S. E. P. P.

SOLAR ENERGY POWER PLANT

Large Parabolic Dish System - LPDS
Cogeneration System for
Desalination and Electricity Production

F I N A N C I A L   S T U D Y

Author:

Arthur G. Sutsch

ACKNOWLEDGEMENT

The author wants to thank Prof. Dr. Ing. Gerhard Deuster from EVO - Energieversorgung Oberhausen, Germany and the late Prof. Dr. Ing. Karl Bammert, Hannover/Germany for their assistance in the compilation of facts for this study.

Table of Contents

Table of Contents 4
Abstract 5
Chapter 1 General Overview 6
Introductory Remarks for the Parameters Used in this Study 6
Chapter 2 Advantages of S.E.P.P. Systems 7
Chapter 3 S.E.P.P. Pilot Plant Configuration 8
Chapter 4 Markets and Uses for LPDS 9
4.1 User Profile - Isolated Load Market 9
4.2 Hybrid versus Solar-only Mode Operation 10
4.3 Stand-alone versus Grid-connected Systems 10
4.4 Process Heat Utilization 11
4.5 Research in Radio Astronomy 11
Chapter 5 Evaluating S.E.P.P. as a Utility Power Plant 12
5.1 General Outline of Parameters Chosen 12
5.2 Installed Equipment on the Island 12
5.2.1 Electricity Production on the Island 12
5.2.2 Desalination for Drinking Water on the Island 13
Chapter 6 Study Parameters 14
6.1 Numeric Values and Comparative Figures 16
Chapter 7 Numerical Analysis 17
7.1 Model I - Emphasis on Electricity Production 17
7.1.1 Electricity Production Figures for 8'000'000 kWh pa. 17
7.1.2. Desalination Production Figures for 330'000 m^3 p.a. 17
Desalination Costs p.a. 18
7.1.3 Model I - Profit and Loss Considerations 18
S.E.P.P. Electricity Production 18
Desalination Income 18
Combined S.E.P.P. Model I System Analysis 19
7.2 Model II - Emphasis on Desalination 19
7.2.1 Desalination Production Costs for 330'000 m^3 p.a. 19
7.2.2 Electricity Production Costs for 8'000'000 kWh p.a. 19
7.2.3 Profit and Loss Considerations Model II 19
Income from Desalination 19
Income from Electricity Production 20
Total S.E.P.P. Plant Net Income from combined System 20
7.3 S.E.P.P. Pilot Plant Payback Time and Financial Considerations 20
Chapter 8 Study Analysis 21
ANNEX - Financial Parameters for a *Series S.E.P.P. System* 22
A. S.E.P.P. Costs p.a. 23
B. Income on Products sold from S.E.P.P. p.a. 23
C. Profit and Loss Statement from S.E.P.P. Unit (first year) 23
D. S.E.P.P. Payback Time 23
E. Reserves 24
F. Monetary Results over Life of Plant 24

Abstract

The financial study for the Solar Energy Power Plant - S.E.P.P., a multi-functional electricity and industrial process heat system, shows a commercially viable and favourable investment considering a required capital of US-$ 15'000'000 with a capital payback time in 12 years at 6% interest p.a. A total additional income of US-$ 8'000'000 throughout the remaining 8 years life of the S.E.P.P. plant after capital repayment is realized at a total plant life of 20 years.

Chapter 1 General Overview

This study describes the market potential for a multi-functional electricity and process heat production system combined in its non-sunshine hours (night) with a scientific application, a radio astronomy research station, the ***Solar Energy Power Plant - S.E.P.P.*** S.E.P.P. utilizes Large Parabolic Dish System (L.P.D.S.) technology based on a utility plant philosophy for providing electricity and process heat utilization on a 24-hour basis in the isolated load market. The plant, therefore, is a hybrid plant employing solar energy whenever possible with a continuous power output through assisted fossil fuel use in the absence of solar radiation.

This study shows that S.E.P.P. presents a favourable investment with short payback time for countries in the isolated load market.

The approach is a departure from the known solar power plant applications, which have mostly been experimental in nature. In order to fulfil this promise, S.E.P.P. makes use of industrially proven components and is not conceived for solar technology experiments: it is considered a ***utility power plant module for electricity production and use of industrial process heat*** and, therefore, contains elements suitable for this purpose. An additional feature is its multi-functional role in the time of non-solar operation as a scientific radio astronomy research station.

The philosophy and operating modes as well as the technical aspects have been described at length in the literature (see ibidem) and - in order to keep this study concise - reference is made to the technical elements presented elsewhere.

Introductory Remarks for the Parameters Used in this Study

Prices mentioned for systems in this study are based on European prices with values expressed in US-Dollars. Changes in exchange rate can influence the calculations.

Annual inflation, as well as the change in prices for crude oil since the summer of 1986 (start date of the study) influence the calculations used in this study. The overall picture, however, for the numerical analysis can be maintained with a varying spread in prices, exchange rates and cost structure.

Chapter 2 Advantages of S.E.P.P. Systems

Comparisons with other types of solar thermal power plants show that S.E.P.P. has considerable advantages over the heliostat-tower, photovoltaic, and farm concepts:

- ***Compact, stand-alone system with 24-hour operation as a power plant due to hybrid mode (fossil and solar operation);***

- ***autonomous system with low man power requirements for service and operation; only high quality components used;***

- ***simple and reliable thermo-electric cycle using air as working medium;***

- ***considerably higher output in annual kWh electric (approx 27% higher than heliostat tower and farm systems) and thermal due to constant two axis solar tracking with parabolic dish pointed constantly at the solar disk centre for maximum and constant radiation flux;***

- ***high efficiency in electric power conversion due to very high process temperature;***

- ***high availability through the use of proven industrial high quality components;***

- ***industrial process heat availability in a wide spectrum of temperatures (starting at over 700º Celsius);***

- ***waste heat utilization at temperature levels of approx. 200º Celsius brings total plant efficiency up to 85 %; application for desalination, food industry, chemicals, fertilizer production, etc. are only a small selection of the industrial process heat utilization spectrum;***

- ***use of the parabolic dish during non-sunshine hours for international radio astronomy research; co-operation with renowned international institutions are an attraction for high-tech research activities in isolated areas;***

- ***clean and ecologically favourable system with a low land use factor.***

Chapter 3 S.E.P.P. Pilot Plant Configuration

This study is based on the following configuration of a Pilot Plant S.E.P.P.:

1. 24-hours electricity production of one Megawatt total power output from two dish collectors at 500 kW (el) each requires a dish collector size of 55 m in diameter;

2. one gas turbine per collector for use with solar and hybrid mode (running on fuel oil or gas) at the rated output;

3. waste heat utilization from the gas turbines to drive one sea water desalination plant delivering 1000 tons metric of drinking water per 24 hour period continuous output;

4. use of dish collector for research activities in radio astronomy in co-operation with international research institutions (interferometry) without any influence on financial parameters;

5. representative energy cost comparison data are taken from an isolated load market island situation considered typical for this type of application market: figures of electricity and water production costs of the considered island in the Caribbean were applied.

As can be seen in the literature, different installation costs for a S.E.P.P. have been considered. This cost model assumes a Pilot Plant S.E.P.P. installation.

The basis of this financial study, therefore, is not the series but a ***pilot plant S.E.P.P.*** considering a unit before unit 5; series production unit costs will be dealt with in a separate study. The Annex to this study gives a brief financial outline of such a series system.

Since the pilot plant installation S.E.P.P. will carry a large amount of subsidy from national and international institutions, figures would be distorted and the comparison with conventional systems not applicable. ***The higher cost for a pilot plant installation are considered offset against the subsidies.***

Since international and national financing is almost always present in one form of subsidy or another when a developing or threshold country is undertaking an infra-structural improvement, whether based on conventional or renewable energy sources, a dividing line cannot be drawn exactly and a "grey area" in a mathematical sense exists; much is left to the interpretation and the viewpoint in question.

One major factor entering any cost comparison study is the depreciation period of the plant versus its repayment of capital; this is being handled differently in every country and possibly has to be adapted to the individual situation; figures, therefore, influence plant cost over the years considerably. In this study of a Pilot Plant S.E.P.P., the repayment of the invested capital

is taking approximately 12 years at a constant repayment amount while still accumulating reserves as unforeseen items of 20 % of net income.
After the repayment of capital period, an increased amount of US-$ 562'000 p.a. is kept in reserves throughout the remainder life of the plant (years 13 - 20).

It is with this situation in mind that the figures presented for the financing of S.E.P.P. have to be seen.

Chapter 4 Markets and Uses for LPDS

4.1 User Profile - Isolated Load Market

Since conventional sources of energy have different costs depending on their size, type, and availability and accessibility to the conventional fuels, three principal user types can be identified for the penetration of solar energy in short term, medium term and long term time frames. These users are:

1. Isolated Load User - including small communities with isolated site characteristics for electricity production and process heat applications, like the island considered in this study;

2. Industrial Process Heat User with the demands for both process heat and electricity in a "total energy systems" market. This market includes production of desalinated water, chemicals or fuels, apart from the smaller industrial process heat consumer in developing countries;

3. Grid Connected Electric Utility User, primarily small communities, the re-powering market - with the bulk electric market as the ultimate goal.

The user profile of the first type mentioned for penetration of solar power plants today can be described as the isolated load market where the user is generally isolated from a national grid.

The local utility plant, if there is one at all, consists of a few Diesel generators with possibly a small transmission and distribution network. This application is typical of small communities on islands, remote military installations, isolated industrial sites, and villages in remote areas with no infrastructure for electricity distribution.

It is certainly these markets that will allow the economic penetration of solar energy in the very near future. Small power plants in the order of one Megawatt are needed for desalinating sea water, pumping water for irrigation, to drive machines in isolated industries, supply lighting, power hospitals, telecommunication and television, etc.

Reliable, simple and compact systems with low maintenance have good possibilities for application in these fields with the added use of the reject heat from the turbine cycle for industrial processes, such as desalination, food drying, chemicals, fertilizer production, etc.

Production cost of electric energy in the isolated load market is considerably higher than in large, grid-connected national networks. In these first markets, solar energy can provide competitively priced thermal and electric energy in utilities, industrial, and related applications for rural communities, as well as municipal and industrial users through modular, individual stand-alone systems of the S.E.P.P. - Large Parabolic Dish System (LPDS) type.

4.2 Hybrid versus Solar-only Mode Operation

Solar power plants today have been conceived as solar-mode-only plants. This may be adequate for experimental stations and in grid connected systems but is unacceptable for use in the isolated load market and in developing countries where a stand-alone power plant is required. S.E.P.P. employs a hybrid solar and fossil operational concept to provide 24 hour system use.

From past experience with experimental research solar power plants, it seems unlikely that solar power plants can compete with fossil and nuclear plants in the near future in grid connected systems; installation costs are considerably higher for solar power plants than conventional systems and accordingly the price per produced kWh. Predictions based on an increase in fossil fuels have been countered with a slump in oil prices worldwide and render such calculations very unreliable for a plant life of 20 years and more. It is obvious and follows general consent that primary energy fuel prices will rise again in the near future to balance the cost comparison for solar power plants against conventional fossil fuel driven plants (Diesel and steam generators); when and for how much remains a speculative process and is a non-predictable item (our computer programs to arrive at such comparisons, therefore, have been conceived by us with the total freedom to parameterise any input data for fuel cost, inflation, maintenance, fuel cost increase factors, etc.).

The market and user profile in developing countries is entirely different from the industrial countries, with electricity consumption per capita decisively lower and the profile of energy use spread more into the application of high quality process heat especially in isolated load market conditions. Conversely, fossil fuel costs can be extremely high due to import and transportation and storage costs in small quantities into such areas.

4.3 Stand-alone versus Grid-connected Systems

The application of the S.E.P.P. type of solar power plant can be seen in either stand-alone or mini-grid configurations in those markets.

Grid connection of solar power plants of the S.E.P.P. type can be achieved in countries with an abundance of solar insolation to feed electricity to a national grid; Large Parabolic Dish Systems can be installed either in single stations or connected to form an array for electric power production. The advantage of connecting LPDS in array configuration is their simple electrical connection, with each individual station having its own power conversion module.

The electricity connection shows further advantages in arrays: servicing one LPDS or using it for other purposes in its off-line hours (such as a radio astronomy research station), does not affect the overall performance of the grid: they are designed with a basic electric load factor and peaks can be assumed by the other units; this also holds true for "mini-grid" systems with as low as approximately five systems for a given power load: one dish can be taken out for service or other purposes since a certain redundancy is built into the peak loads of the grid. Due to the operational principle of a hybrid mode system, constant power (electric and thermal) can be guaranteed to the user.

4.4 Process Heat Utilization

Studies of process heat demands in industry performed in several countries demonstrated the demand of process heat in the temperature range of 150 - 300º and up to 800º Celsius. The primary users in the above-defined market are:

- desalination of seawater for drinking water production;
- foods with drying, canneries, etc.;
- chemical industry on a small scale;
- textile industry;
- paper industries;
- fertilizer production;
- housing (heating and cooling);
- services (laundries, etc.).

Solar process heat generation can supply heat up to 850º Celsius today to the consumer industry (with expansion to much higher temperatures in the future). The operational mode is the same as in electricity production, i.e. the hybrid system that acts as a fuel saver for countries with a fossil firing basis. Any high quality process heat, i.e. temperatures in the given range can be provided for the application of the consumer. The temperature is a question of cycle regulation, heat to power ratio, pressure ratio, fuel to solar radiation ratio, and other factors and can be tailored to the individual application needs.

4.5 Research in Radio Astronomy

The S.E.P.P. system can be used in its non-sunshine hours with the additional installation of the appropriate equipment as a powerful radio astronomy research station.

With the multi-functional role of S.E.P.P. - LPDS providing the basic structure in the form of the antenna with its drive mechanism, the added installation costs are the receivers for the research system. The antenna structure usually accounts for more than 60 % of the installation costs of a station. Application of the Large Parabolic Dish System during its non-sunshine hours for the use as an antenna for international radio astronomy in co-operation with international centres in the USA, Germany and other countries can provide important research activities.

This can be very beneficial to the international esteem of a country, a factor that does not account for any immediate financial benefits but must be valued highly when considering such a venture with its future potential for tourism, increased aperture to new technologies, etc.

Chapter 5 Evaluating S.E.P.P. as a Utility Power Plant

5.1 General Outline of Parameters Chosen

As stated above, S.E.P.P. has been evaluated against real figures from a given situation on the Caribbean island of Curaçao during an extended visit by the author and Prof. Dr. Ing. Deuster in 1986; these figures have been taken as a model for other markets and installations. This approach was chosen in order to arrive at "real world" comparisons and get away from mere hypothetical computer simulation models, as accurate and diverse these may be.

The experience of the author shows the selected island to be a typical installation and application of this type of modular utility power plant with creating electricity and the use of process heat for desalinating sea water, combined with radio-astronomy research spin-offs. Similar conditions have been encountered in the past for Kenia, Morocco, Senegal, and Egypt, to name a few countries that have been studied over time for S.E.P.P. applications by the author.

5.2 Installed Equipment on the Island

5.2.1 Electricity Production on the Island

The installed power on the island is 120 Megawatts including approx. 15 Diesel engines at up to 4 Megawatts each. Many are to be considered unreliable and the following equipment produces electric power of 60 Megawatts peak load with a typical daily load of 50 MW on a more or less spread out load line throughout the day. The power generating equipment consists of:

- 2 gas turbines base load 13 MW (out of operation) and 21 MW;
- 2 coupled steam turbines at 3.75 MW each;
- 2 steam turbines at 25 MW each;
- 2 steam turbines at 7.5 MW each as standby;
- various smaller Diesel generators.

Most of the equipment is relatively old and has grown over the years to the present power production system.

Peak times during a 24-hour period are between 10:00 and 10:30, at 15:00 and between 21:00 to 23:00; peaks are taken care of partially by Diesel generators.

- Minimum load occurs between 3:00 and 4:00 a.m.

- There is no significant increase in load expected within the next few years.

- Electricity production cost is indicated at US$ 0.10 per kWh.
  The uncertainty for this value of electric power production cost is high, as has been stated by the officials; a spread of up to +25% seems appropriate for a safe measure. In our cost considerations and evaluation we are assuming a figure of

- Electric Production Cost US-$ 0.125 per kWh.
  The power production is locally centralized; distribution is through 127 V, 220 V, and 380 V lines to the consumer, transmission is done via 12'200 V and 30'000 V lines. Frequency is 50 Hz.

- The estimated cost of the production is 40 %, fuel cost is estimated at 60 % of total production cost.
  Electric energy is sold to the consumer at a heavily subsidized rate and varies with the different consumers.

It is felt by the people that development of additional electric power production sites is strongly recommended, especially for the expansion of industry and tourist development of the island.
Decentralized power production is regarded as highly desirable. This role can ideally be filled with modular S.E.P.P. stations in the one Megawatt range.

An island's development is strongly dependent on available electric power as well as the availability of drinking water, especially at remote sites; distribution of electricity is difficult and costly in maintenance, so that decentralized production sites are a welcome situation.

5.2.2 Desalination for Drinking Water on the Island

A separate water production facility is installed on the island. Desalination is achieved with a Multi-stage Flash system; its output is rated at 36'000 cubic meters per 24 hour period, a safe installed figure is considered to be 27'000 cubic meters; typical usage on an end of March 1986 day is 30'000 in 24 hours. The installation is 23 years old; a large amount of insecurity is inherent as to the availability of the system. The situation is considered precarious, to say the least, as the system practically operates continuously at its maximum output level. Another problem is the separation of distribution and production; this, however, is seen more a political item that technical.

These problems are typical for the situation studied.

Apart from electricity production, desalinated water to be used for drinking water constitutes the major obstacle in developing the island further: there are no water wells in sufficient quality or quantity, the distribution of the water at present is highly problematic with losses from the production site to the consumer up to 30 % due to various reasons, a figure one estimates to bring down within the next few years to approx. 10 - 15 %.

The production price of one cubic meter drinking water is given at US-$ 3.50; with the added distribution costs of US-$ 1.20 per cubic meter one arrives at a delivered product price of US-$ 4.70.

For uncertainty and distribution losses one has to add a safe 20 % to the above figures and thus one arrives at

drinking water production cost of US-$ 4.20 per cubic meter and total cost of US-$ 5.64 per cubic meter.

Again, this cost is heavily subsidized by the government for the price a consumer pays for one cubic meter of drinking water.

More profound in this case is the importance of available drinking water in a decentralized situation for developing the island. Distribution costs can be minimized when water does not have to be transported over long distances but can be directed to the consumer from a decentralized station.

Chapter 6 Study Parameters

- At the time of writing the original version of this study (Summer 1986) oil prices for crude were at a remarkable low; the price per barrel was between $12 - $15, with prices in January 1994 around US-$ 18 per barrel; almost all experts are of the opinion that a price around $28 - $30 represents a more realistic figure to take into consideration when long term planning of power plants are considered.

- The value of fossil fuel saving, naturally, rises with higher oil prices when considering a S.E.P.P. module in comparison with conventional power and heat production stations (co-generation).

- The study is based on the conventional layout of S.E.P.P. running with a gas turbine at 800º Celsius; the additional raised temperature possibility to 930º turbine inlet temperature is to be taken into consideration at a later stage of development (task of a test station to evaluate those parameter changes).

- The calculations assume S.E.P.P. to operate in a full load configuration for a given decentralized power and desalination station.

- An approach for the possibilities of looking at the cost structures of a Pilot Plant S.E.P.P. are presented:

    1. evaluating the electricity production with conventional energy results in the remaining cost for water production;

2. sale of the water from S.E.P.P. can be calculated against a conventional desalination plant in order to bring down the specific cost for the solar plant installation and lead to a very favourable payback time;

3. Pilot Plant S.E.P.P. costs are calculated against a Series Unit S.E.P.P. taking into account a subsidy situation; an interest free loan as subsidy would result in lowering capital cost.

A subsidy of 50% is assumed in the calculations. For the additional 50%, a commercial loan is assumed. Interest rates are assumed at 8% in the calculations.

In the Pilot Plant S.E.P.P. unit this assumption appears more realistic than assuming a total subsidy without any repayment of capital. This mechanism is considered a compromise applicable to the pilot plant with its higher investment cost than a series production unit. A series production unit will have considerable lower investment cost and, conversely, less of a subsidy to offset capital cost.

4. electricity production from solar "fuel" results in a rest cost for the water production that is weighted against water production from fossil fuel energy;

5. production prices as mentioned above are compared to a S.E.P.P. module energy production cost;

6. prices given for systems in this study reflect European prices with values expressed in US-Dollars. Changes in exchange rate influence the calculations in this study based on the US - Dollar;

7. the calculations presented in this study are influenced by the change in crude oil prices;

8. the cost of a SERIES UNIT S.E.P.P. is set to US-$ 15'000'000 (two collectors delivering one Megawatt electricity and 1000 cubic meters of desalinated water per 24 hour period); The Annex lists a financial outlook for a Series Unit S.E.P.P.;

9. the **Pilot Plant Unit S.E.P.P**. (described in this study) monetary figure for ***capital repayment*** is entered into the calculations at US-$ 10'000'000 total delivering one Megawatt of electricity and 1000 cubic meters of desalinated water per 24 hour period. Actual pilot plant costs will be higher, a total figure of US-$ 20'000'000 can be assumed of which 50% are considered as ONE-TIME NON RE-FUNDABLE subsidies by international organization and are not entered in the calculations for repayment time of the plant;

10. the SALES PRICE of a kilowatt-hour of electricity has been used in the calculations at the same price as the COST for the production cost on the island. This does not reflect a financial basis for sale of electricity when running a commercial power plant but gives the absolute minimum price figure to be achieved and due to non-refundable subsidies is considered a feasible approach.

11. the same situation as under (10.) holds true for the water production: the PRODUCTION COST price on the island has been taken as a worst case for the calculations as a SALES PRICE.

6.1 Numeric Values and Comparative Figures

The following parameters enter the calculations:

1. Attributed plant cost S.E.P.P. US-$ 10'000'000 with one Megawatt electricity production and 1000 cubic meters desalinated sea water production per 24 hour period.

2. Pilot plant additional cost S.E.P.P. assumed to be in the form of a subsidy. The non-refundable subsidies (not requiring interest payments nor capital repayment) are assumed to be added development cost for the pilot plant and not taken into account.

3. Series production S.E.P.P. can have other models of financing that influence figures below.

4. Turbine fuel consumption is taken at 0.230 kg/kW.

5. Plant life is set to 20 years.

6. Fuel cost is assumed to be US-$ 0.15/kg.

7. Maintenance cost per annum is set to 2.5 % of plant cost.

8. Capital cost set to 8 % for Pilot Plant S.E.P.P. of the invested capital.

9. Pilot Plant income after all expenses and reserves is used for capital repayment.

10. Availability of Pilot Plant is 90%, i.e. 8'000 hours of electricity production and 330'000 cubic meters per annum desalinated drinking water produced.

11. Solar energy operation of pilot S.E.P.P. is assumed to one third of electric energy production (eight hours of average solar operation).

12. Figures in two models are presented for sale of the products electricity and water against their production cost figures.

13. The calculations in the two models are based on assuming all costs for electricity production (Model I) and show savings for desalinated water production from reject heat energy; Model II emphasizes the water production to offset the loss from electricity production.

Chapter 7 Numerical Analysis

Two models are considered in the numerical analysis: the model prioritising electricity production and the model that emphasizes water production. Both have different cost distribution parameters associated to them and are enumerated in detail below.

7.1 Model I - Emphasis on Electricity Production

7.1.1 Electricity Production Figures for 8'000'000 kWh pa.

1.	Depreciation 20 years	$ 500'000 or $ 0.0625 /kWh
2.	Fossil Fuel Cost	$ 184'000 or $ 0.0230 /kWh
3.	Maintenance Cost	$ 250'000 or $ 0.03125/kWh
4.	Personnel Cost	$ 100'000 or $ 0.01562/kWh
5.	Capital Cost	(not included)
	Total Plant Cost p.a.	$1'034'000 or $ 0.1323 /kWh

Comparison figures to electricity production figures show a loss of US-$ 34'000 when all costs are assumed to be born against electricity production. The sale of one kWh was taken at US-$ 0.125 per kWh (selling 8'000'000 kWh per annum at $ 0.125/kWh produces US-$ 1'000'000 income).

7.1.2. Desalination Production Figures for 330'000 m^3 p.a.

As the installation cost for S.E.P.P. has been calculated into the electricity production, a comparison would yield a desalination plant that had to be built separately with the cost figures below; depreciation time also has been set to 20 years (linear depreciation for simplicity). Capital cost of 8% was included, as the plant would require commercial financing.

Desalination Costs p.a.

* 1.	Depreciation on plant cost of $ 3.5 million if desalination plant were built separate from S.E.P.P.	$ 175'000 or $ 0.53 /m^3
* 2.	Fuel at 9.4 kg oil/m^3 $0.15/kg	$ 465'000 or $ 1.41 /m^3
3.	Maintenance 4 %	$ 140'000 or $ 0.42 /m^3
* 4.	Capital 8 %	$ 280'000 or $ 0.84 /m^3
5.	Personnel	$ 150'000 or $ 0.45 /m^3
	Total Desalination Costs	$ 1'210'000 or $ 3.66 /m^3

In comparison with drinking water production costs on the island of US-$ 4.20, this constitutes a savings of US-$ 0.54 /m^3 or US-$ 179'000 per annum.

Total desalination costs less costs already accounted for in electricity production marked with an asterisk <*>.

Net Cost $ 290'000 or $ 0.87 /m^3

The sale of 330'000 m^3 of desalinated water produces an income of US-$ 1'207'800 at $3.66/$m^3$. Subtracting the cost yields a net income figure of:

Income from desalinated water	US-$ 1'207'800
Net Costs for desalination	US-$ 290'000
Net Income from Desalination	US-$ 917'000

This income is being used towards repayment of capital for the total plant.

7.1.3 Model I - Profit and Loss Considerations

S.E.P.P. Electricity Production

S.E.P.P. Electricity Production produces a loss of $ 34'000 p.a. when taking all plant costs into account.

Desalination Income

Water desalination produces an income of $ 917'000 p.a.

Compared to the water production costs, an additional US-$ 179'000 or US-$ 0.54 /m^3 have to be credited to the S.E.P.P. desalination plant (S.E.P.P. water production costs are US-$ 3.66 against US-$ 4.20).

The net income on desalination in comparison yields: **US-$ 1'096'000.**

Combined S.E.P.P. Model I System Analysis

Net Loss from Electricity	US-$ - 34'000
Net Income from Desalination	US-$ 1'096'000
Total Net Income S.E.P.P.	**US-$ 1'062'000**

7.2 Model II - Emphasis on Desalination

As desalination plays an important role in the island support structure, an alternate representation with putting the emphasis of cost distribution onto the desalination facility of S.E.P.P. is considered. This yields the following figures.

7.2.1 Desalination Production Costs for 330'000 m^3 p.a.

1. Interest Payments on Capital 8%	\$ 800'000 or \$ 1.515 /m^3
2. Fossil Fuel Cost	\$ 184'000 or \$ 0.557 /m^3
3. Maintenance	\$ 250'000 or \$ 0.757 /m^3
4. Personnel Costs	\$ 150'000 or \$ 0.454 /m^3
5. Capital Costs	(not included)
Cost Desalination Production	\$ 1'384'000 or \$ 3.28 /m^3

7.2.2 Electricity Production Costs for 8'000'000 kWh p.a.

1. Interest Payments	none
2. Fossil Fuel Costs	none
3. Capital Costs	none
4. Maintenance	\$ 140'000 or \$ 0.0175/kWh
5. Personnel Costs	\$ 100'000 or \$ 0.0125/kWh
Total Electricity Costs	\$ 240'000 or \$ 0.0300 /kWh

7.2.3 Profit and Loss Considerations Model II

Income from Desalination

Sale of 330'000 m^3 desalinated water p.a. at \$ 4.20/m^3 yields:

Income from Desalinated Water Sale	US-$ 1'386'000
Cost for Desalination	US-$ 1'384'000
Net Income Desalination	US-$ 2'000

Income from Electricity Production

Sale of 8'000'000 kWh at $ 0.125 /kWh yields:

Income from Electricity	US-$ 1'000'000
Cost for Electricity	US-$ 240'000

Net Income Electricity	US-$ 760'000

Total S.E.P.P. Plant Net Income from combined System

Sale of Desalinated Water (Net)	US-$ 2'000
Sale of Electricity (Net)	US-$ 760'000

Total Net Income S.E.P.P.	US-$ 762'000

7.3 S.E.P.P. Pilot Plant Payback Time and Financial Considerations

The net income proceeds from the S.E.P.P. co-generation system are used in the Pilot Plant model for capital payback to achieve a short amortization of the plant.

Reserves on the above net income figure are set to a figure of 20 % or an amount of US-$ 200'000 for any unforeseen costs incurred. This results in a total annual payback figure of:

Annual Payback US-$ 562'000.

With this annual repayment figure on a capital investment of US-$ 10'000'000 at 8% p.a., a payback time of twelve (12) years is achieved.

Plant life is considered 20 years. After the repayment period, an increase in reserves for parts maintenance, etc. to the amount of US-$ 562'000 p.a. is assumed.

Income on the plant over the remaining 8 years plant life, therefore, amounts to US-$ 1'000'000 p.a. or US-$ 8'000'000 total. This represents an additional net income 80% on the invested capital.

Chapter 8 Study Analysis

In applications with electricity and industrial process heat the S.E.P.P. technology has been shown for an actual isolated load market situation on an island with its comparative electricity and desalinated water production cost figures.

The combined solar co-generation S.E.P.P. technology process has shown considerable advantages over conventional systems which results in very favourable operating conditions and an investment capital repayment time of 12 years, when considering a standard utility plant life of 20 years with considerable profits from years 12 to 20 in the amount of a total of US-$ 8'000'000.

Two financial models have been selected to show the favourable situation with S.E.P.P. co-generation technology. In Model I with emphasis on electricity all costs have been levied against electricity production, which results in a positive outcome for the desalination application. The case presented in Model II has also giving priority to electricity production but burdens the water desalination facility with the major plant costs per annum.

Every application of S.E.P.P. systems requires an individual look at the given situation within the country and locality where the plant is to be built; this then dictates the approach and weighting of calculation components.

Since desalination constitutes a major problem for the development of the given island from which the comparative figures were taken, it seemed appropriate to put the emphasis on water desalination and thus make electricity production come out less favourable.

The purpose of this study was to show the viability for S.E.P.P. solar co-generation technology in one example of the total system concept, with little importance attached to its individual components for economic performance and leaving out any considerations for radio astronomy research activities.

In order to produce a realistic situation for financing of the Pilot Plant S.E.P.P., the assumption was made that the subsidies were granted as non-refundable with the additional capital provided as a loan at 8% interest payments and a capital repayment obligation; for this reason, the study assumed a period of depreciation of 20 years.

Obviously, financing models can be thought of that represent other schemes for depreciation (from non-reimbursable subsidies to commercial investment banking financing). Since a developing country will always be in a position to finance part of its infrastructure with outside help, the above model has been chosen. The S.E.P.P. pilot plant installation will require additional funds over the mentioned plant costs; since these will be covered by non-reimbursable subsidies, these figures have been left out in the Pilot Plant S.E.P.P. calculations and a Pilot Plant cost at US-$ 10'000'000 has been assumed in the calculations; this same figure of US-$ 15'000'000 has been used in the calculations of the Series Unit S.E.P.P. described in the Annex.

ANNEX - Financial Parameters for a *Series S.E.P.P. System*

The calculations assume S.E.P.P. to operate in a full load configuration for a given decentralized power and desalination station. The cost structure of S.E.P.P. is presented with the following parameters:

1. prices given for a complete S.E.P.P. system for power generation and desalination are set to US-$ 15'000'000;

2. an investment capital of US-$ 15'000'000 for 100% of plant financing is required; interest rates on capital are assumed at 6 %;

3. electricity production from solar "fuel" results in a rest cost for the water production that is weighted against water production from fossil fuel energy;

4. the system consists of two collectors delivering one megawatt electricity per hour and 1000 cubic meters of desalinated water per 24 hour period;

5. a full load operation is assumed, i.e. 24 hrs at one Megawatt electricity with 1000 cubic meters of desalinated water produced in a 24 hr period;

6. the sales price of a kilowatt hour of electricity has been set in the calculations at US-$ 0.20 /kWh;

7. the sale of one cubic meter of desalinated water has been set to US-$ 4.20;

8. loan repayment is carried out in full from achieved profits at a predetermined schedule;

9. turbine fuel consumption is taken at 0.230 kg/kW;

7. fuel cost is assumed to be US-$ 0.15/kg;

8. maintenance cost per annum 2.6 % of plant investment cost;

9. availability of plant is set to 90%, i.e. 8'000 hours of electricity production and 330'000 cubic meters per annum desalinated drinking water produced;

10. solar energy operation of Series S.E.P.P. is assumed to one third of electric energy production (eight hours of average solar operation). The figure of Fossil Fuel Cost is arrived at by the following calculation:

8'000'000 kWh p.a. electricity are delivered x 0.23 kg/kW turbine consumption x US-$ 0.15 /kg fuel x 2/3 for fossil operation.

A. S.E.P.P. Costs p.a.

1. Fossil Fuel Cost (2/3 of total)	$ 184'000 or	10.7%
2. Maintenance Cost (electricity)	$ 250'000 or	14.5%
3. Maintenance Cost (desalination)	$ 140'000 or	8.1%
4. Personnel Cost (electricity)	$ 100'000 or	5.8%
5. Personnel Cost (desalination)	$ 150'000 or	8.7%
6. Capital Cost (first year)	$ 900'000 or	52.2%
Total Plant Cost p.a.	$ 1'724'000 or	100 %

B. Income on Products sold from S.E.P.P. p.a.

Electricity Production Figures for 8'000'000 kWh per annum sold at US-$ 0.20 per kWh	$ 1'600'000
Sea Water Desalination Production Figure 330'000 m^3/ annum sold at US-$ 4.20 per cubic meter	$ 1'386'000
Total Income from products sale	$ 2'986'000

C. Profit and Loss Statement from S.E.P.P. Unit (first year)

Combined Income	$ 2'986'000
Total Plant Costs	$ 1'724'000
Gross Income	$ 1'262'000
Reserves	$ 262'000
Net Income from plant	$ 1'000'000

D. S.E.P.P. Payback Time

The net income proceeds from the S.E.P.P. system will be used in this model for capital payback to achieve a short amortization of the plant.

The first year payback figure is the Net Income or US-$ 1'000'000. The payback figures are increasing with decreasing capital, so that - with a constant interest rate of 6 % over the period

- US-$ 1'000'000 plus the difference between $ 900'000 and the actual decreased interest rate can be used for repayment.

This results in a payback period of 11.5 years for the $ 15'000'000 capital.

E. Reserves

Reserves of $ 262'000 per annum have been set aside for miscellaneous positions (20 % of gross income). This value accumulates to $ 1'475'839 including 4 % annual compounded interest after 5 years and approaches $ 4'000'000 after the payback period in the 12th year. Total reserves over the design life of the plant (20 years) amount to $ 7'800'000.

F. Monetary Results over Life of Plant

Given a total design life of the plant, the monetary balance contains the following key figures:

1. **Design life of plant 20 years.**

2. **Repayment within 12 years of invested $ 15'000'000 capital.**

3. **Accumulated reserves within 20 years $ 7'800'000 or 52% of total plant cost.**

4. **Total income derived from plant during its life span $ 59'720'000 or 4 times the plant cost.**

5. **Net Income after repayment (years 13 to 20) US-$ 13'300'000 or 88% of original plant cost.**