
0
0
23
24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
TURBINE-GENERATOR RUN TIME-(HOURS PER RUN)


3-CLUSTER 6 MW CENICOM POWER PLANT
Thermal Energy Storage Vault Capacity Factor
ENERGY STORAGE VAULT CAPACITY FACTOR
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
HOURLY DATA FOR FULL YEAR

The above plot shows the hourly status of the storage vault throughout the year from January through December. Most of the year, the vault capacity remains below 50% as the system cycles through its daily capture, store and dump cycles. There is a short period during the middle of the year that the vault exceeds 100% capacity by approximately 5%. This is easily within the vaults margin of safety. If the size of the turbine was increased to accommodate this, the annual capacity factor would be lowered.

4.3. Comparative Analysis of The Performance of a CENICOM™ Cluster and a Photovoltaic Array In Lhasa

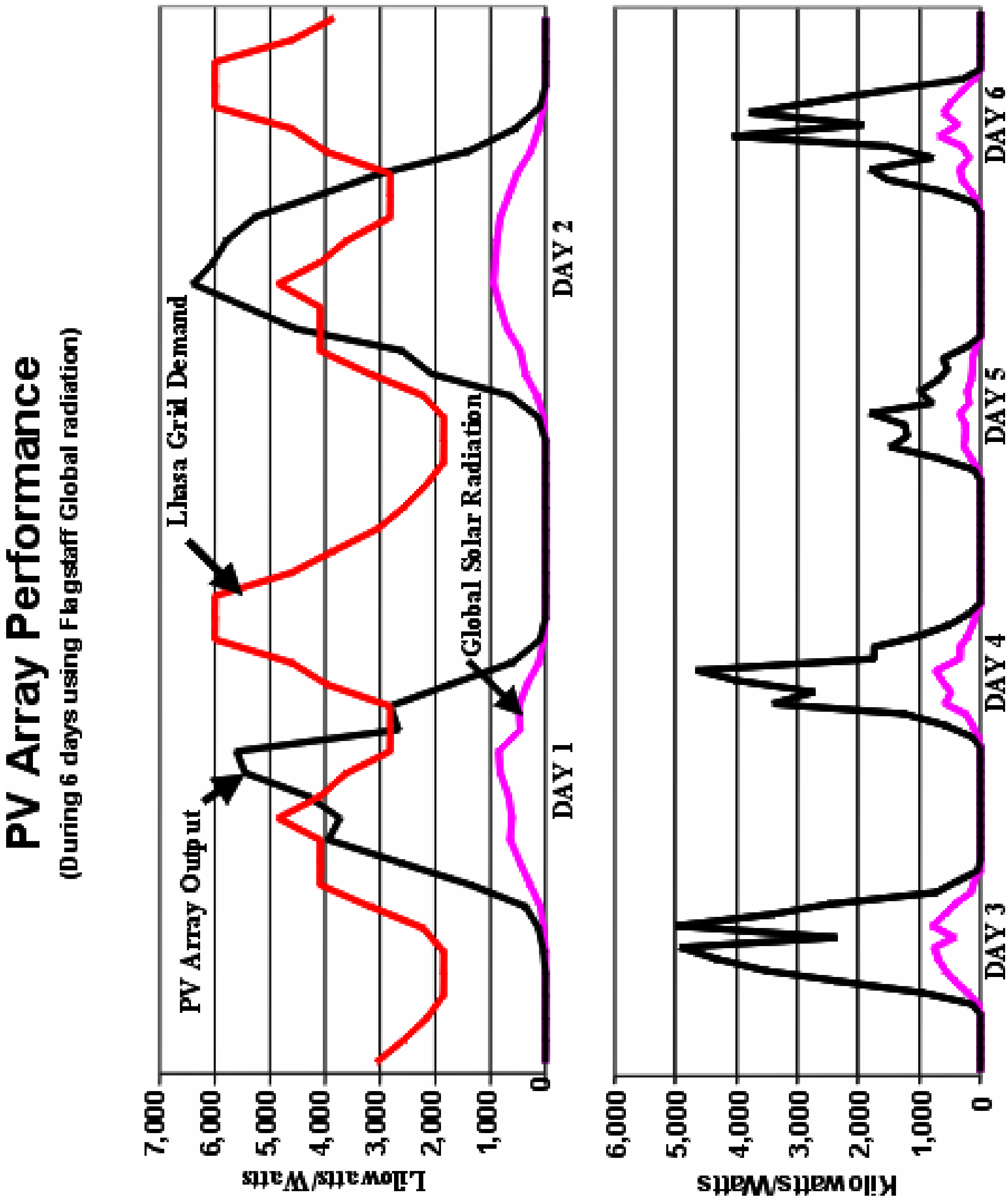
A computer simulation has been run to determine the hour by hour performance of a CENICOM™ Cluster power plant located in Lhasa, Tibet. The simulation used actual measured data for a location, which has been considered to be similar to Lhasa. The measured data included direct sunlight as well as global (total direct plus indirect) measurements for every hour of the year 1990 in Flagstaff, Arizona. The direct data was used for the CENICOM™ evaluation, and the global total was used for the Photovoltaic (PV) array evaluation.

The comparison strategy was to compute CENICOM™'s total annual production in the Dispatchable Power mode of operation—that is, to deliver its energy to the Lhasa grid only during peak demand periods of the day. Once this total for the year is determined, then, a PV array is sized to produce the same amount of energy to the grid for the same year. Once the number of square meters of PV array has been determined, than real published cost per square meter from suppliers of PV equipment give us an estimate of PV power plant cost.

The result of the simulation for CENICOM™ indicates an annual production of 13,380,000 kWh-e. A PV panel manufactured by Siemens was selected as a typical example of the technology. The panel is monocrystalline (high efficiency) and has a long guaranteed service life similar to CENICOM™. The panel efficiency used in the analysis is a function of solar flux density, and was computed for each hour of the year. The overall efficiency includes the panel efficiency (which produces direct current), interconnection losses, and D.C. to A.C. inverter efficiency. The evaluation of performance for a Siemens panel array indicates a specific energy output to the grid of 215.99 kWh/sq-m for the year.

The PV array must then contain 61,854 square meters to produce the same annual energy as the CENICOM™ Cluster power plant. The published price per square meter is 4,384 RMBI. The cost of a complete PV power plant equivalent to the output of the CENICOM™ Cluster is 271,167,936 RMBI not including the costs of installation.

There are other undesirable factors related to PV array power plants. Power is generated and put into the grid only when the sun is shining and not necessarily when the demand is greatest. It is sporadic in time, duration, and magnitude unlike the CENICOM™ plant which has the ability to store energy and deliver it to the grid at a specific time and at a fixed rate.


PV Array Performance
(During 6 days using Flagstaff Global radiation)
PV Array Output
Lhasa Grid Demand
Global Solar Radiation
DAY 1
DAY 2
DAY 3
DAY 4
DAY 5
DAY 6
Kilowatts/Watts
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0

4.4. CASE 2a: 3-CENICOM™ Heat/Cooling to Apartment Complex in Beijing, China

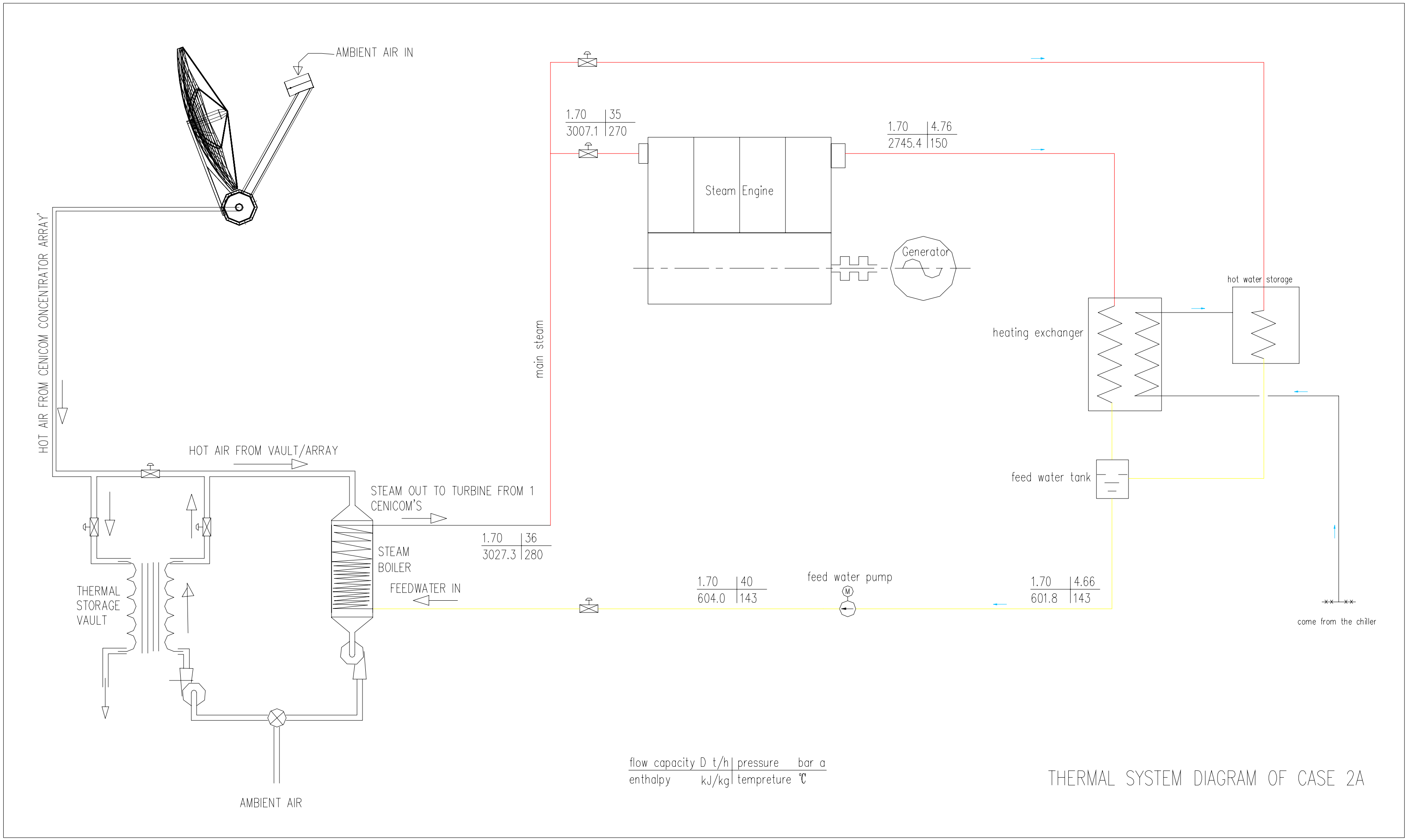
A CENICOM™ system consisting of a group of 3 CENICOM™ collector arrays with steam generators combining their outputs to supply the energy needs of an apartment complex in Beijing. In this configuration, thermal heating and cooling were assigned the top priority, and electrical generation was assigned second priority. It was during the heating season that the effect of these priorities was noticed because of the combination of high heating energy demand and long periods of very little sunlight thus highlighting the importance of high temperature thermal energy storage.

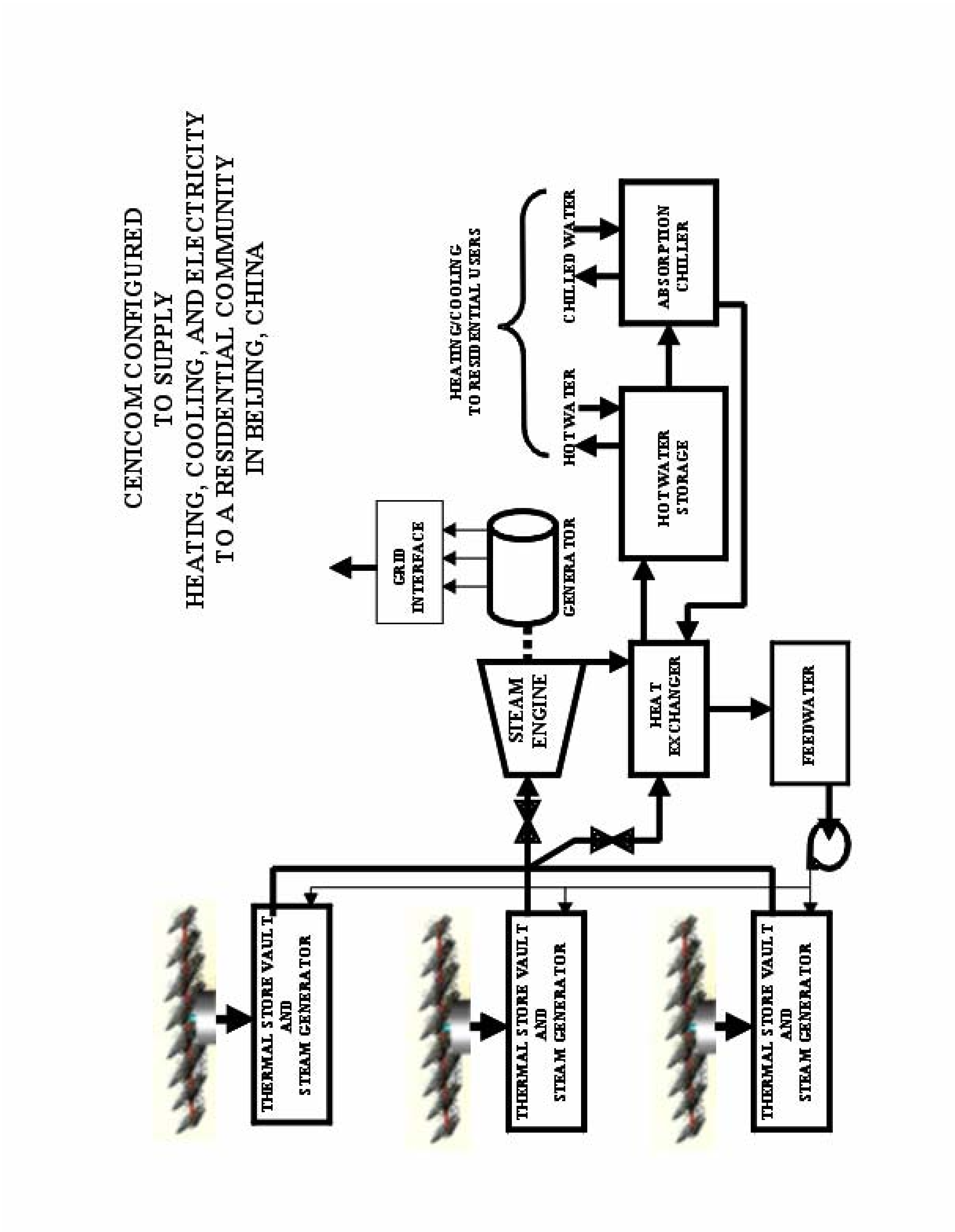
A computer simulation was run using direct sunlight data measured hourly for an entire year. Since this kind of measured data for Beijing was not available for this analysis, a city whose annual sunlight and weather were thought to be similar to Beijing was chosen instead. The demand for heating, cooling, and electricity were modeled for every hour of the year and for a programmable residential area in square meters. Other variables such as electric generator daily minimum run-time, low temperature storage size, and storage water tank temperatures and pressures were adjusted to produce the best combination of results.

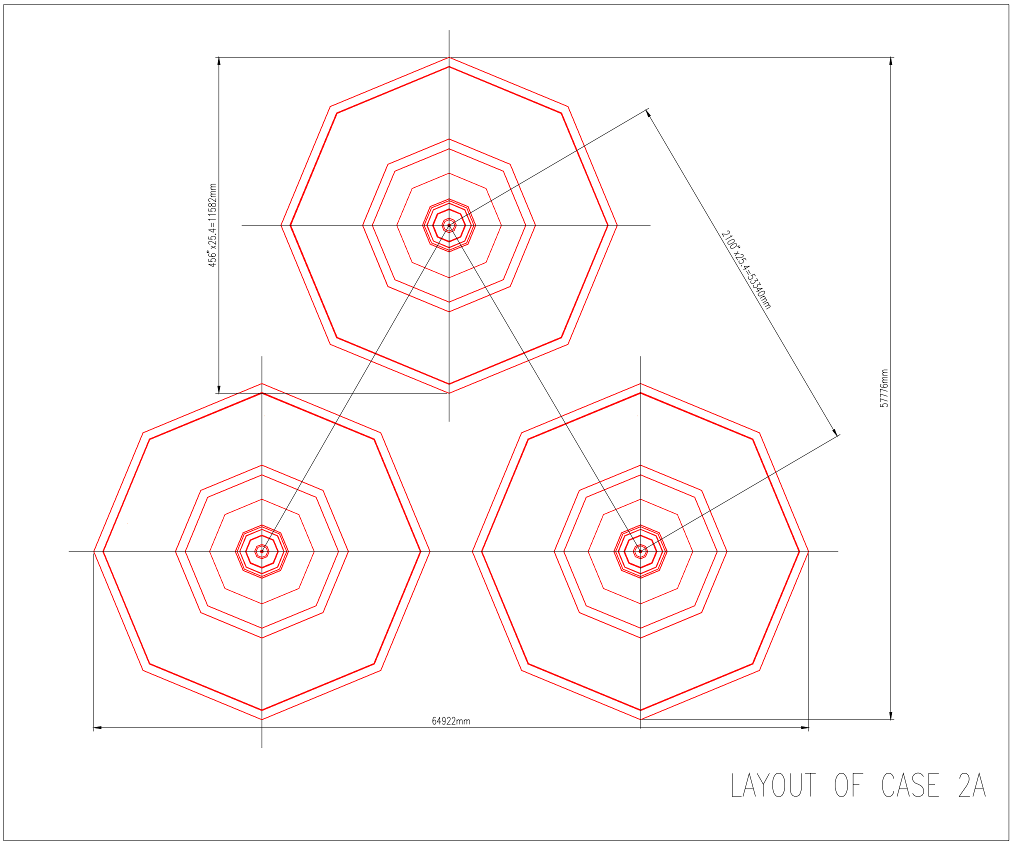
A block diagram of the system is presented on the following page. The steam generated from each boiler (steam generator) is combined into a single line to a Rankine cycle machine. For this application, a 130 kW steam engine-generator is planned. The steam generators are capable of producing steam at 435 degrees C and 40 bars pressure, but the steam engine planned requires a maximum of only 270 degrees C and 40 bars. The search for a prime mover with a better match continues. The thermal energy in the exhaust steam is recovered, stored in an insulated water tank, and used as the main source of thermal energy to the residential units for heating and cooling. There are long periods, during the year, with very little daily sunlight during the winter. During these periods, heat is drawn directly from the high temperature storage vault to supplement the engine exhaust heat to meet the heating demand.

In this analysis, an absorption chiller was selected to provide cooling to the residential area. This component is driven primarily with hot water. A small amount of electrical power is required. A 350 kW unit requires 5 kW electrical input and a large supply of cooling water to support the lithium bromide chiller process. An alternative to the use of the chiller is to make different use of the excess electrical energy CENICOM™ put into the grid during the year (especially during the cooling demand season) and use this electricity, instead, to power individual electrically driven refrigerant compressor types of cooling units for each apartment.

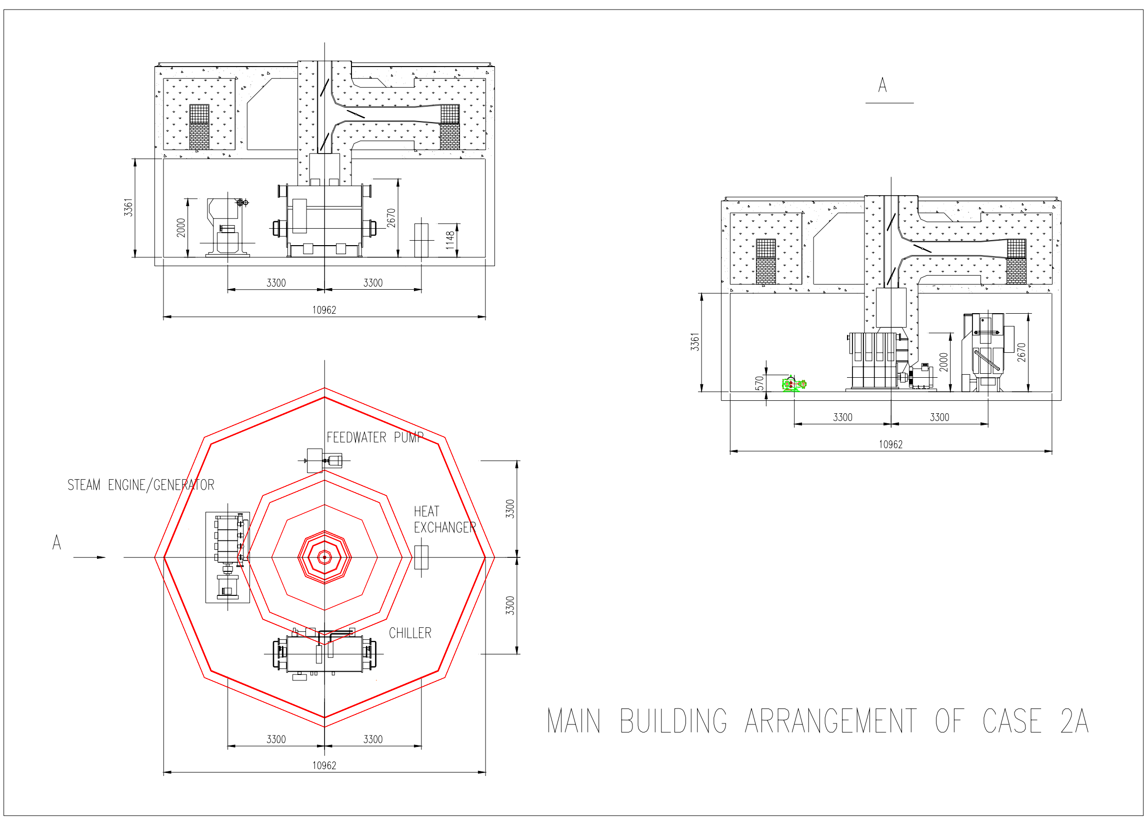
The results of the simulation for the entire year are summarized in the following table of system characteristics. Note that 100% of the cooling demand was satisfied for the stated residential area. The electrical demand was easily met with considerable excess delivered to the grid. The heating demand was the pacing demand. For the same area, 90.5% of the demand was met over the entire heating season. It is now evident that a different thermal vault strategy using the lower temperature section could have supplied the remaining 10%.


AMBIENT AIR IN
HOT AIR FROM CENICOM CONCENTRATOR ARRAY
HOT AIR FROM VAULT/ARRAY
THERMAL STORAGE VAULT
STEAM OUT TO TURBINE FROM 1 CENICOM'S
STEAM BOILER
FEEDWATER IN
AMBIENT AIR
main steam
1.70 | 35
3007.1 | 270
1.70 | 36
3027.3 | 280
Steam Engine
Generator
1.70 | 4.76
2745.4 | 150
heating exchanger
hot water storage
feed water tank
feed water pump
1.70 | 40
604.0 | 143
1.70 | 4.66
601.8 | 143
come from the chiller
flow capacity D t/h | pressure bar a
enthalpy kJ/kg | tempreture ℃
THERMAL SYSTEM DIAGRAM OF CASE 2A


CENICOM CONFIGURED
TO SUPPLY
HEATING, COOLING, AND ELECTRICITY
TO A RESIDENTIAL COMMUNITY
IN BEIJING, CHINA
GRID INTERFACE
GENERATOR
STEAM ENGINE
HEAT EXCHANGER
FEEDWATER
HOT WATER STORAGE
ABSORPTION CHILLER
HEATING/COOLING TO RESIDENTIAL USERS
HOT WATER
CHILLED WATER
THERMAL STORE VAULT AND STEAM GENERATOR
THERMAL STORE VAULT AND STEAM GENERATOR
THERMAL STORE VAULT AND STEAM GENERATOR



LAYOUT OF CASE 2A

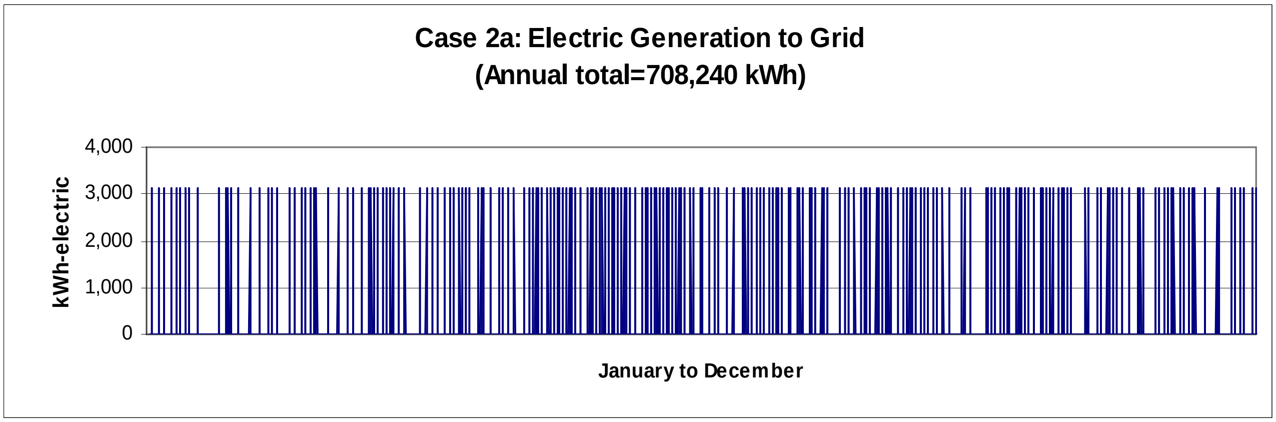


MAIN BUILDING ARRANGEMENT OF CASE 2A

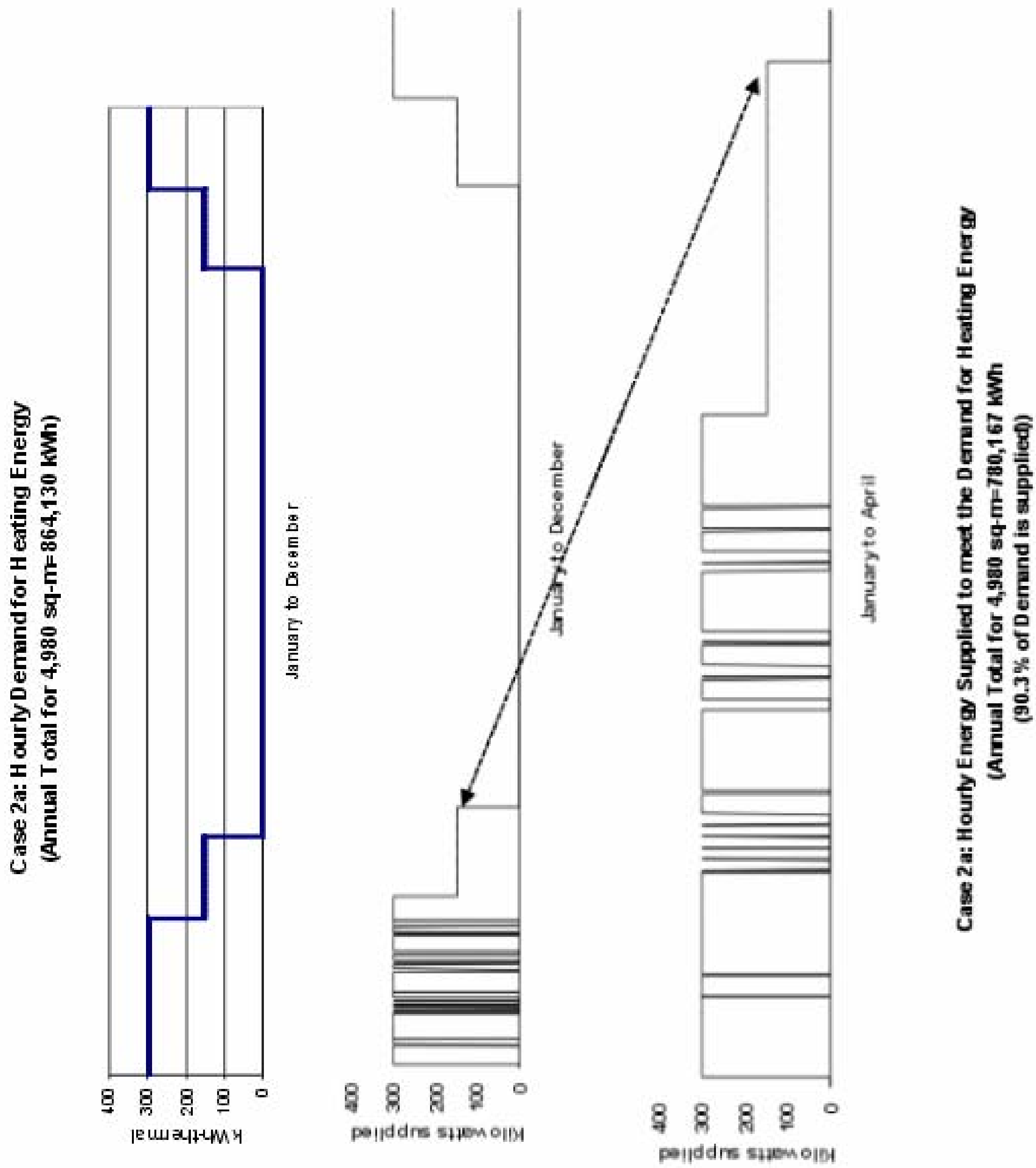
CASE 2A: SYSTEM CHARACTERISTICS

Item	Value	Units
POWER PLANT LOCATION	BEIJING	
TOTAL DISH COLLECTING AREA	1,951	SQ-M
ANNUAL INTERCEPTED DIRECT SOLAR RADIATION*	4,750,314	KWH
ANNUAL ELECTRICAL ENERGY GENERATED	708,240	KWH
ANNUAL THERMAL ENERGY DELIVERED FOR HEATIN/COOLING	1,110,142	KWH
TOTAL POWER PLANT ANNUAL DELIVERABLE ENERGY	1,818,212	KWH
RESIDENTIAL AREA SERVICED	4,980	SQ-M
HEATING SEASON DEMAND SUPPLIED FROM SOLAR	90.5%	
COOLING SEASON DEMAND SUPPLIED FROM SOLAR	100%	
YEAR-ROUND ELECTRICAL DEMAND SUPPLIED FROM SOLAR	100%	
EXCESS ELECTRICAL SOLD TO THE GRID	607,903	KWH
RANKINE ENGINE-GENERATOR CAPACITY	130	KW
ABSORPTION CHILLER MAXIMUM CAPACITY	350	KW
HIGH-TEMPERATURE THERMAL STORAGE VAULT CAPACITY	90,000	KWH
LOW-TEMPERATURE STORAGE CAPACITY	30,000	KWH

The following chart shows how electrical generation is distributed throughout the year. Each line represents a 24 hour period that the engine-generator ran continuously. This action was permitted only when thermal demands were met, and there was stored energy for a continuous 24 hour run. Note the frequency of generation days difference between the winter and summer months.

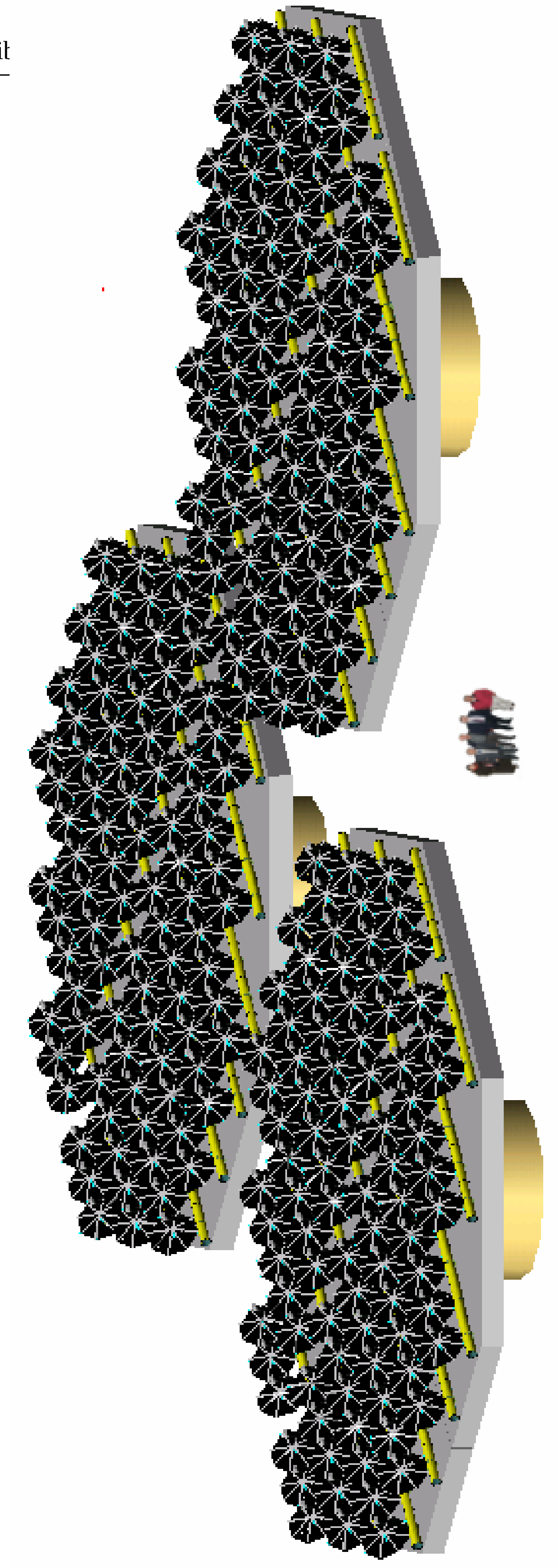


The annual heating demand model used in the simulation analysis is shown in the upper plot of the chart on the following page. The middle plot is the systems response to meeting that demand noting that 90.5% of the annual hourly demand was met. The bottom plot is an expansion of the winter season period showing the periods where no heating was supplied to the residential area. Recall that the analysis was done hour by hour.


Case 2a: Hourly Demand for Heating Energy
(Annual Total for 4,980 sq-m=864,130 kWh)
kWh-thermal
400
300
200
100
0
January to December
Kilo watts supplied
400
300
200
100
0
January to December
Kilo watts supplied
400
300
200
100
0
January to April
Case 2a: Hourly Energy Supplied to meet the Demand for Heating Energy
(Annual Total for 4,980 sq-m=780,167 kWh
(90.3% of Demand is supplied))

The 3-CENICOM™ system is ideally suited for placement on the roof top of an L-shaped or T-shaped apartment building. In area where land area is available, the triad could be placed in a parking area or a park thus taking advantage of the useable area under the arrays. The following drawing shows the triad in proper perspective. The three base enclosures contain the high temperature thermal energy storage vaults, the steam generators, the steam engine, the absorption chiller, the hot water storage tanks, and the control room.

The final picture shows how such an apartment building would appear in a city setting.



4.5 Comparison to Flat Plate Collectors

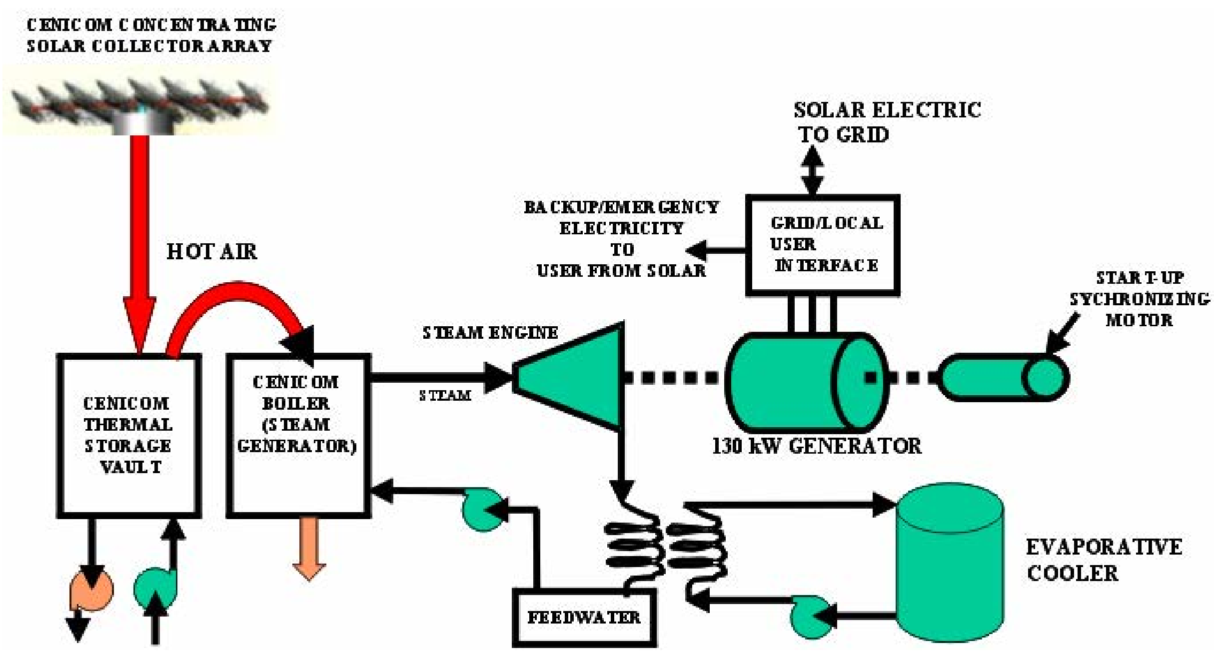
The following table compares the cost of a KWHr. – Thermal for CENICOM™ and Flat plates. The thermal energy cost from the two systems is similar though the unit cost of CENICOM™'s energy is about 1/3 less costly.

	3 CENICOM™s		**Flat Plate**
Rating of Flat Plate	1 square meter of collector / 5 square meters of Space		
Percentage Supplied at rating			40%
Square Meters required at 100%			2,250
Flat Panel Cost at 1000 RMB / square meter			2,250,000
Pumps and piping (RMB)			112,500
Total (RMB)			2,362,500
Amortization 30 years @ 8% interest (RMB)			209,855
Maintenance - Flat Plates (RMB)			9,042
Pump Power (RMB)			864
CENICOM™ System Cost		7,511,470	
Amortization 25 years @ 8% interest (RMB)		703,665	
Maintenance – CENICOM™ (RMB)		18,085	
Maintenance - Prime Mover (RMB)		39,787	
Annual Total (RMB)		761,537	219,761
	Factor	Value	
Value of Electricity (RMB)	0.668	508,577	
Value of Heating (RMB)	0.213	161,906	219,761
Value of Cooling (RMB)	0.120	91,054	
Amount of Heating (kWHr)		780,167	780,167
Heating Cost (RMB / KWHr –thermal)		0.208	0.282

4.6 CASE 2b: 1-CENICOM™ Electric Power for Emergency Backup to Building in Beijing, China

This application of CENICOM™ consists of a single CENICOM™ unit configured to deliver maximum electrical energy to the grid during peak demand periods of the day. In addition, it maintains a thermal energy reserve large enough to generate 2,500 kWh electric for a local user as emergency backup power in the event of an interruption of the grid.

The following diagram depicts the main elements of this configuration. The major difference with case 2a is that no low grade heat energy is stored or delivered to the user. The prime mover is a steam Rankine engine configured for maximum shaft power output.

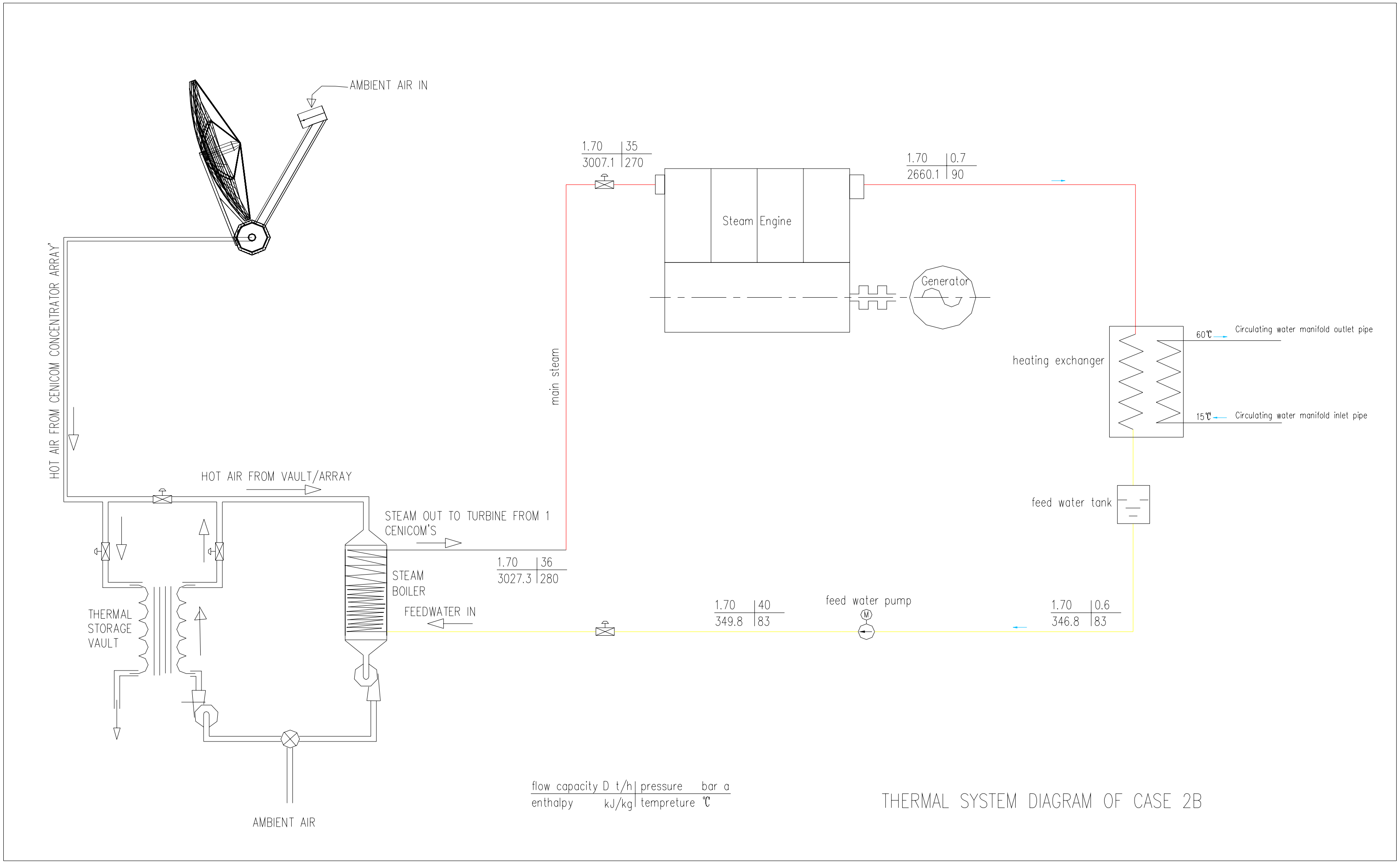


An hour by hour simulation using actual direct solar data for a full year shows an annual electrical energy production into the grid of 311,759 kWh. The following table lists this and other results of the performance analysis for this application. If the emergency reserve is used in the event of a grid interruption, the thermal energy reserve would be replaced after 2 sunny days. That is not the only way that the vault can be recharged. It is entirely practical to recharge the reserve energy by using night time grid electricity to produce hot air for injection into the vault.

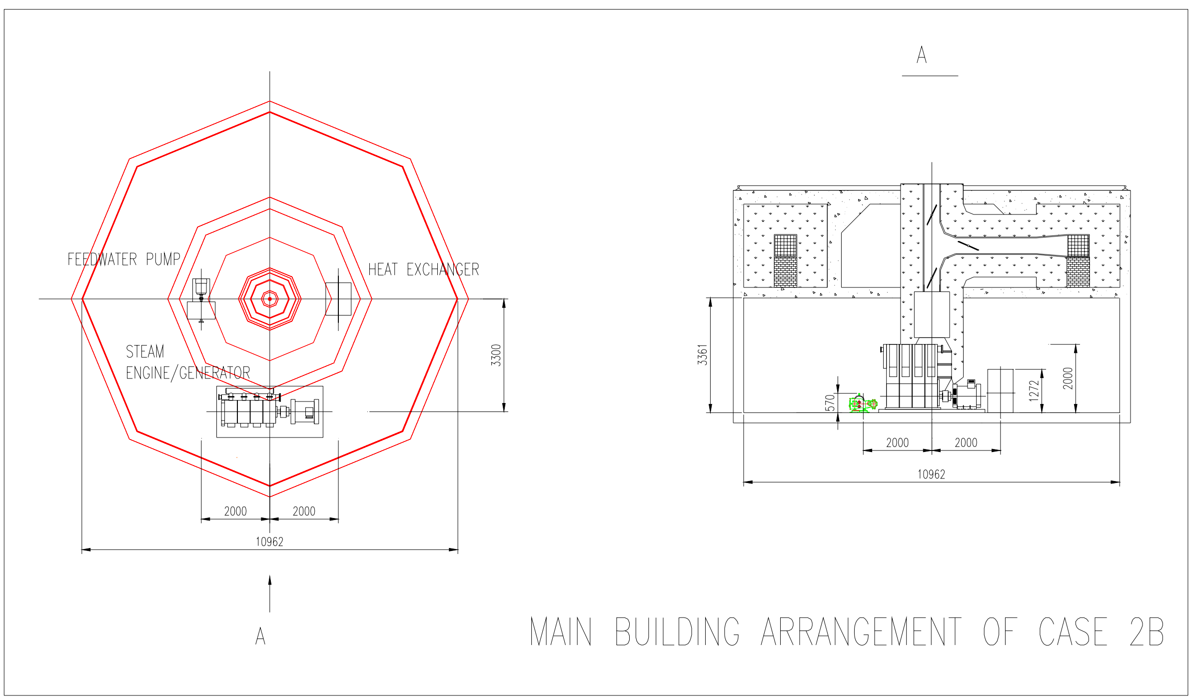
Item	Value	Unit
ANNUAL ELECTRIC ENERGY DELIVERED TO THE GRID	311,759	KWH*
STORED ENERGY RESERVE (AVAILABLE 24/7)	2,500	KWH
DELIVERY RATE DURING EMERGENCY	130	KW
DELIVERY TIME	20	HOURS MINIMUM
STORAGE VAULT RECOVERY TIME AFTER EMERGENCY BACK UP CYCLE	2 SUNNY DAYS	
OVERALL ANNUAL SUNLIGHT-TO-GRID EFFICIENCY	19.7%	

* DETERMINED USING HOURLY MEASURED DIRECT SUNLIGHT

The following picture illustrates the practical use of this application of CENICOMTM. It is shown on the roof tops of several buildings where the emergency back up power would be useful to run elevators, hospital emergency rooms, food storage refrigerators, etc during a grid interruption.


AMBIENT AIR IN
HOT AIR FROM CENICOM CONCENTRATOR ARRAY
HOT AIR FROM VAULT/ARRAY
THERMAL STORAGE VAULT
STEAM OUT TO TURBINE FROM 1 CENICOM'S
STEAM BOILER
FEEDWATER IN
AMBIENT AIR
main steam
1.70 | 35
3007.1 | 270
1.70 | 36
3027.3 | 280
Steam Engine
Generator
1.70 | 0.7
2660.1 | 90
heating exchanger
60℃ Circulating water manifold outlet pipe
15℃ Circulating water manifold inlet pipe
feed water tank
feed water pump
1.70 | 40
349.8 | 83
1.70 | 0.6
346.8 | 83
flow capacity D t/h | pressure bar a
enthalpy kJ/kg | tempreture ℃
THERMAL SYSTEM DIAGRAM OF CASE 2B

BEIJING BUILDINGS WITH CENICOM™ POWER PLANTS OPERATING AS DISPATCHABLE AND STANDBY EMERGENCY POWER SOURCE DURING GRID INTERRUPTIONS



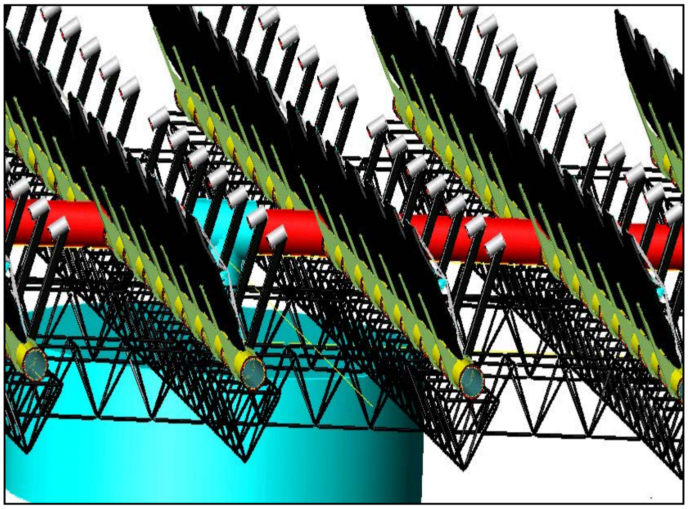
4.7 Initial Cost Estimate

Unit: RMB

Case 1a & 1b	1 Cluster		3 Clusters
	1a		1b
Annual Output KWHr	13,380,000		40,146,000
CENICOM™ Manufacturing Cost	65,884,122		197,652,366
Profit @ 15%:	11,626,610		34,879,830
CENICOM™ Cost	77,510,732		232,532,196
Steam Generator & Others	58,510,000		58,510,000
Total static Cost	136,020,732		291,042,196
Unit Cost (RMB/kW)	22,670		48,506
Planed Total Fund	139,510,000		298,390,000
Tariff (RMB/MWH)			
With Factors for Tibet	1,046		634
Case 2a & 2b	**3 CENICOM™s**		**1 CENICOM™**
	2a		**2b**
Heat/Cooling Annual Output (equivalent KWHrs Heat = 0.289 Cool = 0.384)	1,060,510		
Electricity Annual Output KWHr – Electricity	708,240		314,259
CENICOM™ Manufacturing Cost	5,623,542		1,874,514
Profit @ 15%	992,390		330,797
CENICOM™ Cost	6,615,932		2,205,311
Steam Engine – Generator	1,000,000		1,000,000
Others	360,000		65,000
Total static Cost	7,975,932		3,270,311
Unit Cost (RMB/kW)	61,353		25,153
Planed Total Fund	8,178,000		3,351,000
Tariff (RMB/MWH) (Heat Price Used: RMB / GJ)	(38)	(64.25)	/
No Income Tax	853	706	934
Reduced Income Tax	952	805	1,018
No Concessions	1,250	1,109	1,306
Note: Case 2a and 2b tariffs do not include special loan interest, CDM and special tariff credits available for Solar Energy Installations			

5 Manufacturing Operations and Typical On-site Assembly

5.1. Manufacturing Facility



A factory is required to produce modules and parts that will be assembled and put in place at the site location. Some elements of the manufacturing process are produced in an environment that must be separated in a large shop. To satisfy this environmental condition, the overall manufacturing concept is to have distributed workshops located in regions where there are employment needs. This multiple shop approach emphasizes making piece parts as fast as possible and moving to finish goods store. Parts are then distributed to meet assembly schedules as required.

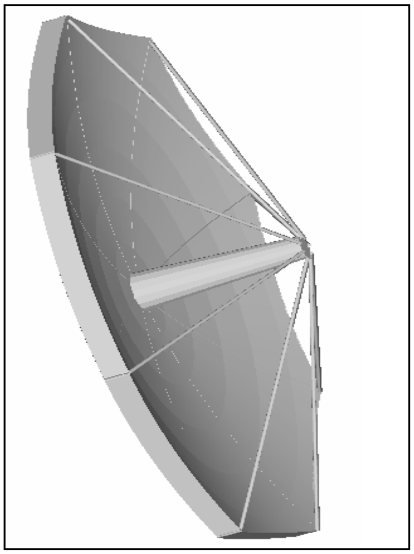
Initial factory implementation requires a minimum of three separate buildings with a combined 4,890 m^2 size plus an additional 5,000 m^2 outside pre-assembly area for test of components, subsystems, and site assembly procedures... Afterwards, plant scale-up for large-scale production can be achieved by linearly increasing space, tooling, and personnel with very low risk.

Initial case study shows labor, raw materials, components, and equipment are available in the Peoples Republic of China to produce the CENICOM™ power plant.

The initial factory is divided into five major areas:

- Mirror
- Converter
- Air Transport
- Support Structure
- Tower Facility (Assembled on site by approved subcontractor)

Mirror Shop - The mirror shop consists of a structural work station in an area separated from a finishing work station. Mirror fabricators cast the structural portion of the mirror. Importantly, no other activity is permitted in the mirror fabrication building, thus forming the rationale for a manufacturing facility comprised of three separate buildings. Safety procedures are the same as used in the insulation industry for products such as roofing, refrigerators, automobiles' boating, etc. The activity can be established in a large shop or many small distributed shops that can be established where there are employment needs. Structural shops require standard tools for cutting, drilling, and grinding; and compressed air, as well as special tooling and fixtures (substrate forms, vacuum bags, etc) that are relatively low cost. A minimum 500 m^2 container housing with humidity control is needed for work-in-process storage.



The precision mirror segments are the "crucial" element enabling CENICOM™ system operation. The fabrication process involves complex procedures and substrate profiles. The process remains out of the public domain and is trade-protected. To protect this procedure, each employee will be trained and given access on a "need-to-know" basis, and then only to that portion the employee is responsible for. Each employee is required to sign a confidentiality statement to not disclose any proprietary information. Documentation is rigidly controlled and individuals must sign a receipt to acknowledge transfer of possession. This procedure is very similar to the US Department of Defense method of handling SECRET material. This approach has maintained integrity of our process for over 25 years without an infringement.

A finishing work station in a clean environment is required to finish the mirror by mating the reflector sheet with the structure substrate. This shop can also be in a large partitioned shop or in small distributed shops. The finishing shop requires relatively low cost sheet metal tooling, diagnostic measurement devices, compressed air, and a vacuum source.

Typical Mirror Shop Equipment is listed below:

Casting Mold	Shaping Tool
Assembly Mold	Precision Shear, 7 ft
Air Compressor	Mirror Diagnostic Device

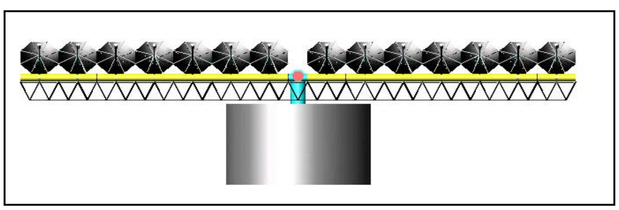
Converter Shop- The converter shop consists of a welding fabrication work station and an assembly work station. The welding fabrication work station will create the metal parts of the converter and support arm structure. This activity would be part of a larger area. It requires low cost fixtures and standard metal working and welding equipment.

The assembly work station will integrate the ceramic parts and metal parts and install insulation density to produce finished converter modules and support arm structure.

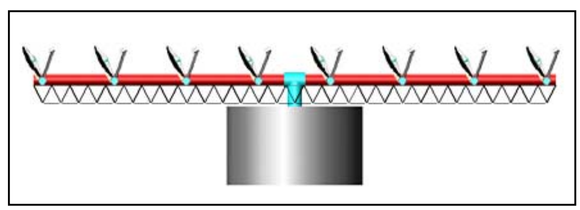
Typical Converter Shop Equipment is listed below:

TIG Welders	Plasma Arc Cutters
Saw, Auto-feed	Drill Station, 2-head
Shear, 6 ft, 18 GA	Turret Lathe, 12" x 20"

Air Transport Shop - The air transport shop consists of a welding fabrication work station and an assembly work station. The welding fabrication work station will create the flanged outer portions of the air transport lines. It requires low cost fixtures and standard metal working, welding equipment, and overhead lifting devices.



Branch Lines



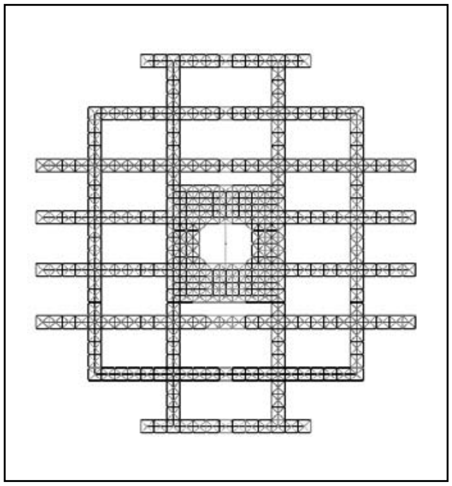
Trunk Lines

The assembly work station will create the finished trunk and branch air transport lines.

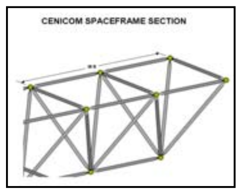
Typical Air Transport Shop Equipment is listed below:

Overhead Hoist	MIG Welder, Auto wire-feed	Circle Cutter
Abrasive Belt Grinder	Saw, Auto-feed	Drill Station, 4-head
Horizontal Band Saw, 36"	Vertical Band Saw, 24"	Spray Paint System
NC Mill	Hydraulic Press, 50T	Engine Lathe, 17" x 60"
Punch Press, 10T	Shear, 10 ft, 10 GA	

Support Structure Shop - The support structure consists of a welding fabrication work station and an assembly work station. The welding fabrication work station will create the dish support assembly, the azimuth rails and drive trucks, elevation drive link arms and stator bearing support. The basic support structure is manufactured by a qualified vendor selected by a subcontract competitive bid.



The assembly work station produces the finished dish support tower, flanges, plates, strut tubes, and the azimuth and elevation components for attachment to the support structure at final assembly at the site location.



Typical Support Structure Shop Equipment is listed below:

TIG Welder	Overhead Hoist
Cutoff Saw, Auto-feed	Drill Station, 2-head
Iron Worker, 4" angle	Vertical Bandsaw, 24"
Arc welder	Brake, 4 ft, 10 GA
Roller, 4 ft, 18 GA	Shear, 6ft, 18 GA
Abrasive Belt Grinder	Air Compressor, 15 Hp

5.2. List of Main Equipment

Study results confirm that all raw materials and components are available for manufacturing CENICOM™ in China, with the possible exception of two items that might be purchased outside China. These two items are the Clayton Steam Boiler and the small Spilling Steam Engine. We believe that a more exhaustive search may reveal that these two items may also be available in China

ITEM	DESCRIPTION	QUANTITY		SUPPLIER INFORMATION
		CENICOM™	CLUSTER	
1	CONVERTER AIR BLOWER	88	3168	9.25 SCFM, 7 INCHES Water Column, Motor Power =14 Watts DC, Suitable for Variable Speed Control, Weather Protected
2	ELEVATION GEARMOTOR	2	72	DC Drive , Output Speed = 1 Rev/Hour Max, 18,000 FT-LB Torque
4	AZIMUTH GEARMOTOR	24	864	1/2 HP DC, 500 FT-LB Torque, 10 RPM, 2,000 LB Overhang Load, Weather Protected
5	DIVERTER VALVE GEARMOTOR	3	108	1/8 HP DC, 10 RPM, 1 FT-LB Torque
6	VAULT DISCHARGE BLOWER	2	72	Centrifigal, 2,000 SCFM, 500 Watt DC Motor, 5 Inches Water Column Delta P
7	STEAM GENERATOR RECOVERYBLOWER	1	36	Centrifigal, 900 SCFM, 1KW DC Motor
8	STEAM BOILER	1	36	CLAYTON INDUSTRIES, Model ECO-100 Waste Heat Boiler
9	TURBINE, 6000 kW	0	1	Selected by SWEPDI
10	STEAM ENGINE GENERATOR	3	0	SPILLING, Model not selected, Power 130KW Gen, 35 bar/g pressure, 435 C Temperature
11	ABSORPTION CHILLER, 350 KW	3	0	SHUANGLIANG, 2-Stage, Lithum Bromide, Hot Water Operated

5.3. Scaling Risks for CENICOM™ Manufacturing Plant

There are some small risks associated with scaling up a CENICOM™ manufacturing plant. They fall into the following categories:

- Hiring and Training of factory workers
- Finding means for transportation of sub-assemblies to power plant site for final staging.
- Continual training of all workers to maintain proper quality assurance
- Securing funding of additional capital equipment.
- Finding sources of working capital

Hiring and Training

The process and tasks involved in producing collectors, hot air transport lines, and storage vaults are unique to CENICOM™ and will require extensive training and monitoring to achieve the results needed in producing easily installable and reliable power plants.

Transportation

Power plant sub-assemblies are somewhat bulky and have shapes that do not lend themselves to easy packing and transporting. Special equipment for erecting the power plants will also have to be transported to the power plant site. Special trailers or special transportation fixtures may be required.

Continual Training

CENICOM™ power plants are assembled from precision mirrors, special hot air transport piping and there associated control mechanisms. High quality construction is required to achieve the desired power plant results. This can be accomplished by a program that provides training to workers so that the work force focus is on teamwork and quality.

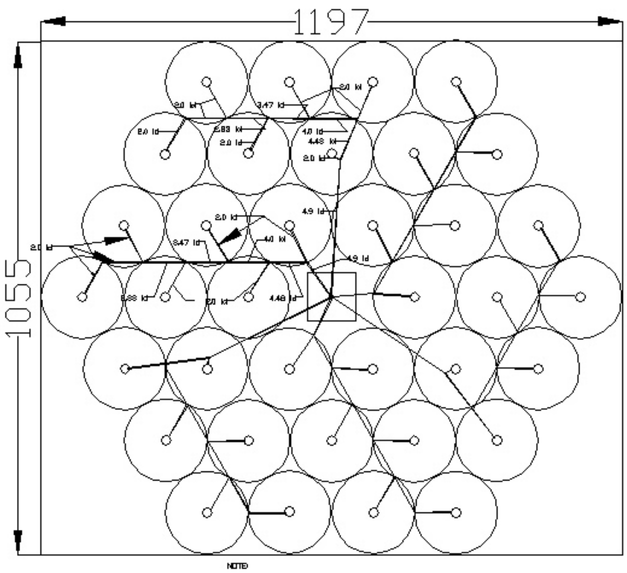
Equity for manufacturing plant expansion

Increasing plant output means increasing the number of workstations in each factory area. Special tooling must be produced and the supporting equipment must be purchased. Production can be multiplied by increasing the use of existing tooling for multiple shifts. Once the tooling is being used for 3 shifts, then additional tooling is required to increase production. Plant expansion funds could be financed by equity, debt or most likely both.

Finding sources of Working Capital

Power plant construction takes quite a long time. Significant amounts of working capital will be required. Working capital will come from upfront payments, progress payments, construction loans, lines of credit, credit from suppliers, retained earnings and equity. The company model indicates that each of these sources will be required to achieve the desired volume of business. Generally, scaling up production means scaling up working capital.

5.4. On-Site Assembly



Land Area – Thirty-six (36) CENICOM™ modules are grouped together in a hexagon-shaped pattern, along a 1,055 ft (321.6 meters) East to-West and 1,197 ft (364.9 meters) North-to-South positions, centered around a central power generation control facility. Six (6) sub-cluster steam lines are combined, after a cutoff valve for each line, into one line to the turbine generator in the central equipment building.

Site preparations include surveyed position of each CENICOM™ module, steam line trenches, and central equipment building. The initial assembly area, with tooling and fixtures, is established near the 6 sub-cluster modules being installed. This assembly process moves as each 6 sub-cluster module is being installed.

After installation of the CENICOM™ cluster power plant, 93.15% of the total land area is useable to a height of 7.34 meters for a variety of other applications such as houses, shops, manufacturing, medical, etc.

5.4.1. Site Requirements

A geo-technical survey of the selected site location will be conducted by a certified agency to determine topography and soil conditions. Suitability of soil to bear foundations without subsoil compaction will be established.

1. Land Area	91,362 M^2
2. Topography	Land surface area to be horizontal in the EAST-WEST position
3. Soil	Suitable to bear major foundations without subsoil compaction
4. Location	Lhasa, Tibet

5.4.2. Site Preparations

A subcontractor will be retained to create the surveyed position for each CENICOM™ tower, steam line trenching pattern, and central power generation and control facility. The entire site will be cleared and grubbed to remove soil and vegetation, level surfaces, and haul waste to disposal area. Right-of-way access road and transportation parking are prepared, including fine grading and slope drain. Trenches will be excavated for the steam & feed water lines, tower stabilizer beams, and system cables. The central housing slab will be evacuated and paved with concrete base.

TASK	ACTION REQUIRED
1. Geo-Technical Survey	Conducted by certified agency
2. Clear & grub	Remove soil and vegetation, level surface, and haul waste to disposal area
3. Cluster access road (include fine grading & slope drain)	(a) Prepare right-of-way surface (b) Install road base course of ¾" crushed stone x 18" deep, including shoulder (c) Install 3" thick binder course (d) Install 1 ½" thick wearing course
4. Transportation parking (include fine grading & slope drain)	(a) Clear & grub 25000 SF (b) Install 9" deep base course (c) Install 3" thick binder course (d) Install 1/1/2" thick course
5. Steam &Feed water lines & System Cables trenches	Excavate 36 trenches x 541.5' length x 3.0' deep x 1.5' wide
6. Central facility slab	Excavate & pave housing slab 30'x 30'x 6" thick

5.4.3. Construction And Staging (Per Each CENICOM™)

An overhead hoist system will be constructed on site to lift the collector support structure atop each tower module. The same device will also be used to lift other components and assemblies for installation atop the structure. The traveling crane will move along the surface from tower to tower and complete the lifting and assembly process. Afterwards, the transportable lifting device can remain on site or be disassembled and moved to another installation.

- Collector Support Structure (Space frame)

ITEM DESCRIPTION	ASSEMBLY METHOD	INSTALLATION
1. Space frame	Ground-level Jig & Fixture assemble near outside tower	Lift space frame to tower per plot plan sequence
2. Azimuth Drive	Check form, fit, & function with space frame jig & fixture	Post-lift, attach space frame to azimuth truck assembly
3. Elevation Mount and Elevation Drive	Check form, fit, & function with space frame jig & fixture	Post-lift, attach elevation mount to El Drive
4. Trunk Line	Check form, fit & function with space frame jig & fixture	Post-lift, mount 16 trunk line 20 ft section to space frame
5. Branch-Trunk RJ	Check form, fit, function with space frame jig & fixture	Post-branch/trunk line mounting, assemble stator/rotor RJ elements

- Collector Group

ITEM DESCRIPTION	ASSEMBLY METHOD	INSTALLATION
1. Collector elements (less dish assembly)	Check form, fit, function of 1 assembly with space frame jig & fixture	Post-lift, mount 88 branch line 10’ sections to space frame.
2. Dish Assembly	Check form, fit, function of 1 concentrator using space frame Jig & fixture	Post-lift, mount 704 petals to 88 branch line sections with strut-to-petal tubes
3. Converter and Arm	Check form, fit, function of 1 converter and support arm using space frame jig & fixture	Post-lift, connect 88 converters & support arms to the 88 branch line sections

- Tower and Vault

ITEM DESCRIPTION	ASSEMBLY METHOD	INSTALLATION
1. Foundation	On-site construction from raw materials, including concrete, steel, forms, and accessories.	(a) Excavate & backfill 36 slabs 38 ft ODx6.5’ thick (b) Fill with 243yrds^3 concrete & rebar150 lb/cy (c) Remove waste and over pour
2. Housing enclosure	On-site construction from raw materials, including concrete, rebar, forms, and accessories.	(a) Form and pour reinforced concrete shell and inside partitions.

- Overhead Lifting Hoist

1.Overhead Hoist System	On-site assembly of Hoist sections using small crane	(a). Start hoist assembly near first 6 towers to be installed (b) Position hoist for travel over line of towers from space frame assembly area (c) Lift space frame and move hoist over tower and lower into position

5.5. Construction Schedule

The case study considers all system design engineering and component manufacturing design has been done to establish the best procedures for manufacturing, testing, packaging, shipping and on-site assembly. This forms the basis for the construction schedule shown in the figure.

The case study describes how a CENICOM™ Cluster demonstration system is applied to a specific project. A cluster of 36 CENICOM™ modules are grouped together in a hexagon-shaped pattern area of 91.362 m^2, centered around a central power generation control facility. A geo-technical survey of the selected demonstration site will be conducted by a certified agency to determine topography and soil conditions. The entire area will be cleared and grubbed to remove soil and vegetation, level surfaces and haul waste to disposal area. Right-of-way access road and transportation parking area are prepared, including fine grading and slope drain. Trenches will be excavated for the steam lines, feed water lines, and system cables.

A surveyed position will be established for each CENICOM™ tower, steam line trenching pattern, and central power generation and control facility. Tower foundations and central housing slab will be excavated, paved or filled with concrete and rebar base.

A temporary on-site construction and assembly area will be established to receive raw material, components, assemblies, and equipment used to construct the final assembly of the CENICOM™ Demonstration Power Plant. The production concept is to have maximum shop assembly and minimum field activity. But certain large mass components require on-site construction from raw materials, such as concrete, steel, forms, tooling and fixtures. For example, the CENICOM™ tower housing requires 60 cubic yards of concrete; the vault core has a volume of 245 cubic feet weighting 84,451 lbs. and insulation of 3,240 cubic feet weighing 35,590 lbs.

Other major components requiring final assembly on-site are:

- Collector support structure
- Trunk Line (16 sections)
- Branch Line (88 sections)
- Dish Assembly (88 mirrors)
- Cluster Field Steam Lines (6,240 Ft; 1,902 meters)
- Central Equipment Building
- System Elements (cables, sensors, controllers

The space frame is a truss support structure that holds the CENICOM™ collectors and air transport lines. The assembly method uses ground level jig and fixtures near the towers before lifting the 15,281 lb assembly atop the tower. A 300 ton-meter tower crane is needed on-site to lift completed space frames atop each tower.

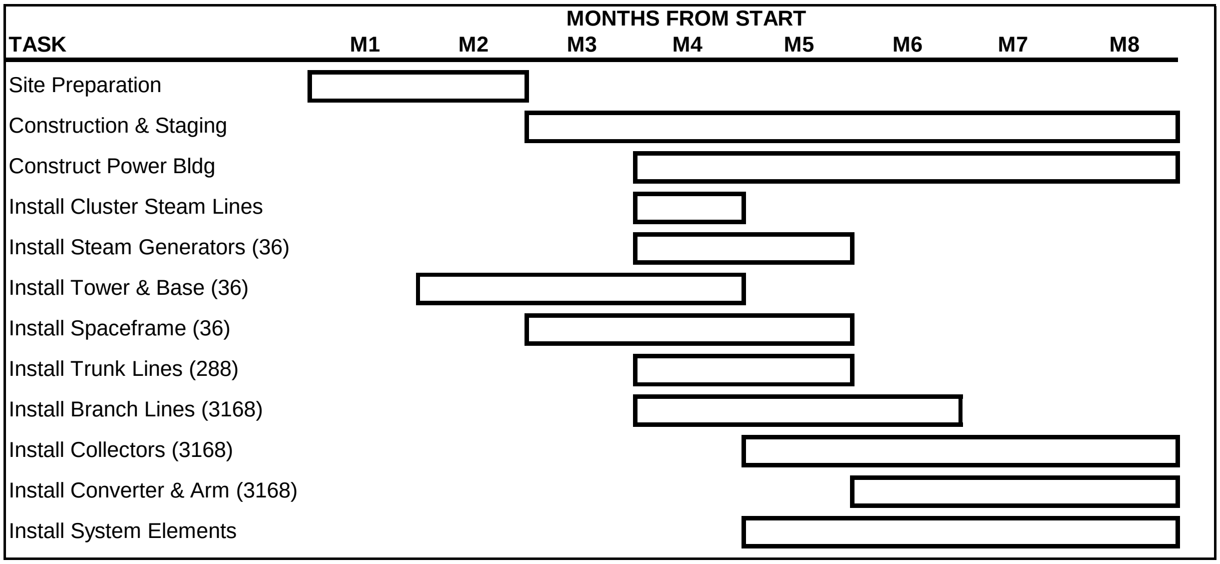
Before lifting the space frame, the twenty-four (24) azimuth drive trucks are attached to the specified node plate on the bottom of the structure. As the space frame is positioned over the tower, these trucks are guided to the azimuth rails imbedded on the top of the tower as the crane lowers the structure into position.

Once the space frame is securely mounted to the tower, each of the sixteen (16) air transport trunk lines are lifted and bolted together in 20 ft. sections, starting from the vault rotary joint and moving outwards from the center on both sides. Each of the eighty-eight (88) air transport branch lines are lifted and bolted together in 10 ft. sections starting from the trunk line and moving outward on each row.

After branch lines are installed, the converter and support arm assembly is connected to each branch line. Care is taken to make sure that the converter rows are indexed identically in elevation

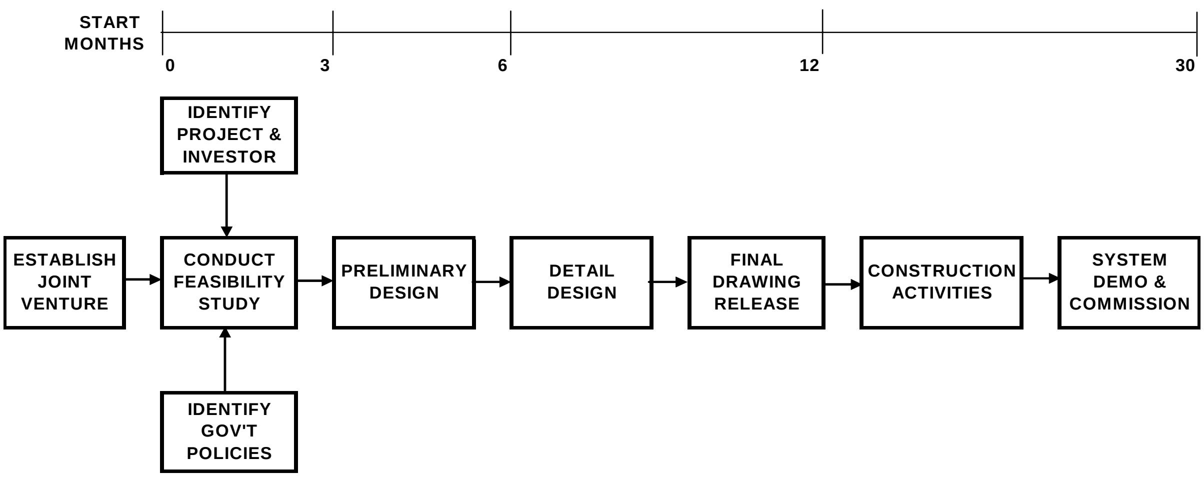
Next, the eighty-eight (88) dish assemblies are lifted and connected to its support tower at each branch line position.

The cluster field steam lines and feedwater lines between CENICOM™ Modules and the power generation and control facility can be installed early after site preparation is completed.


MONTHS FROM START
TASK
M1
M2
M3
M4
M5
M6
M7
M8
Site Preparation
Construction & Staging
Construct Power Bldg
Install Cluster Steam Lines
Install Steam Generators (36)
Install Tower & Base (36)
Install Spaceframe (36)
Install Trunk Lines (288)
Install Branch Lines (3168)
Install Collectors (3168)
Install Converter & Arm (3168)
Install System Elements

6 Implementation Plan

CENICOM™ is now seeking a recognized Chinese manufacturing firm as an investor/ joint venture partner to manufacture CENICOM™ system components i.e. mirrors, solar to hot air converters, hot air transport piping, and storage vault components. Major standard components such as boilers, generators etc. will be purchased locally (China). Once the new company is established the Manufacturing Joint Venture will seek project investor joint ventures with power engineering organizations to assist in preparing the project feasibility study, to be the principal technical design resource for the power generation segment of the project and to assist in obtaining required government/regulatory approvals in order to build CENICOM™ solar based power plants in those areas shown in the study as having an abundance of sunshine. The demonstration project in Lhasa is an example of a project joint venture.



The Lhasa project is expected to take approximately 30 months as shown in the chart above.

Appendix A – Archive of Experience and Documentation

1. Archive of Experience and Documentation

A summary of excerpts from a bibliography of formally published reports, proceedings, proposals, and research projects provide substantial historical evidence of pragmatic implementation experience by OMNIUM-G. Also included is a list of nearly two-dozen systems delivered worldwide, some of which are shown in the historical photo gallery section.

The company's principals designed, produced, delivered and installed single-collector systems world wide from 1973 to 1982. They have been directly involved with solar thermal technology using point-focusing dish concentrators since the Nation's oil embargo of 1973. In 1977, the company won the prestigious IR-100 Award for one of the Nation's most significant products of the year. Our parabolic solar collector was one of the first pieces of equipment in the U.S. Department of Energy (DOE) outdoor testing facility in Golden, Colorado. In May 1978, it provided the photo-op background of President Carter's dedication of the Solar Energy Research Institute (SERI) (now National Renewable Energy Laboratory-NREL) and establishing the first National Sun Day. The first commercial, point-focusing dish system was provided to Jet Propulsion Laboratory's (JPL) Parabolic Dish Test Site (PDTS) in 1979 for commercial evaluation, O&M experience, and acquisition of cost data. An archive of documentation is included in the following section.

Through the years, continuous improvements evolved in a most cost-effective and pragmatic implementation of solar-thermal-electric processes. Single-collector systems were supplied to Universities to enhance their research studies, supplied to developing nations and other foreign countries to evaluate rural use and village power systems, and finally to research institutions like the Solar Energy Research Institute and The California Institute of Technology. An attempt was made to market to the private sector.

These pioneering research and development projects in high-energy processes and dozens of other remote and urban locations in eight countries around the world led to the CENICOM™™ process. The engineering design and statistical performance calculations were completed for this technology showing cost-effective regional energy production, even in urban America.

The CENICOM™™ process is derived from over 30 years of refinement to the effort of collecting solar energy for convenient storage and conversion of thermal energy to electrical power for delivery when needed.

2. OG Parabolic Dish

Beveridge, Brian "Parabolic Concentrator Designs and Concepts". Pasadena, CA: Jet Propulsion Laboratory; JPL 400-98; December 1980.

"The Solar Thermal Power Systems Project at JPL, sponsored by the U.S. Department of Energy (DOE) is assisting private industry in the development of cost-effective, modular solar power systems for both thermal and electric applications"

Pages 12-13: Photo of OMNIUM-G dish undergoing system-level testing with implementation description of concentrator reflective surface, support structure, drive mechanisms, control system, receiver, and thermal transport.

Dish under evaluation at JPL test site

HTC Tracking Concentrator

Zelinger, S. H. 1980. "The OMNIUM-G HTC-25 Tracking Concentrator". Proceedings of the First Semi-Annual Distributed Receiver Systems Program Review. Conference held in Lubbock, TX; 22-24 January 1980. JPL Publication 80-10.

Pages 23-24: "---Testing and evaluation of these dish power modules are performed at the JPL desert test site shown in Figure 7. Evaluation of early dish hardware is already taking place at this site. A 6-meter diameter dish module purchased commercially from the OMNIUM-G Company of Anaheim, CA has been under evaluation at the test site since early 1979---".

Pages 53-57: "---This paper deals specifically with OMNIUM-G's model HTC-25 Tracking Concentrator, the initial problems and their subsequent solutions. These solutions have guaranteed the continued success in dramatically reducing the costs of the concentrator to the extent that large field applications may now be realized economically and to a high degree of reliability---"

Callorimeter

Omnium-G

Flux Mapper

OG Concentrator Test Results

Patzold, J. D. 1980. "OMNIUM-G Concentrator Test Results". Proceedings of the First Semi-Annual Distributed Receiver Systems Program Review. Conference held in Lubbock, TX; 22-24 January 1980. JPL Publication 80-10.

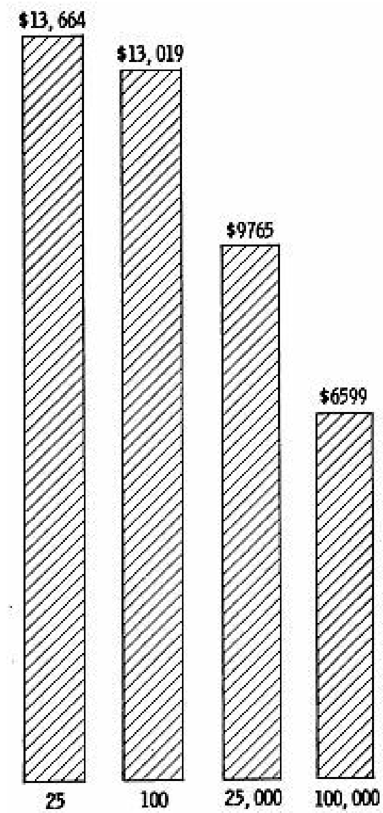
Pages 125-131: "---conducted a performance evaluation on a commercially available point-focus solar concentrator manufactured by the OMNIUM-G Company---"

OG-7500 Production Cost Analysis.

(1) Fortgang, H. R. 1980. "Costing the OMNIUM-G System 7500". Proceedings of the First Semi-Annual Distributed Receiver Systems Program Review. Conference held in Lubbock, TX; 22-24 January 1980. JPL Publication 80-10.

Pages 139-144: "---A complete OMNIUM-G System 7500 was cost analyzed for annual production quantities ranging from 25 to 100,000 units per year. Parts and components were subjected to in-depth scrutiny to determine optimum manufacturing processes, coupled with make-or-buy decisions on materials and small parts. When production quantities increase – both labor and material costs reduce substantially. A redesign of the system that was analyzed could result in lower costs when annual production runs approach 100,000 units/year---".

(2) Blake, C A. 1980. "Cost Analysis of the OMNIUM-G System 7500 in Selected Annual Production Volumes". Report by Solar Thermal Systems Project, May 1980. Pasadena, CA: Jet Propulsion Laboratory; DOE/JPL 5105-23.



Quantity vs Cost $

Solar Thermal Technology

(1) Solar Thermal Energy Systems. "Annual Technical Progress Report FY 1980"; Golden, CO: Solar Energy Research Institute DOE/CS/1012-2.

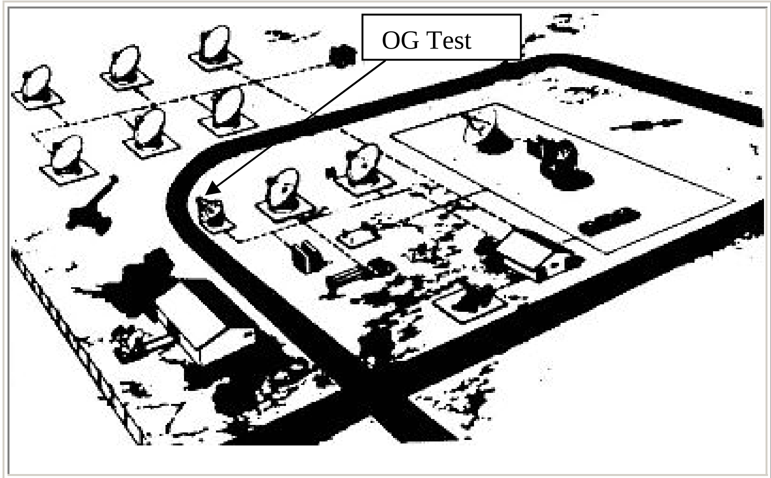
Pages 20: "---A costing study that ranked 1- to 10-Mwe solar power systems, including dishes, troughs, component parabolic collectors, bowls, and central receivers, was completed; the results are shown in Figure I-17. The study was a companion to studies conducted by SERI and Battelle Pacific Northwest Laboratory. The results were similar, although ranking positions differed for some systems. The JPL study concluded that point-focusing systems in general, and dish systems in particular, have the lowest levelized busbar energy costs---".

"---Test results of thermal power output by the OMNIUM-G module [3] are shown in Fig.I-18".

Page 21: "---A number of 24-hour tests were performed on the OMNIUM-G module to gather operation and maintenance data. Thermal performance was assessed by using the OMNIUM-G 20.3-cm (8-in) diameter aperture converter (receiver) as a cold water calorimeter".

Page 22: "---The Point-Focusing Solar Test Site (PDTS) was established at Edwards Test Station in the California Mojave Desert to test point-focusing concentrator systems and related hardware for DOE". "The site occupies approximately 10 acres of the 600 acre Edwards Test

Station (Fig. I-19 shows OMNIUM-G's 6-meter diameter parabolic dish)".



JPL test site at Edwards AFB

Page 32: "---The Southern New England Telephone Company was awarded a $44,000 grant from DOE in 1979 toward construction of a $100,000 parabolic dish system to provide power and space conditioning for a small switching station in Bethany, CT". "---The telephone company awarded contracts to OMNIUM-G of Anaheim, CA for the dish module---". "---The installation was completed early in FY 1980, followed by system check-out and personnel training".

New Haven, CT Installation

Page 103: "---The purpose of the Advanced Component Research Facility at SERI is to provide the capability to test and develop advanced components related to point-focus solar concentrating collectors". "---In late FY 1979 and continuing through FY 1980, two 6-meter dishes (purchased commercially from OMNIUM-G Company) were converted into flexible test loops to provide the aforementioned test capability. The north dish was converted into a high-temperature thermal test loop with the ability to deliver a wide range of coolant flow rates, pressures, and temperature for testing receivers over a wide variety of operating conditions. The south dish was converted into an optical test fixture with the development of several test techniques including a real-time flux mapper, a technique for optical alignment (reverse reflection method), and the development of a cold-water calorimeter. The facility (including the OMNIUM-G dishes) is shown in Fig. 4-10 and results from the flux mapper are shown in Fig. 4-11".

(2) Jaffe, L. D. 1982. "Dish Concentrators for Solar Thermal Energy: Status and Technology Development". Report by Solar Thermal Power Systems Project, January 1982. Pasadena, CA: Jet Propulsion Laboratory; JPL Publication 81-43.

Page 8: "---Table 1 (page 8) is a summary of the characteristics of some current U.S. dish concentrator concepts; the concentrators are pictured in Figures 1 through 27 (pages 14 through 40)". Note: OMNIUM-G is the first dish concentrator to be evaluated and is pictured in Figure 1 on page 14.

Page10-12: Optical materials for solar Concentrators. "---Metal sheet has the advantage of easy formability to doubly-curved shapes. Panels of polished aluminum sheet, generally with an anodized surface finish, have been used for dish concentrators (Fig. 1 OMNIUM-G Concentrator)". "---The optical element itself can be supported in a number of ways. A mirror may be placed on a continuous structural backing of metal, cellular glass, reinforced polymeric material (Fig. 1 OMNIUM-G Concentrator), or wood". "---Dish solar concentrators most commonly use azimuth-elevation ("az-el") mounting (Fig. 1 OMNIUM-G Concentrator".

Page 14: Photograph of fully operational OMNIUM-G Concentrator at the JPL Test Site under going performance evaluation.

OG-7500 Concentrator at Jet Propulsion Laboratory (JPL), Edwards AFB

Pages 41-49: Section III Concentrator Performance and Cost

Pages 51-54: Section IV Technology Development

Page 57: Section VI Summary

(3) Solar Thermal Technology. "Annual Technical Progress Report FY1981; Volume 1: Executive Summary". Pasadena, CA: Solar Energy Research Institute DOE/JPL-1060-53.

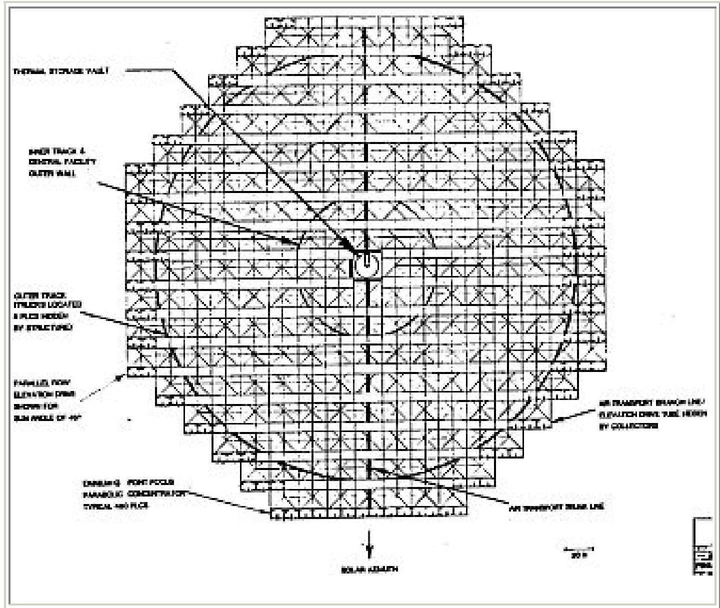
Page 5: "---significant progress occurred in two major areas of the parabolic dish program in FY 81. The first parabolic-dish solar total-energy plant neared completion; successful operation of the plant will provide a model for other potential industrial users".

(4) Solar Thermal Technology. "Annual Technical Progress Report FY1981; Volume II: Technical". Pasadena, CA: Solar Energy Research Institute DOE/JPL-1060-53.

Page 3-11: "---(7) Completed flux mapping of the OMNIUM-G concentrator. Tested the OMNIUM-G steam engine using TBC-1. Mounted and aligned new concentrator petals".

<u>Chemehuevi Solar Electric Facility</u>

30 MWe solar electric plant for the Council of Energy Resource Tribes (CERT) by The Consortium of Alternate Energies, Proposal May 1986, San Diego, CA.



Top view of standard 1 MWe power module

ABSTRACT: Construction of a 30 Megawatt solar electric plant for the Chemehuevi Indian Tribe at Lake Havasu, CA. This project evolved as a part of Project CENICOM™ which uses OMNIUM-G parabolic dish technology together with unique methods of assembling and controlling large numbers of collectors in a cluster. The result is a power plant featuring conversion and land use efficiency, and cost economics superior to all other available conventional forms of solar-derived electrical generation. To accomplish this, the collector cluster is supported on a common structure in such a manner that the structure---which resembles a large wheel and hub lying on its side---is rotated as one unit to follow the sun.

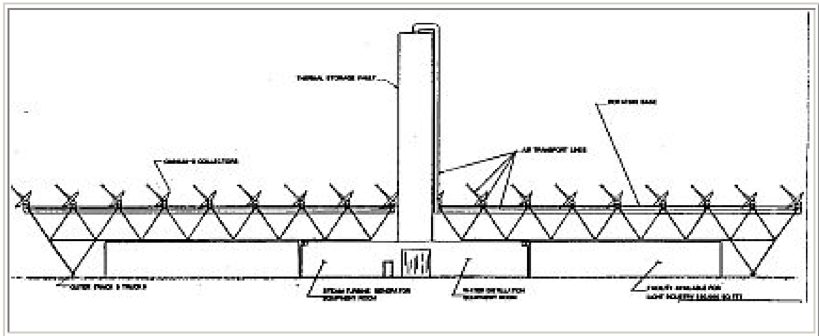
Accordingly, OMNIUM-G has set a goal of providing this technology as a major energy alternative to conventional sources. This new energy-neutral concept, when implemented, will generate more over-all revenue and job opportunities than any other total solar installation now available. Installed cost is low to begin with, but considering the plant's several income streams---from cogeneration and creative use of space---real cost becomes dramatically less.

Solar Thermal Cogeneration Facility

Installation of 1 MWe and higher solar electric plants at pre-selected sites in the U.S. Southwest. "Solar Thermal Cogeneration Facility". Proposal by: The Consortium of Alternate Energies, August 1986, San Diego, CA.

ABSTRACT: Solar parabolic dish concentrators have been developed to a high state of refinement by the scientists, engineers, and members of the Consortium group. Years of development, sophisticated testing, evaluation, and field experience have proven the equipment feasible, practical to construct, and economically competitive with other power sources. It is a market-ready resource with vast potential.

Accordingly, the Consortium of Alternate Energies and its proven project partner, OMNIUM-G of Anaheim, CA, have set a goal of providing this technology as a major energy alternative to conventional power sources.



Standard 1 MWe power module used in clusters to provide 30 MWe power to the grid.

<u>Advanced Solar Cogeneration Systems.</u>

Standard 1 MWe solar electric plant at Borego Springs, CA. “Advanced Solar Cogeneration Systems”. Proposal by: The Consortium of Alternate Energies, March 1984, San Diego, CA.

ABSTRACT: System design is considered a “standard plant”, well adapted for use throughout the world. It is designed to perform several functions. It will produce 1,000 kilowatts of electricity, desalinate brackish underground water, and provide residual heat for a variety of agricultural, commercial or residential uses. No by-product of the plant will go unused; even the very residue left from the water purification process will be sold as a fertilizer component.

The facility utilizes parabolic concentrator solar thermal technology, a well-proven process based on common thermal, mechanical, electronic and materials engineering principles.

<u>African Village Development Project</u>

Standard 1 MWe energy clusters for developing nations. “African Solar Energy-Based Village Development Project”. Proposal by: The Consortium of Alternate Energies, September 1987, San Diego, CA.

ABSTRACT: Utilizing proven parabolic dish concentrator equipment, grouped in 1-Megawatt or higher arrays, in areas proximate to underground water sources, local inhabitants may purify and distribute vast quantities of water for farming, culinary or livestock uses. Electricity and waste heat is also available for pumping, lighting, heating, cooling or any number of other functions needed in basic village or community development.

The systems are modular and expandable, according to need. Plant energy output may be shifted into different modes of production as conditions dictate. Around these power clusters may develop other facilities and projects. The over-all goal, and very probable outcome of this activity, is actual local self-sufficiency in water resources, food production, nutrition, and economic development.

3. Pragmatic Implementation Experience

Accomplishment & Breakthroughs.

Through 30 years, continuous improvements evolved in a most cost effective and pragmatic implementation of solar thermal processes. It is a long and tedious road from the scientific experiment to where all may derive benefit and share in the wealth and welfare of an idea.

Life Cycle Considerations

30 Year Life

Superior performance of aluminum over glass collectors

Construction Techniques

Simplified light-weight and durable mirror design

Conventional off-the-shelf materials and processes

Manufacturing Processes

Standard commercial tools, materials, personnel

Refined and finely tuned “lessons learned” methods

Safety

Concern for environment, human and animal hazards in construction, implementation, and utilization—no environmental risk

Maintainability

Environmentally protected components requiring only preventative maintenance and cleaning to insure long life

Reliability

Inclement weather resistant and durable conventional utility power components with minimization of moving parts

Survivability

Innovative techniques to protect against potentially destructive high velocity wind and wind-driven particles

Cost/Effectivity

Optimally sized for maximum utility of energy

Installations.

The product is designed for crating and shipping via any land, sea or air transport carrier. At any worldwide destination, the product is re-assembled on-site and installed manually using included tools and lifting devices. Installations are:

DESCRIPTION	CUSTOMER	CONTRACT	DATE
Chemical storage system	U.of Houston, Houston, TX	HOU-8-4837-S	Dec 1977
Water pumping for greenhouse	El Marj, Libya	PO-9552	Jan 1978
Lasers & satellite energy xmission	U.of Washington,Seattle,WA	None Assigned	Mar 1978
President Carter dedication	SERI, Golden, CO	AB-8-0914-1	May 1978
Evaluation for industrial processes	SERI, Golden, CO	AB-8-0914-1	May 1978
Evaluation for process heat	JPL, Edwards AFB, CA	KH-692900	Sep 1978
Evaluation for rural use	U.of Queensland, Brisbane,A	174051	Nov 1978
United Nations demo facility	Tangallie, Sri Lanka	78/11597	Dec1978
Evaluation for village power system	Hyderabod, India	4671-01	Dec 1978
Developing heat engines	Martin-Marietta, Marietta, GA	727709	Feb 1979
Evaluation for island fishing village	Kaeya Island, Korea	796001	Mar 1979
Power/heat for phone switching bldg	New Haven, CT	None assigned	Jun 1979
Evaluate rocket engine nozzle	RPL, Edwards AFB, CA	FO470079c0095	Sep 1979
Power for employee canteen	FIAT, Brindisi, Italy	300.004/8	Nov 1979
Irrigation pumping	TexasTech Univ, Lubbock,TX	TTU-0-1684-H	Nov 1979
Irrigation pumping	TexasTech Univ, Lubbock,TX	TTU-0-1684-H	Nov 1979
Evaluation for small power system	JPL, Edwards AFB, CA	955845	Aug 1980
Residential heating unit	Monument, CO	Retail sale	Sep 1980
Residential heating unit	Clementon, NJ	Retail Sale	Oct 1980
Evaluation for industrial process heat	Anaheim, CA	None assigned	Dec 1980
Pizza oven furnace unit	Elgin, IL	Retail sale	Feb 1981
Process for chemical company	C.Itoh, Kawasaki, Japan	56-1001	Mar 1981

Projects.

Plentiful operations and maintenance field data has been documented from the proposals, installations, and projects:

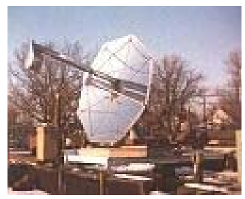
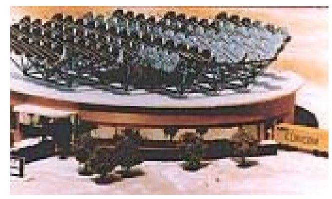
African village development	CAE, San Diego, CA
Solar thermal enhanced oil recovery	EXXON, Pittsburgh, PA
Parabolic dish solar thermal cogeneration	CAE, San Diego, CA
Solar power plant, 30 mWe	Chemehuevi Indian Reserve
Solar thermal power plant	Borrego Springs, CA
Solder manufacturing process	Litton, Anaheim, CA
Potato Chip Process	Laura Scuddar, Anaheim, CA

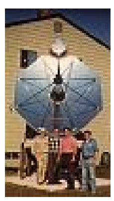
4. Historical Photos Gallery







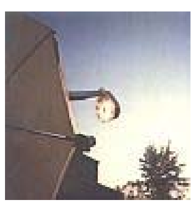




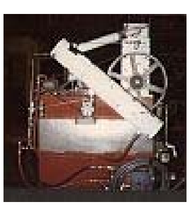













Appendix B

Sensitivity Analysis of the Production Cost of CENICOM™ Clusters.

The method used is the learning curve method applied to labor costs and material costs separately for the eight major identified tasks required to produce a CENICOM™ Cluster.

As stated in the NASA 2004 Guide "Learning curves, sometimes referred to as improvement curves or progress functions, are based on the concept that resources required to produce each additional unit decline as the total number of units produced increases. The term learning curve is used when referring to an individual's or organization's performance. If the analysis involves all the components of an organization, it is referred to as a progress function or an improvement curve."

"The learning curve concept is used primarily for uninterrupted manufacturing and assembly tasks, which are highly repetitive and labor intensive. The major premise of learning curves is that each time the product quantity doubles the resources (material and/or labor costs) required to produce the product will reduce by a determined percentage of the prior quantity resource requirements. This percentage is referred to as the curve slope. Simply stated, if the curve slope is 90% and it takes 100 hours to produce the first unit then it will take 90 hours to produce the second unit. As the quantity doubles (from 1 to 2) the resource requirement reduces from 100 to 90 (100 * 90%). The two types of learning curve approaches are unit curve and cumulative average curve. The main difference between the two approaches is as indicated by their names, the cumulative average curve calculates the average unit value for the entire curve to a set point while the unit curve calculates the unit value for a specific quantity point.

High proportion of manual labor,

Uninterrupted production,

Production of complex items,

No major technological change, and

Continuous pressure to improve."

The production of CENICOM™ contains all of the above items. Therefore learning curves were used to project the cost of future CENICOM™ clusters. The unit curve method also called the Crawford method was used for this study.

The eight task divisions are:

CENICOM™ Collectors
Air Transport

Storage Vault

Steam Generation

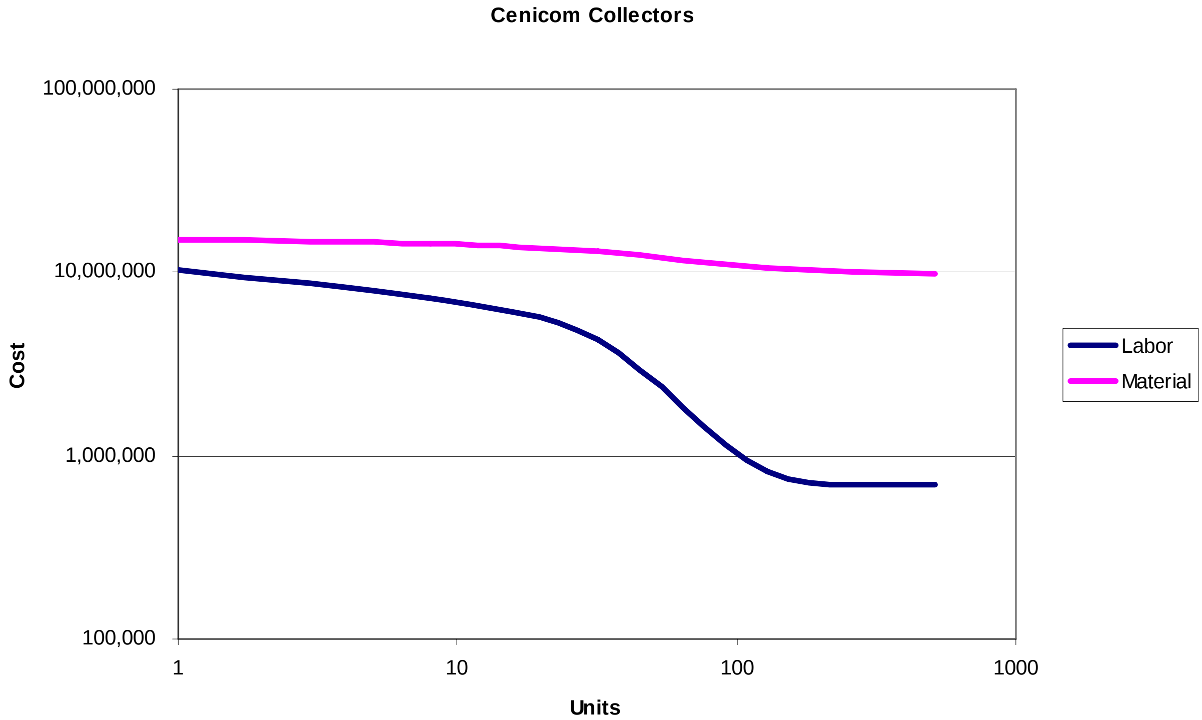
Collector Support Structure

Tower & Base

System Elements

On Site Assembly

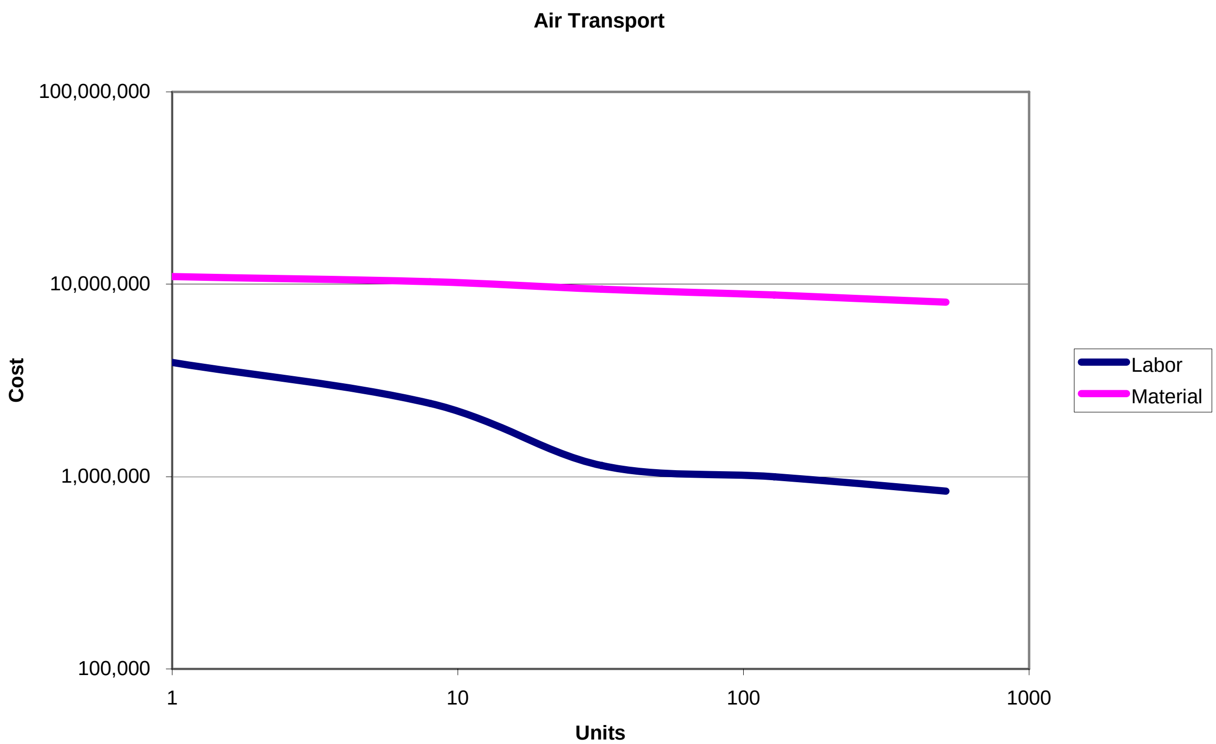
CENICOM™ Collectors



The mirror production will have a modest material learning curve. It could be improved by some vertical integration in the processing of the aluminum mirror surface. This curve does not anticipate that integration thus the material curve slope is a very conservative 98% at the beginning of build up. It dips to 98% during the introduction of automation. Then it settles to 99% for continued production. This is a very conservative estimate of material costs for the highest volume component.

The labor required to produce mirrors will have a learning curve slope of 89% before the introduction of improvements in the production of the mirror support structure and 99% after the introduction of the automation improvements. There is dip in the curve that is the result of a 78% learning rate during the introduction of automation.

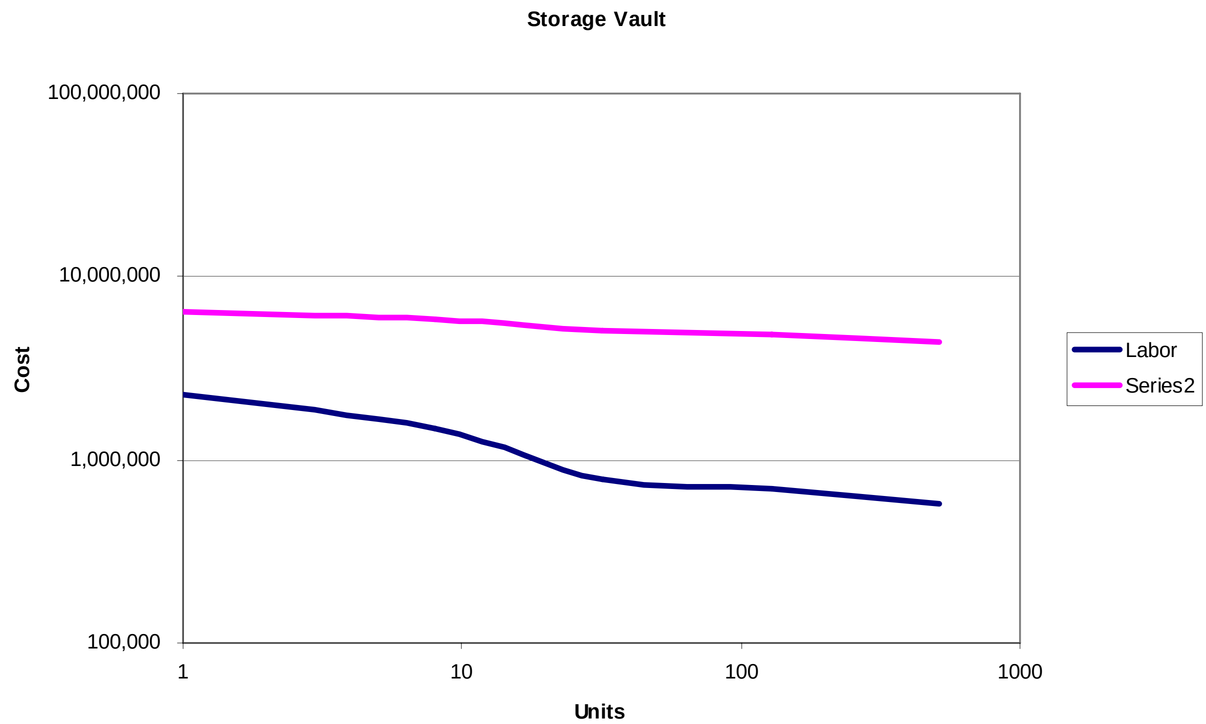
Air Transport



The air transport lines are of two types the branch lines that act as the elevation control axle and the trunk lines that manifold the hot air to the storage vault. The air transport pipes are ceramic and are heavily insulated to limit the heat losses. The shells of the lines are large diameter steel tubes. It is estimated that the material costs will follow a 98% curve at the beginning of the build up and settle to a 99% curve at higher rates. The ceramic tubes and fittings are custom made thus the material cost has followed a very shallow curve.

The production of the outer shells and the assembly of the line sections is quite labor intensive. It starts out on an 85% curve and decreases to a 98% curve as training of new assemblers decreases the overall learning efficiencies.

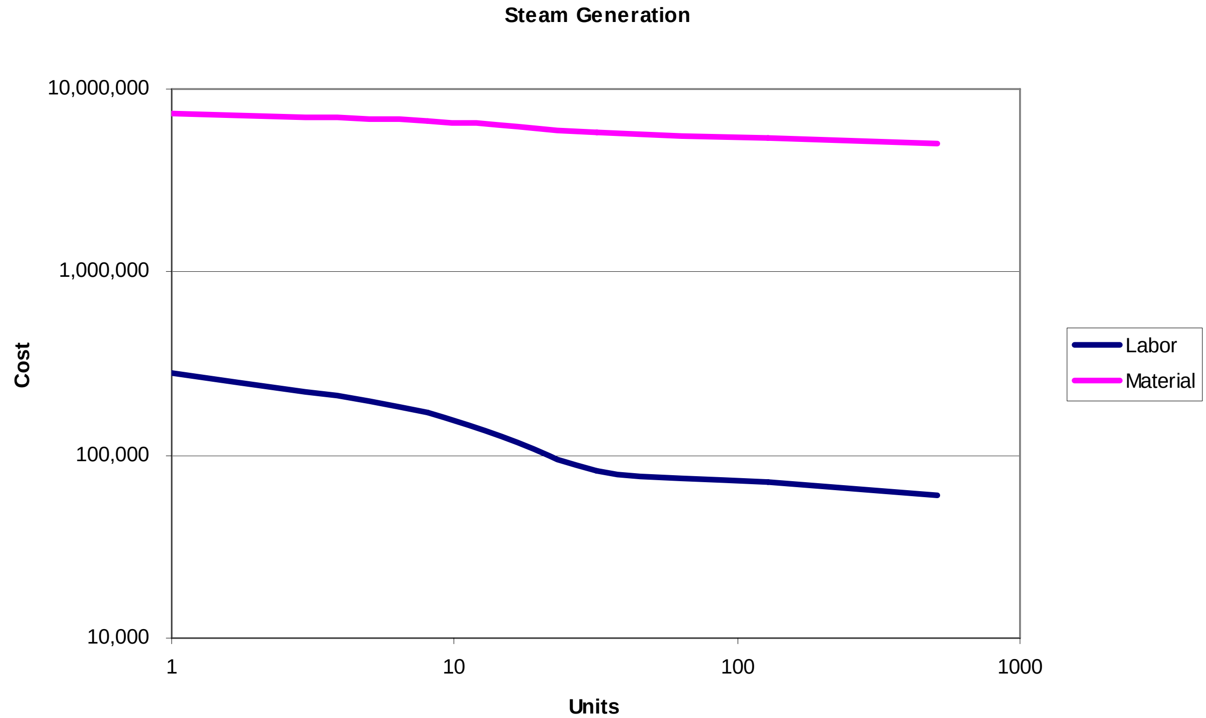
Storage Vault



The storage vault is a highly insulated cavity that contains the solid inert material used for heat energy storage. The material has to be delivered to the site to be placed in the system tower. The materials are bulk materials. The material cost learning curve starts at 97% and settles at 99% for large volume production.

The labor learning curve starts at 87% for relatively low volumes and then changes to 98%, as more and more installation crews have to be trained.

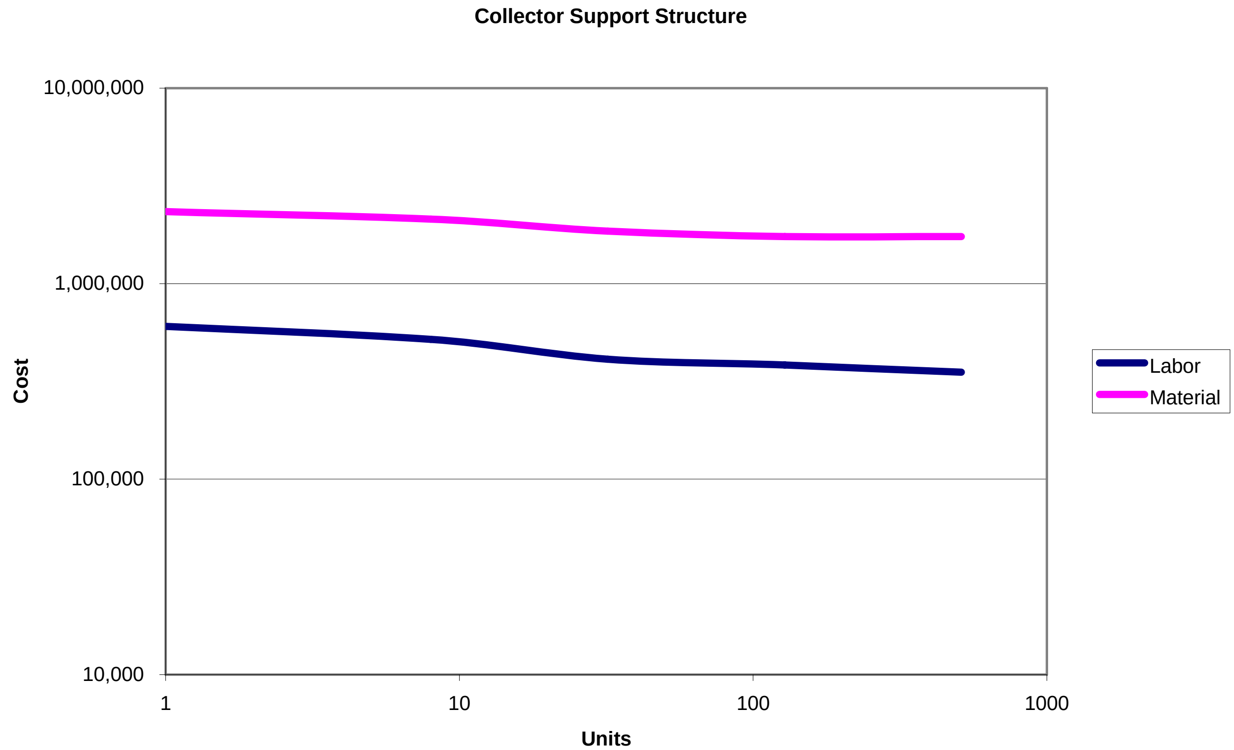
Steam Generation



The steam generation system takes a commercial boiler and attaches it to the feed water system and to the steam manifold. The hot air from the storage vault is directed into the firebox of the boiler. The material learning curve starts at 97% and settles at 99% for the boiler and other purchased components.

The labor learning curve starts at 85% for the early installations and flattens to 98% as tooling is produced that allows the plumbing to be prefabricated in the factory.

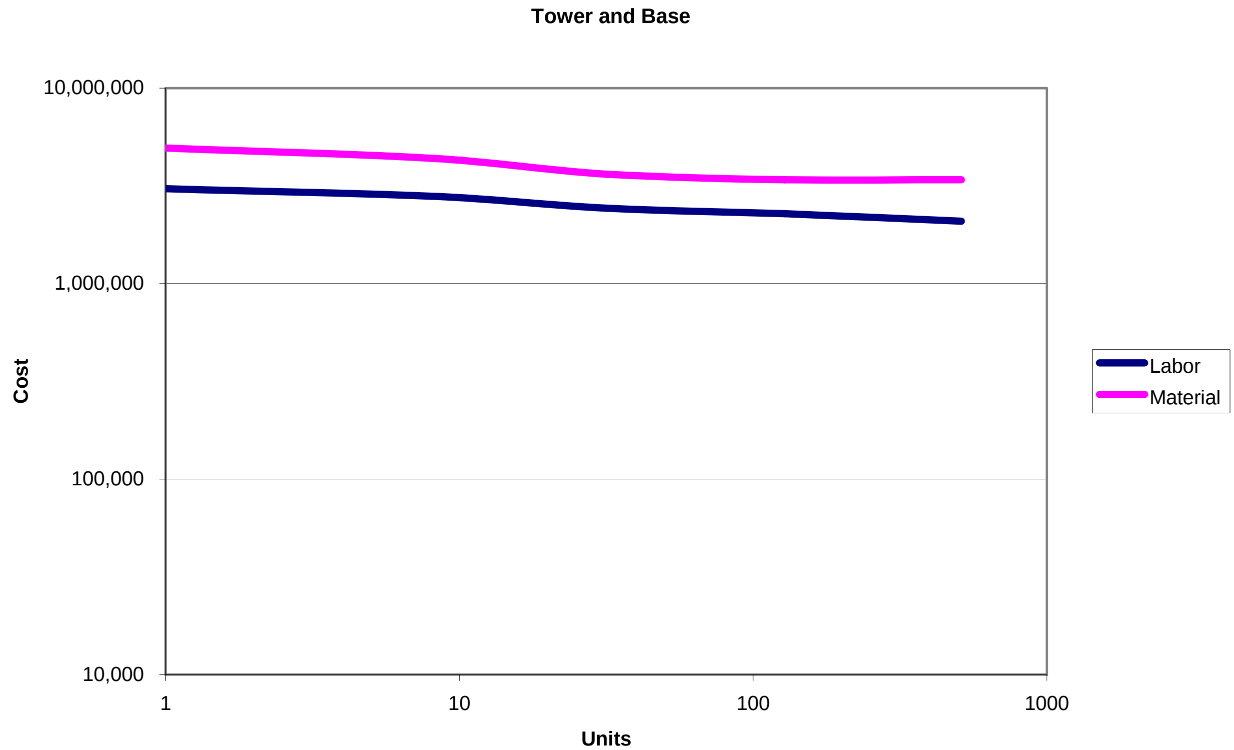
Collector Support Structure



The collector support structure or "space frame" will be produced in moderate quantities. The learning curves for material start at 97% and increases to 100% for large quantities because the elements are mass-produced fort other customers.

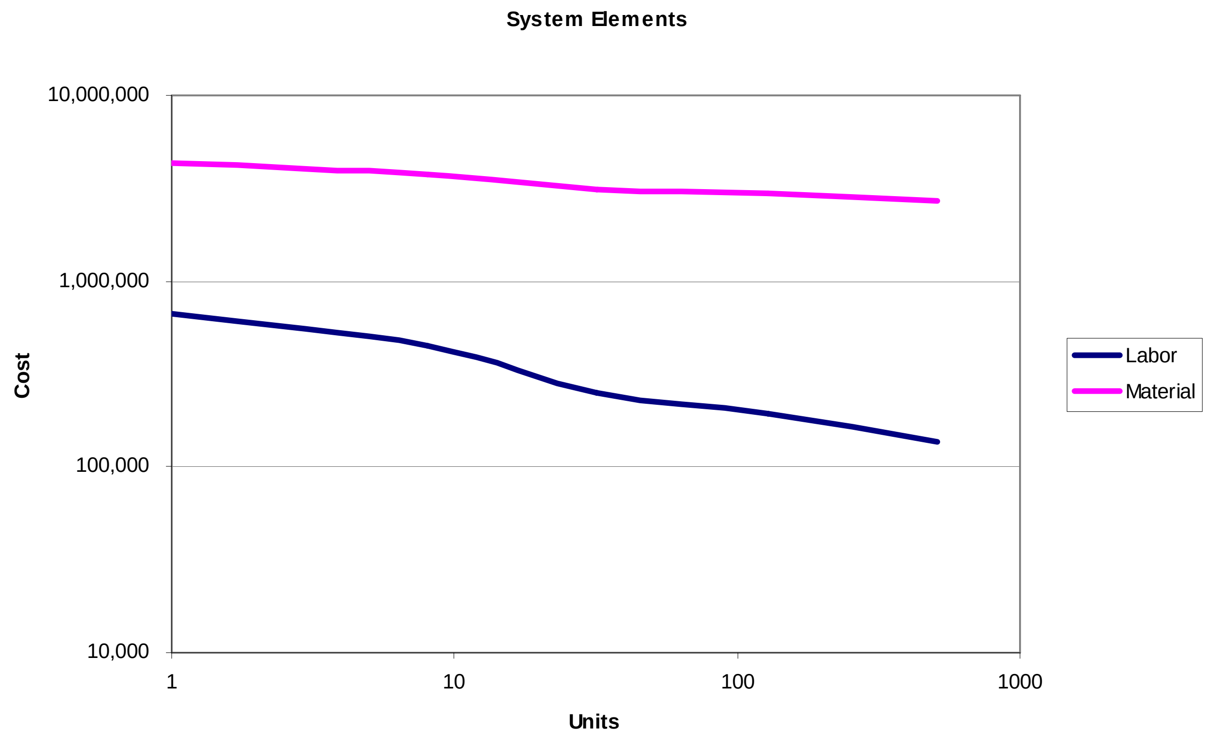
The labor learning curve is also very shallow starting at 95% and settling at 99%. Since the space frame supplier would have experience in assembling the frame, there is not room for large improvements.

Tower and Base



The tower is a poured concrete structure reinforced with steel. . Since concrete construction is a mature activity, there is not much room for either material or labor learning. The material learning curve starts at 97% and settles at 100%. This means that there is no reduction in material cost with additional volume. The labor learning curve is also shallow, since experienced workers do this type of construction. The learning curve starts at 97% and settles to 99%.

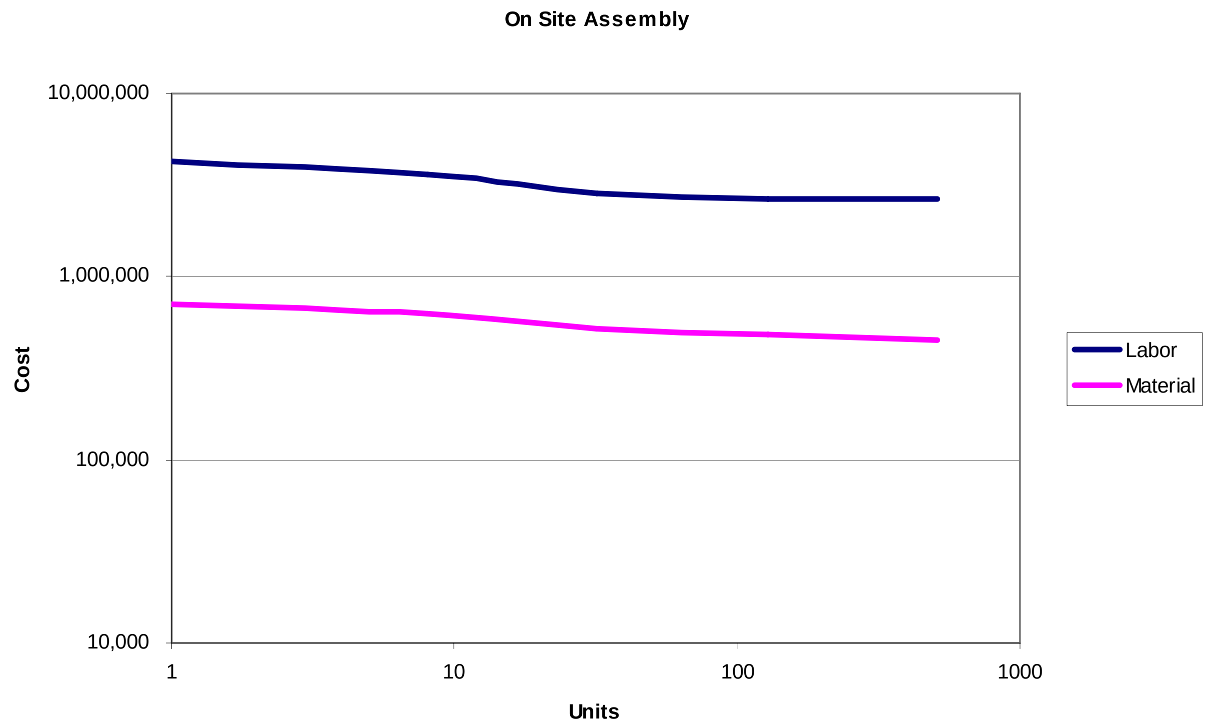
System Elements



The system elements are the sensors, servo controls, monitoring and control computers, wiring and installation of the management software. The material learning curve for these components starts at 96% and settles at 99%. The components that are being used are standard components in volume production thus material learning will be modest.

The labor learning curve starts at 88% and settles at 96% as the effects of factory built wire harness and other prefabricated assemblies are used.

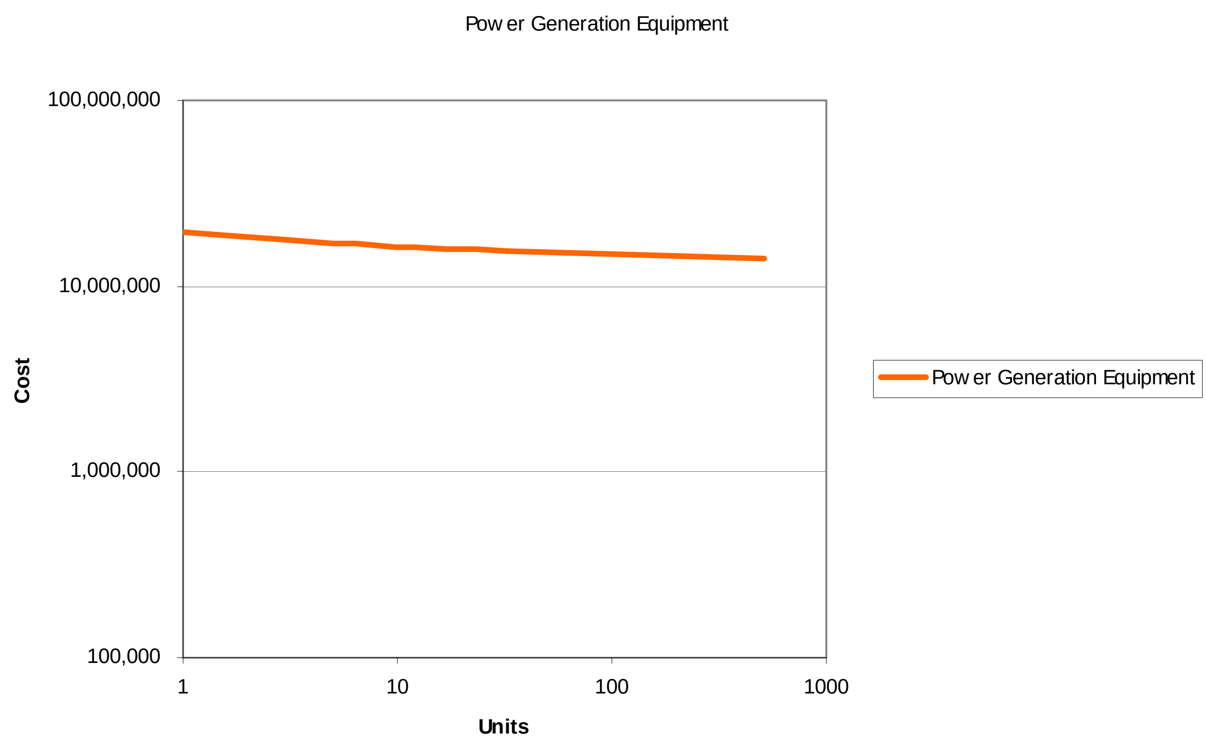
On Site Assembly



On site assembly consists of putting the support structure in place on the tower, lifting the mirrors and the air transport assemblies into place, wiring up all of the components, and completing all of the feed water and steam plumbing. The materials required for this activity are purchased components and standard wiring and plumbing materials. The material curve starts at 95% and settles at 99%

The labor curve is quite shallow since most of labor will be hired locally for each installation and there will not be a significant chance to have a steep learning curve. The management of the installation will be able to carry forward some learning experience. The curve starts at 95% and settles at 99%.

Power Generation



The power generation suite of equipment includes the prime mover, the generator, the condenser, the feed water pump and water conditioning equipment. The reduction in cost of this equipment is mainly due to larger systems being installed. As systems increase in size the amount assigned to a single CENICOM™ cluster will decrease since larger systems are less expensive per megawatt. The curve resulting from this fact starts out at 94.6% and settles at 99.5%

The learning percent is usually determined by statistical analysis of actual cost data for similar products. Lacking that, you may use the following guidelines from "Cost Estimator's Reference Manual- 2nd Ed.," by Rodney Stewart:

75% hand assembly/25% machining = 80% learning

50% hand assembly/50% machining = 85%

25% hand assembly/75% machining = 90%

or

Aerospace 85%

Shipbuilding 80-85%

Complex machine tools for new models 75-85%

Repetitive electronics manufacturing 90-95%

Repetitive machining or punch press operations 90-95%

repetitive electrical operations 75-85%

Repetitive welding operations 90%

Raw materials 93-96%

Purchased Parts 85-88%

The guide above was used as a starting place to select the learning factors. However, due to the fact that we expect an extremely aggressive ramp-up of production, the learning factors used were more conservative than the guidelines.

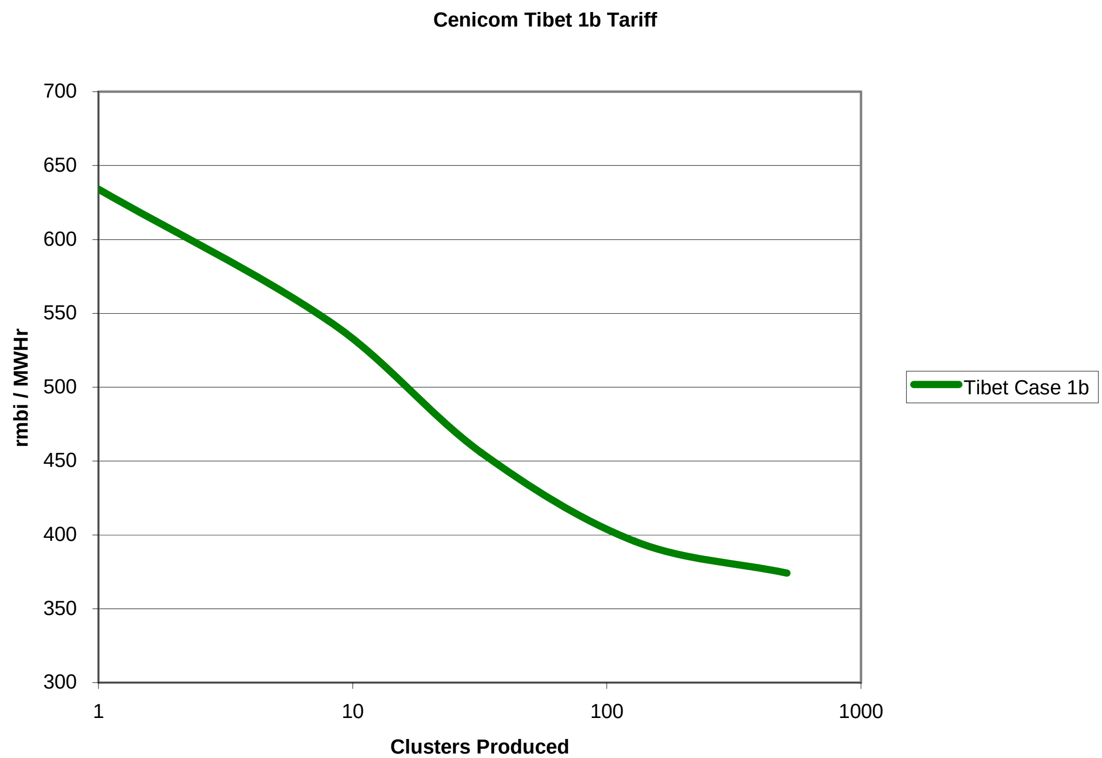
Output Adjustment

We now believe that the sunshine at Lhasa is better than the proxy we used for the case studies. The proxy was Flagstaff, Arizona. It does not rank in the top sites. Lhasa was noted in the literature to rank second only to the Sahara Desert. This was reported in the Wednesday, June 15, 2005 *South China Morning Post* "**Beijing steps in to prevent power cuts"** by CARY HUANG in Beijing.

That means the Lhasa sunshine is nearly the best in the world. We used the profile from Daggett, CA to generate a closer approximation to the output we would expect. This means the annual output from a single cluster would increase from 11,113,333 KWHrs per year to 13,380,000 KWHrs per year. The tariff calculation is inversely proportional to the annual output. :

Tariff Type	Flagstaff Data	Daggett Data
Tibet Case 1a	1,257 RMBI per MWHr	1,046 RMBI per MWHr
Tibet Case 1b	762 RMBI per MWHr	634 RMBI per MWHr

The Official Program for calculating the tariff is virtually linear with respect to plant cost. Using the Daggett Data as the starting point for the Tibet 1b tariffs and the plant cost from the learning curve study the projected future tariffs will follow the following curve:



The tariff for new CENICOM™ Solar Energy plants would fall on the Reduced Tibet Case 1b Curve. This would give a tariff of 634 RMBI per MWHr. for the initial system. The 32nd installation would have a tariff of 456 RMBI per MWHr.