FINAL DESIGN REVIEW REPORT

7TH DECEMBER 2007

Weather Protected Solar Power Unit

(Internet-enabled Closed-Loop Product Incorporating Clean Energy)

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ABSTRACT: The proposed product is an internet-ready closed-loop power module for clean energy generation, providing for end-of-life requirements. It combines internet-connectivity to reduce wear by weather elements and timely part replacement by fault-detection, apart from providing a functional module which may be adapted to several uses as per the company's targeted end-user in that market.

GLOBAL PRODUCT DEVELOPMENT

FALL 2007

EXECUTIVE SUMMARY

The proposed product is a module to produce electricity from the energy in the sun's rays. It is a straightforward process: direct solar radiation is concentrated & collected by a using the best Concentrating Solar Power (CSP) technology, viz. Parabolic Trough, to provide medium-to-high temperature heat. This heat is then used to operate a conventional power cycle, for example through a steam turbine or a Stirling engine. Solar heat collected during the day can also be stored in liquid or solid media like molten salts, ceramics, concrete or, in the future, phase-changing salt mixtures. At night, it can be extracted from the storage medium and, thus, continues turbine operation.

HelioWork's Parabolic trough module uses a trough-shaped mirror reflectors to concentrate sunlight on to receiver tubes through which a thermal transfer fluid is heated to roughly 400°C and then used to produce superheated steam. It is the most mature solar thermal power technology, with installed capacity of more than 2m sq. m. worldwide of parabolic trough collectors. These plants supply an annual 800 million kWh at a generation cost of about 14-17 US cents/kWh. Further advances are now being made in the technology, with utility-scale projects planned in Spain, Nevada (USA), Morocco, Algeria, Italy, Greece, Israel, Egypt, India, Iran, South Africa and Mexico. Electricity from trough plants is thus expected to fall to US 7-8cents/kWh in the medium term and upto 5-6cents/kWh in the long term.

Applications:
- Grid-connected plants, mid- to- high process heat (Highest single-unit solar capacity to date: 80MWe.)
- Direct building-heating systems.

Advantages:
- Commercially available – over 12 billion kWh of operational experience; operating temperature potential up to 500°C (400°C commercially proven)
- Commercially proven annual net plant efficiency of 14% (solar radiation to net electric output)
- Commercially proven investment and operating costs
- Modularity (the more modules used, higher the efficiency)
- Best land-use factor of all solar technologies
- Lowest materials demand
- Hybrid concept proven (354MWe of plants connected to the Southern California grid since the 1980s)
- Storage capability

Disadvantages:
- The use of oil-based heat transfer media restricts operating temperatures today to 400°C, resulting in only moderate steam qualities

Business Case:
WIT remains a technology and innovation company without getting into power generation. We partner with Solel, Solar Millennium, etc. to use their expertise in energy markets and provide the downstream technology for producing and distributing electric power to the utility companies. We sub-contract under them and provide the crucial parabolic troughs with our USP – protection from weather elements and web-enabled monitoring, part-replacement and downtime reduction improving efficiency by ~ 30%.

With service fees (for maintaining power plant) covering our operating costs and providing positive cash flow, HelioWork's proposal makes WIT independent of the cost of the manufacturing operation. The latter is profitable solely on the profit margin of 50% charged per module. The cumulative cash flow is positive from year 4 (which is very reasonable for the capital-intensive energy market) and we estimate a net present value of $6 billion for the operation (conservative estimate based on assumption of securing 5% market share over 10 years!)

Hence in conclusion we can state with confidence that WIT should invest in this business opportunity.

TABLE OF CONTENTS

1. INTRODUCTION

With several legal requirements coming into force in the developed countries of the world (and some other markets), which require compliance with end-of-life disposal norms and uses for products sold in those markets, it is important that World Innovative Technologies be strategically positioned so as not to be left without relevant products to cater to its customers. Also, development of a sustainable product portfolio would ensure the company's competitiveness in the future by providing a 'green' image apart from hedging for environmental regulations that can be expected to permeate to the rest of the world in the future.

Team HelioWorks was formed in response to this strategic mission of World Innovative Technologies (WIT) and will attempt to provide a viable business case to invest the company's resources in renewable energy market. Greenpeace reports, that there are no technical, economic or resource barriers to supplying 5% of the world's electricity needs from solar thermal power by 2040 – even against the challenging backdrop of a projected doubling in global electricity demand. The solar thermal industry is capable of becoming a dynamic, innovative $16.4 billion annual business within 20 years. [Greenpeace] This makes for a fantastic opportunity for an innovation company like WIT.

Until now, solar-thermal power-plants (solar power derived from Concentrated Solar Reflective Technology) were made only in the deserts in the US and other sun-belt countries, like Spain, because of low generation-efficiency and difficult maintenance in other areas. With the internet-enabled monitoring process and weather-proof shielding system, we propose to allow companies like SOLEL to set up solar-thermal power-plants in other areas such as Korea (where rain and hail can severely damage parabolic troughs) also, apart from the initial markets. In the following report, we have prepared a case for investing will use the primary market as both a technology demonstrator as well as experimental/proving ground for perfecting our own product solution. This is essential, because adoption by more discerning secondary market is dependent on proving benefit to the building and currently the technology in CSR-type solar-powerplants is skewed toward efficiency when there are a larger number of modules. When energy o/p per module increases as a result of further research and progress, it will allow the product to be far more suitable and viable for use in lower numbers (such as on housing societies' rooftops in Korea).

The team has developed a concept for a weather protected solar-thermal power module to place WIT ahead of contemporary competitors with an internet-enabled closed-loop product. The solar thermal power plant would fits well into WIT's existing portfolio of internet-enabled products and offers an entry point into the emerging market of sustainable energy sources. Team HelioWorks is a diverse global team consisting of members in three countries across 3 continents. The design of the primary plant module and mechanical moving parts was carried out by Lukasz Skalsi while the market research and business case preparation is carried out by Vazir Fatehi, both in the US. The engineering analysis, Korea-market expertise and thermal calculations will be provided by Jinki Kim and Tae Yong Jung in South Korea. In Germany, Saskia Zurth has written the software code for monitoring plant sensor information and developed the graphical user interface while Kai Ide worked on the electric hardware and actuator/sensors to connect the plant via TCP/IP.

2. NEEDS IDENTIFICATION & PROBLEM STATEMENT

The primary need for HelioWorks to propose a technological solution

[2] (a) Top Five Needs/Proposals Considered

The following were the top 5 proposals drummed up by the team. A more detailed analysis of each is provided in **Appendix 1**.

(i) **Camping tent**

A concept camping tent, with internet connectivity for the camping world. The internet features considered included weather forecasting, maps and satellite guidance, Park Service warnings, etc. The water-proof fabric could be reused afterwards in regions of water scarcity for water retention purposes, as canvas for struggling artists, etc.

(ii) **Greenhouse**

The internet-connectivity would enable constant monitoring of temperature, plant moisture content, humidity, amount of oxygen and CO_2, etc. and make use of the entire greenhouse materials at end of life from soil being used as compost to wood for houses.

(iii) **Solar-Thermal power-plant**

A sustainable solar-power power plant. The internet enable closed-loop factor is applied in a business model that involves a large number of plants all around the globe. Spare part management as well as plant monitoring is largely automated, enabling closed-loop economy by constant monitoring and replacement.

(iv) **Modular furniture**

Modules that can be put together to form a large number of different objects ranging from desks to chairs to comfortable couches Internet connectivity would allow a furniture piece to be set (for example, from office before returning home) to one of 3-4 pre-adjusted memory settings depending on person's mood.

(v) **Treadmill / Grocery store belt**

This device could monitor the user's workout online, track progress, and analyze heart rate. It could connect with other treadmills making it possible to compete against others online (races, distance running, a "virtual marathon", etc). At the end of life, the treadmill belt would allow reutilization as a grocery store belt, while monitors could be used in third world clinics and hospitals.

[2] (b) Final Proposal Selection

The team decided to propose the power plant project. Key points motivating this decision was the internet-enabled closed-loop capabilities that could not be fully addressed by the other project ideas. The market need also makes good use of each of the team member's strengths like Mechanical & Electrical Engineering and Math, as well as addressing a pressing need for WIT to get into new markets.

Project Definition: We are only making the trough with shield (oil flow) and we will use a business model as described in the Business Case (Section 7) of the report. In that we have indicated that we do not want to be a power generation company. Instead, we will use complementary assets (distribution and power-generation) of companies like SOLEL to build a power plant in US and boiler in Korea.
We considered three options for WIT:

- One was to build the whole power plant -------- We have found that not viable for World Innovative Technologies to invest in.
- Other was to focus on the trough with shield (& oil flow) and sell it -------- Our complementary assets partner would be SOLEL and such companies who themselves sell to electric utilities.

- Third option was to focus on the trough with shield (oil flow) and cooperate with SOLEL for the downstream part of the power-generation and sell electricity -------- Customer: US energy-utility companies.

We chose the 2nd CHOICE. Customers being solar-thermal technology pioneers like SOLEL (successor to LUZ) makes sense, because we are offering them an accessory to their product (internet-enabled closed-loop technology, such as weather protection and constant online preventive maintenance).

What we have shown to support our case is the calculations that show the Shield will save 2/3 of maintenance cost of parabolic-reflector troughs - it is only one of the reasons mentioned to cover the trough. The project has been deemed technically feasible and market analysis indicates a global demand for the product, as supported by data in the report.

[2] (c) Problem Statement

Current solar power plants rely on breakdown maintenance rather than preventive maintenance, apart from having no end-of-life usability. There is a need for **protection of solar panels** or reflectors in both Concentrated Solar Reflectors (CSR) and Photovoltaic applications of solar power plants in case of bad weather.

Other strong needs are (i) easy **monitoring** of functioning from remote locations and (ii) making sure parts/components of these plants are disposed of, at the **end of their work-life** in an environmentally friendly manner by reuse or recycling or reduction.

The above problems are integral to a modern solar-thermal power-plant and Team3 endeavors to address these problems with our solar power-plant module.

[2] (d) Element of Closed-Loop Economy Targeted By HelioWork's Product

The following points summarize the internet-ready closed-loop aspects of HelioWork's proposal:

- Protection from Weather-elements (sand, hail etc which could damage/scratch parabolic trough reflectors)
- Constant Plant monitoring & immediate fault-detection (fall in sensor/trough-reflectivity performance)
- Timely replacement for parts to minimize downtime and eco-friendly disposal/re-use of scrap
- Data sharing which could provide feedback for concentration of research activity.

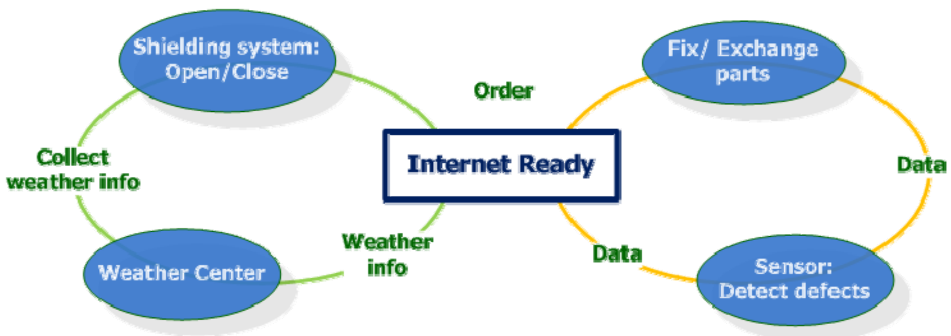

Figure 2.1: Internet-Ready Closed-loop Aspect Addressed

The internet-connectivity allows constant monitoring of plant functioning which will allow for **timely protection in adverse weather conditions** and enable closed-loop economy by notifying a central control monitor in case of **fault detection**. This fault could be because of failure of some part of the module or because of sub-par performance, indicating end of life of product.

The **replacement of parts** could be carried out by WIT and recycled/repaired-&-reused, instead of disposal by product user, since the company would have first knowledge of breakdown. Large scale monitoring could also determine statistically which parts of the system are most vulnerable to failure, thus making it possible for WIT to redesign and re-engineer in a Kaizen system of continuous improvement.

Closed-loop in the context of this project is defined as the recycling or reuse or repair of the product at the end of worklife. This is addressed by the internet-connectivity of the solar power module that we have designed. The program code designed by HelioWorks informs the central monitoring center of any disruptions in the optimum power supply. If this is due to a need for replacement of parts, HelioWorks can take care of the requirement by replacing those parts for the efficient operation of the plant.

Not only is downtime reduced in this way, but HelioWorks can also ensure the recycling or repair of those parts. We have reason to believe that this is not the case currently. Large scale plants are adversely affected by small problems such as scratches on the surface of a reflective trough, which has a multiplier effect, thus reducing the efficiency of the entire plant. This causes massive downtimes in the maintenance (breakdown schedule).

Since it is not possible to detect exactly where the problem may have occurred, the entire faulty 'row' of parabolic troughs is replaced with new ones. This causes huge environmental problems and also is a waste of resources. HelioWorks' product solution enables data to be collected in a constant monitoring process of several client plants.

The data collected at each plant by the aforementioned sensors would be transmitted to a central server at HelioWorks' distribution and data center in that market. This server would monitor each plant's processes and allow for early detection of any anomalies. When a component is deemed as not performing properly, a technician would be dispatched to fix or replace the component. If a replacement is necessary, **only** the faulty component would be sent back to HelioWorks for refurbishment or salvage. The internet connectivity would also allow for real-time inventory tracking across all HelioWorks plants and in case a parts shortage occurs at one location, parts from a neighboring plant can be sent over to assist in a timely conflict resolution.

The malfunction incident and replacement-cost data would be stored on the central server for each individual plant as well as a collaboration of all the plants. This would allow for a fast and accurate cost and quality analysis to aid in any redesign efforts to ensure proper distribution of engineering resources to the most critical areas. Statistical process quality control is ensured.

3. MARKET ANALYSIS

Solar thermal power is a relatively new technology which has already shown enormous promise. With few environmental impacts and a massive resource, it offers a comparable opportunity to the sunniest countries of the world as offshore wind farms are currently offering to European nations with the windiest shorelines. Solar thermal power uses direct sunlight, so it must be sited in regions with high direct solar radiation. Among the most promising areas of the world are the South-Western United States, Central and South America, North and Southern Africa, the Mediterranean countries of Europe, the Middle East, Iran, and the desert plains of India, Pakistan, the former Soviet Union, China and Australia. In many regions of the world, one square kilometer of land is enough to generate as much as 100 -120 gigawatt hours (GWh) of electricity per year using solar thermal technology. [Greenpeace Report]

Following the 2002 Earth Summit, the Johannesburg Renewable Energy Coalition was formed, with more than 80 countries proclaiming that their goal is to "substantially increase the global share of renewable energy sources" on the basis of "clear and ambitious time-bound targets". Modern solar thermal power plants can provide bulk power equivalent to the output and firm load characteristics of conventional power stations.

[3] (a) Primary and Secondary Markets & Characteristics

3.a.1 Identification of markets and estimation of size

For the **primary market** HelioWorks will focus on the south & south-western United States, because it has the most conducive environment. However, any developed country within the sun-belt, may be considered for a future expansion. Based on calculations (see *Market Calculations* below) what future demand for renewable solar energy will be the **market size for America will be about 1,000,000 modules** (a module being our product as defined in section 4 of this report).

For the secondary market HelioWorks will concentrate on Southern Korea. In general countries within the sun-belt that satisfy the requirements can also be taken into consideration for a future expansion of HelioWorks. Based on calculations the attempted **secondary market size will be about 100,000 HelioWorks-Modules**. There is one major difference between both markets. For the primary market these countries must have large, flat landscape, whereas for the secondary market houses with flat housetops are needed.

3.a.2 Why these two markets?

- Initially we considered India as a target since it is a huge market and has huge growth potential. But, in the market analysis we could not justify why farmers in India would buy our product. Apart from the cost aspect, we also had to consider internet infrastructure in the country. Similarly, other developing countries were ruled out.
- Australia is a market that could be taken into consideration; however it is too similar to our US market and much smaller in size (which negates the interest as a primary market). There is no product differentiation between the Australian and US markets; therefore it could be a market for later expansion.
- We went with Korea as a secondary market to diversify the product base more between the primary and secondary market. In South Korea internet infrastructure is good differentiation is possible. Also, Koreans are very receptive to new technology.

3.a.3 Justifying need for HelioWork's Proposed product

Verification of need for shielding system in primary market:
The high reflectivity of the parabolic trough is a critical parameter to make high efficiency of parabolic trough solar thermal electric power plants. But conventional parabolic trough power plants don't have a shielding system to protect the parabolic trough from soiling and any harm by wind, rain, etc., to keep the parabolic trough clean and highly reflective. During summer period high soiling rate 5%/day was experienced in Arizona, US. [http://www.energylan.sandia.gov/sunlab/overview.htm]

Calculations: We estimate simply, that the after 14 days the trough would reflect only half the sunlight to the collector (i.e. assuming 50% efficiency).

- Reflectivity: R - Soiling rate: $5\%/day$ - Half reflectivity: 0.5R	$0.5 \times R > (1-0.05)^n \times R$ $n > 13.51$ $n = 14\,days$

We can save maintenance (cleaning/scratched surface refurbishing) expenses through the shielding system. A lot of water is used for washing out dirt on the trough, and the problem is that parabolic trough solar power plants are located in the deserts in US. It is not easy to get water in deserts. If we suppose, for example, that we run the shielding system equipped power plant 8hrs/day, it needs 42days to be half reflective due to soiling.

- Reflectivity: R - Soiling rate: $5\%/day \times \frac{8hrs}{24hrs} = 1.667\%/day$ - Half reflectivity: 0.5R	$0.5 \times R > (1-0.01667)^n \times R$ $n > 41.24$ $n = 42\,days$

The trough shielding system keeps the trough shiny **3 times longer**! This result is just by a simple calculation, so if we consider that it gets dirty easily due to the early morning dew, the shielding system can keep the trough clean much longer.

This shielding system is not a optional, but a mandatory part for the secondary market in Korea. Because there isn't any desert in Korea, the shielding system is essential to protect the trough surface from rain and lower the cleaning cost.

Verification of need for shielding system in secondary market:

Average size of the apartment: 110m x 12m (80 houses=8 houses x 10 floor)
The size of one module (Luz LS-3, 1989): 95.2m x 5.76m.
-> That size just fits to put 20 modules on the roof of the apartment building

Based on the solar power map, average solar power here in Korea
- spring: 3850 kcal/m^{2}day , summer: 3790 kcal/m^{2}day , winter: 2021 kcal/m^{2}day

Let's consider operation in winter, which means 2021 kcal/m^{2}day.
--> 8848.2 kJ/m^{2}day(4.2J=1cal) --> 2.358kWh/m^{2}day(1kWh=3600kJ)

The area of the solar panel: $54.5m^2$ x 20 module = 1090 m^2
Thermal Efficiency of the solar panel: 80%.
Energy into the oil in the pipe: 2.358 x 1090 x 0.8 = **2056.18 kWh/day**

Assuming efficiency of the boiler : 85% [http://www.energysolutionscenter.org/BoilerBurner/Workshop/BoilerTypes.htm]

Then we get 1747.75 kWh for hot water!

Heating energy using in normal house in Korea: 15451000 kcal for a year,
That means in winter, 95.16 kWh/day.

2056.18 kWh/day / 95.16 kWh/day = 21.61 houses.
21.61 / 80 = 27% - That is **27% saving energy in one apartment**

For other seasons, we might be able to use that for auxiliary electricity generator.

By rough calculation,

= **2056.18 kWh/day** into the oil in the pipe.

…[assuming turbine/Generator efficiency (37.6%)] that equates to = 1472.8 kWh/day

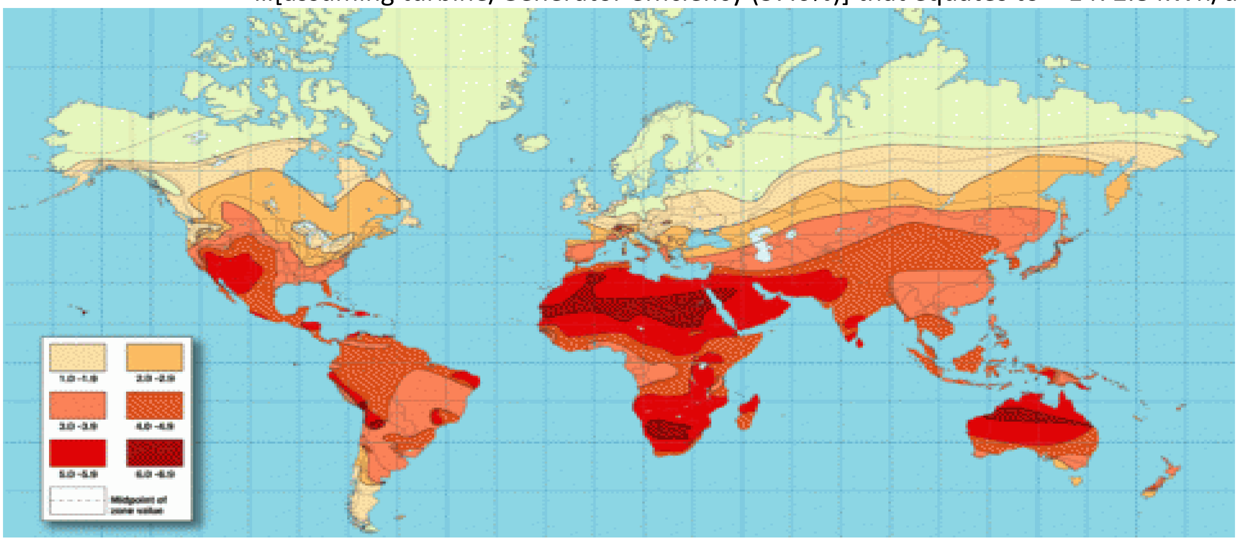

Figure 3.1: Amount of solar energy in hours, received each day *on an optimally tilted surface* during the worst month of the year.

3.a.4 Calculations for Size of Target Markets (in terms of Unit Products WIT will build)

Primary Market:

"by 2015 in the six South-Western States (California, Nevada, Arizona, New Mexico, Colorado, Utah) will grow by 34 GW, of which 20% (7 GW) is targeted to be provided through renewable power sources. "

[http://www.solel.com/solel_usa/]

Now, one power plant of HelioWorks will consist out of 20 000 Modules that will produce 80MW of electricity

⇨ the maximum market size is: (7000MW/80MW)*20000 Modules = 1750000 Modules

- Taking into consideration, that with "renewable power" not only solar energy is addressed, there is still a potential market of about <u>**1,000,000**</u> Modules.

Secondary market:

- Inhabitants of Korea: 48 294 000 [http://www.asien-auf-einen-blick.de/korea-sued/index.php]
- 52% live in many story buildings in an owned apartment
  „Korea National Statistical Office“

- Families per building: 80 families consisting out of 4 Persons in average
  Total: 80*4 = 320 persons per building

- Number of HelioWorks-modules that will fitt on one roof:

⇨ Maximum number of modules that can be sold in Korea
(48,294,000 * 0.52) / 320 = (approximately) 78477 buildings

Where each building can hold two HelioWorks modules of 78 477 * 2 = 156 955 modules

- Taking into consideration, that not all houses will add on HelioWorks modules, there is still a potential market of about 100 000 modules. Since HelioWorks is covering a Niche with that marketing plan.

⇨ **100 000** modules for the Korean market

[3] (b) Customer Profile and Targeted Functionality

For the primary market the targeted customer will be electricity producing companies. HelioWorks will supply the mechanism to heat up the oil which will be used for powering turbines of the company. In addition to that HelioWorks will handle the maintenance of the product, by establishing an internet coordinated monitoring and advising system that also handles the shield mechanism.

HelioWorks is focused on designing the solar collecting module array. We will make a strategic partnership with SOLEL to provide an advanced solar thermal power plant which will be more cost efficient and increase the availability on normal weather. HelioWorks will work on the internet-enabled recycle process and weather-element resistant shielding system to increase cost efficiency. SOLEL is the world leading company in the solar thermal power plant field and will contribute on the power generation system to allow for integration into the broader thermal power plant system.

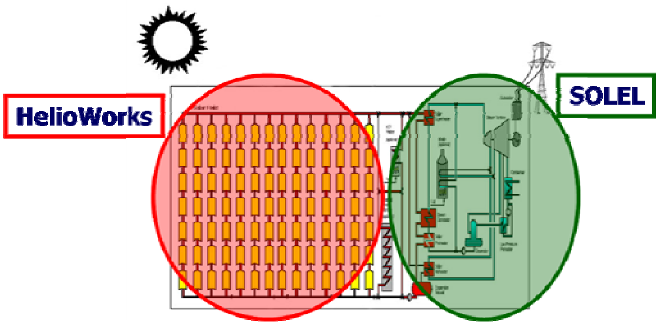

Figure 3.2: Targeted Functionality

For the secondary market main customers will be communities of an ownership of apartments. HelioWorks will offer a system that will add on to the central heating floor system of a multistory building. Instead of using LNG, LPG or Gasoline, during sunny days the solar-thermal heated oil will take over the heating of the water.

[3] (c) Different Requirements To Enable A Global Platform Product

The product is designed modularly for different requirements. In the primary market, a vast field can be installed by attaching many modules. The major requirement that makes the plant a global platform product is on one side, that it is designed to be either build in places with wide spaces to supply the energy source to electric power companies and on the other side it can be used in city with limited space as an additional water heat-up system for housings. Another requirement that makes it a global platform product is the management via internet from a central station. The companies that use HelioWorks Modules will be coordinated from a central station that supervises all power plants. Selected companies that are familiar with HelioWorks-Modules will be informed via internet and are in charge of repairing malfunctioning parts of a Module.

We have defined that the primary market product would consist of the platform structure module along with a turbine and generator for generating electricity, which will be supplied by our business partner (complementary assets holder like Solel). CSR (Solar-trough) technology becomes more efficient when a greater number of modules are put together – such as in the California solar power-plant operated by US DOE. Those are used in huge quantities of modules for power generation.

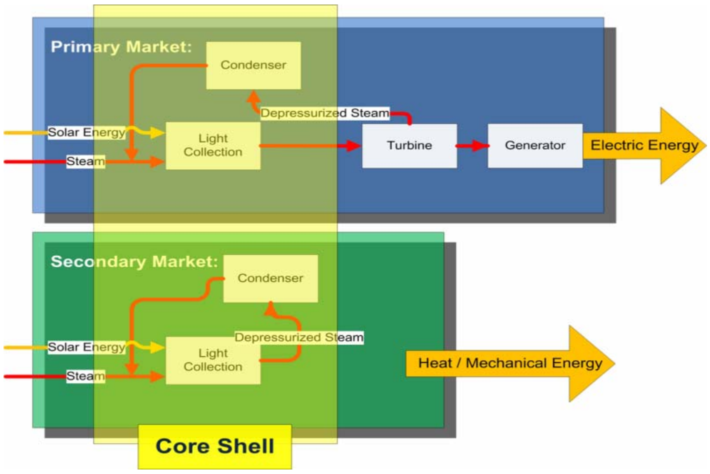

Figure 3.3: Global Platform Structure

The secondary market would omit the turbine and generator and circulate the heated oil directly through a network of pipes to heat the home. In Korea, only one or two modules per apartment block are used. To avoid the efficiency degradation due to energy conversion, we directly use hot water made by solar system. There is no turbine and no generator. The Korean heating system is quite different from the western style. They don't use a radiator, but heat up the floor by putting hot water pipes under the floor, since cultural propriety dictates that shoes are taken off inside house. Many apartments use central heating system and they use LNG, LPG or Gasoline for boiling water. We believe this provides a single product platform /architecture with different application in each market.

[3] (d) Current Competition and HelioWorks' Product Differentiating Factors

In the primary market there are companies that build thermal solar power plants which HelioWorks will convince to use HelioWorks Modules. For example SOLEL that is building a large power plant in California which produce about 553 Megawatts. Until 2011, this plant will expand to supply power to more than 400,000 homes in northern and central California will be supplied with electricity when it is finished. In the targeted markets, there is no company that is a direct competitor to HelioWorks. Please see **list of Patents in the Appendix A2**.

The difference between HelioWorks Modules and existing Modules from Competitors is, that HelioWorks added a shield which will function as a protection against harmful weather conditions and therefore diminish the maintenance cost. Furthermore an internet-ready closed loop economy will be supported by adding a central coordinated monitoring system which will combine information of sensors and internet based weather data to activate the protecting shield.

Why should they use our product and not build something of their own?

We have a weather protection system and constant performance-monitoring capability. We position ourselves as a company offering a solution to a need that is evident for those companies focused on solar-power generation through CSR (concentration solar reflective) technologies – i.e., solar-trough means of creating electricity. Those companies however, will know how to work with steam turbines (that is their domain and we do NOT compete with them). This makes us a good partner in solar energy. This way we are splitting up the core competencies of the companies: one company can focus their engineering resources towards electricity generation and plant logistics, and we can focus ours towards the solar array modules.

How does our product compare with photovoltaic solar power plants that would directly generate electricity without the messy oil heating?

We believe the following (supported by references) ~

- Photovoltaic Technology is still very expensive as compared to CSR technology (Solar-trough) and this is proved as per the table below taken from a research paper of US DOE – which had been mentioned in our References. The report that states that the leveled cost of energy for photo-voltaic arrays, in 2000, was 29 cents/kWh versus a parabolic trough solar thermal plant was 11.8 cents/kWh. These numbers are forecasted to fall to 8.1 and 7.6, respectively, in 2010, but nonetheless the solar thermal trough will be cheaper for long time.
- Additionally, Photovoltaic solar power plants can apply small size market. But our primary market is big size(so it is more efficient) and secondary market don't need electricity.
- Lastly, Photovoltaic cells lose about 50% of their original efficiency after a couple of years, which means low-use life.
- As seen in table below, cost of Solar Power generated by CSR technology is far cheaper and photo-voltaic solar arrays will catch up only by 2030 in cost.

		Levelized COE (constant 1997 cents/kWh)				
Technology	Configuration	1997	2000	2010	2020	2030
Dispatchable Technologies						
Biomass	Direct-Fired	8.7	7.5	7.0	5.8	5.8
	Gasification-Based	7.3	6.7	6.1	5.4	5.0
Geothermal	Hydrothermal Flash	3.3	3.0	2.4	2.1	2.0
	Hydrothermal Binary	3.9	3.6	2.9	2.7	2.5
	Hot Dry Rock	10.9	10.1	8.3	6.5	5.3
Solar Thermal	Power Tower	--	13.6*	5.2	4.2	4.2
	Parabolic Trough	17.3	11.8	7.6	7.2	6.8
	Dish Engine -- Hybrid	--	17.9	6.1	5.5	5.2
Intermittent Technologies						
Photovoltaics	Utility-Scale Flat-Plate Thin Film	51.7	29.0	8.1	6.2	5.0
	Concentrators	49.1	24.4	9.4	6.5	5.3
	Utility-Owned Residential (Neighborhood)	37.0	29.7	17.0	10.2	6.2
Solar Thermal	Dish Engine (solar-only configuration)	134.3	26.8	7.2	6.4	5.9
Wind	Advanced Horizontal Axis Turbines - Class 4 wind regime	6.4	4.3	3.1	2.9	2.8
	- Class 6 wind regime	5.0	3.4	2.5	2.4	2.3

* COE is only for the solar portion of the year 2000 hybrid plant configuration.

Table 3.1: Leveled Cost of Energy for General Co-Ownership

4. PRODUCT ENGINEERING

[4] (a) Task Clarification And List Of Plant Requirements

Solar thermal power plants, often also called Concentrating Solar Power (CSP) plants, produce electricity in much the same way as conventional power stations. The difference is that they obtain their energy input by concentrating solar radiation and converting it to high-temperature steam or gas to drive a turbine or motor engine.

Four main elements are required: a concentrator, a receiver, some form of transport media or storage, and power conversion. Many different types of systems are possible, including combinations with other renewable and non-renewable technologies, but the most promising solar-thermal technology is the parabolic trough.

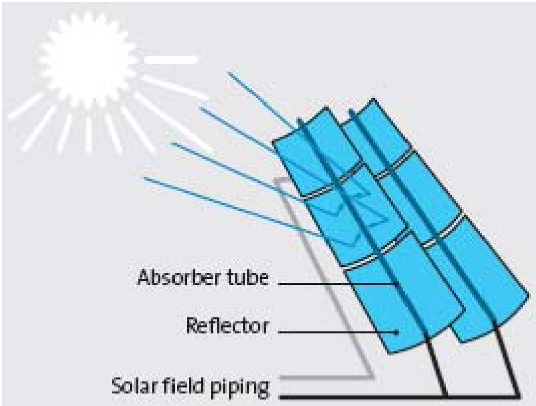

Figure 4.1: Parabolic Trough – Design Requirements

Parabolic trough-shaped mirror reflectors are used to concentrate sunlight on to thermally efficient receiver tubes placed in the trough's focal line. A thermal transfer fluid, such as synthetic thermal oil, is circulated in these tubes. Heated to approximately 400°C by the concentrated sun's rays, this oil is then pumped through a series of heat exchangers to produce superheated steam. The steam is converted to electrical energy in a conventional steam turbine generator, which can either be part of a conventional steam cycle or integrated into a combined steam and gas turbine cycle.

The trough array is to be designed in a modular way with each module collecting solar energy. The key functions and processes are:

Collect sunlight: the modules must collect and focus the sunlight in order to operate. This can most efficiently be done by maximizing the area exposed to sunlight and providing the correct module geometry for focusing this energy.

Heat oil in pipe: by optimally focusing the solar energy on the pipe, the oil flowing through it is superheated. The geometry of the module must be carefully designed as to provide the quickest and most efficient method for superheating the oil.

Superheated oil creates steam: The oil is pumped back through a heat exchanger where the energy from the oil is used to boil water and create steam.

Steam powers turbine: the superheated steam is then used to power the turbine.

Turbine powers generator: the rotational motion of the turbine is then converted into electricity by the generator.

Team 3	Requirement list for solar thermal power plant	2007. 10. 04
D / O	Required functions and constraints	
D	Geometry 10m x 5m x 0.05m for "single module" Modules can be interconnected in series Sunlight collection system (protective shielding system included): Parabolic shape to concentrate the solar energy Internet-ready system	
O	Motion Cover the sunlight collection system protecting it from rain, sand storms, etc.	
O	Force The covering system should resist strong winds It has to be deployed within 30sec.	
D	Energy Solar energy (light) Electricity 230V 50Hz or 110V 60Hz	
D	Material Fluid (water), Stainless Steel, aluminum(mirror), etc	
D	Control Internet connection kit + PC: Send the information from sensors to a central server (Debian based Apache web server) and weather information from internet to the protective shield system. PCB circuit for motor control	
D	Sensors Pressure sensor, Flow sensor, Thermometer, Strain gauge, Wattmeter.	

[4] (b) Functional Analysis

The following provides a step-by-step analysis of the different critical part-functions of our project proposal

The first function of the solar array is to harvest and focus the sun's solar rays. This can be most efficiently realized by using a reflective surface and positioning a series of such surfaces so as to focus their reflections on the desired area. HelioWorks considered five distinct methods for focusing the sun's solar rays on the heat pipe: (1) parabolic trough, (2) parabolic bowl, (3) vertical cylinder, (4) tower with mirrors, and (5) lenses. We chose the parabolic troughs because of the ultimate aim of providing protection from weather-elements made most sense in the business case developed for marketing such troughs to the power companies like Solel.

The second function of the solar array is to utilize the focused solar power and use it to superheat oil. This superheated oil is the medium which flows through the pipe (the area onto which the solar energy is focused).

The third function is the conversion of water to steam in the heat-transfer sink. This steam will drive a turbine. This process eliminates waste of energy because steam does not have to be condensed into water since it is not re-circulated. The oil can simply being driven through the pipe in multiple circles.

The fourth function is the generation of electricity by the turbine powering a generator and a compressor to pump

The fifth function is the weather-protection, which forms the center-piece of our product offering. This is the main focus of the internet-ready application which provides us the closed-loop economy. Sensors detect adverse weather conditions (our system also reads it from weather reports by internet-connectivity) and activate the weather-protection system.

The sixth function is the monitoring for close-loop economy. When plant sensors detect malfunction or deterioration in plant performance, a message is sent to the central 'command' center and replacement parts are automatically ordered and routed to the plant.

[4] (c) Design Alternatives

All these design alternatives are summarized ***in Appendix A3****.*

For the heat collector we had the following design alternatives:

Parabolic troughs: contain an additional five sub-categories, each with a unique configuration for altering the path of the solar rays:
(a) *parabolic trough*: a simple, low-cost configuration consisting of a parabolic trough with the heat pipe running along its longitudinal axis;
(b) *parabolic trough with glass sheet on top*: using the same trough/pipe configuration as the above sub-category, a glass sheet is added to the top of the trough to aid in trapping the heat within the trough and preventing any wind drafts from cooling the pipe through surface convection;
(c) *parabolic trough with parabolic one-way mirror on top*: building off of the same heat-trapping principle as the glass sheet, but utilizing a parabolic one-way mirror to allow for sun rays to penetrate into the trough, but then re-reflecting any stray rays which may have missed the pipe after being initially reflected off of the bottom trough surface;
(d) *parabolic trough with a one-way mirror pipe shield*: a shield is affixed above the pipe which allows for the passage of sun rays to directly heat the pipe, but also re-reflects any stray rays in the same manner as the parabolic mirror described above. Additionally, with the shield located in close proximity to the pipe, a thermal layer can be established in the region between the pipe and shield to aid in heat conservation;
(e) *flat elements in parabola configuration*: similar to the basic through configuration, but with flat elements arranged along the longitudinal axis rather than a smooth contoured surface.

Parabolic bowl: a parabola-like shape revolved around the vertical axis to produce a bowl-shaped configuration with the inside surface of the bowl reflecting the solar rays towards the common focus point of the revolved parabolas.
Vertical cylinder: a vertical cylinder containing the heat pipe running along its vertical axis. The solar rays entering the top of the cylinder would be reflected down the cylinder and onto the length of the pipe.
Tower with mirror: the heat pipe forms a vertical tower-like structure with a set of mirrors positioned strategically around the tower to focus the solar rays on the tower.
Lenses: a set of lenses located above the heat pipe to refract the solar rays passing through them and focus them on the pipe.

For the pipe configuration we had the following alternatives:
The simplest pipe configuration is a **single large pipe** running along the longitudinal axis of the solar ray reflecting structure. This single pipe can also be broken up into a series of smaller pipes in order to increase surface area and thereby heat transfer rate. In an attempt to increase the time that the fluid is exposed to the solar heat, alternate pipe geometries can be considered to keep the fluid in the focusing region longer. Three such geometries would be an **S-shape pipe** which would traverse the length of the focusing region three times before passing into the turbine, a **longitudinal coil** which would direct the fluid in a circular pattern as it passes through the focusing region, and a **sine-wave pipe** resembling a geometry of a sine wave.

The four pipe material types considered were steel, aluminum, brass, and ceramic. The key material properties taken into consideration are thermal conductivity, yield and ultimate strength, and melting point. Another consideration in this category was external to the pipe material properties and dealt with externally insulating the pipe with fiberglass to reduce pipe heat loss to the ambient.

For the heat transfer medium we had the following alternatives: water and oil.

We chose **oil** because almost all such plants use oil (lower specific latent heat) and not water. Also, **water** is a corroding medium for the materials we have chosen for reflecting trough and pipe. A report on solar thermal energy power plants describes in great detail how these actually work and one of the aspects they talk about is the heat transfer fluid (HTF): “The current heat transfer fluid (Monsanto Therminol VP-1) is an aromatic hydrocarbon biphenyl oxide.” The current plants heat the oil up to 390 degrees Celsius.

For the **internet-enabled weather-protection system**, we had the following alternatives:
HelioWorks considered several options for protecting the array from environmental threats when the plant is not being utilized (such instances would include nighttime, rainy days, and natural disaster). **One such option** would be to use a motor and pulley system to pull a durable tarp over the plant either directly above the trough structure or following a set of support arches over the reflecting region. **Another choice** would be a series of interconnected rigid plastic parabolic modules which would be fixed to one side of the reflecting region and rotated open and shut. A **third alternative** shield would be a telescoping system of either rigid plastic parabolic modules or durable tarp interconnecting support arches which would run on rails parallel to the reflecting region. **Finally**, a combination of motor/pulley tarp system and rail system can be utilized to pull a durable tarp over the plant along its longitudinal axis.

Since the turbine and electrical generator are components of the system which would be purchased from an external supplier, their design is non-value added to the system at this stage of the project and their explanation has been omitted for brevity.

Please See Appendix A3 for Alternate designs

[4] (d) Final Design Concept

Figure 4.2 below shows the optimal module concept as selected by the HelioWorks engineering team. The concept utilizes the parabolic trough to maximize the amount of solar rays captured by the array. The reflective surface is a layer of thin stainless steel (approximately 0.1 – 0.2 mm) polished to achieve maximum reflectivity. The layer of steel is affixed using rivets to a support structure of the same shape.

Along the longitudinal focus of trough runs a single pipe. Affixed above the pipe is a shield which serves two purposes: First, it redirects any stray solar rays which were not optimally reflected directly at the pipe and focuses them back towards the top of the pipe. Second, its close proximity to the pipe allows it to trap a thermal layer and reduce the heat loss to the ambient through surface convection from wind gusts.

Spaced along the trough are support arches for the durable tarp shield. The tarp is folded and runs along the side of the trough. When needed, the tarp is pulled over the support arches through a system of motors and pulleys which interlock with a set of rings attached to the inside of the tarp surface. (For a discussion of alternative concepts considered, please see Appendix A3).

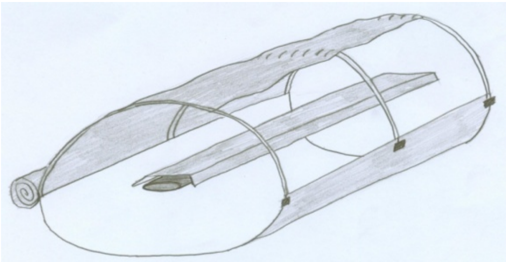

Figure 4.2: Optimal power plant concept.

[4] (e) Platform Product Structure

The common platform of the HelioWorks solar array lies in the solar ray harnessing and focusing and oil superheating systems. Each array module will be ten meters in length. Each module will consist of the above mentioned components as described in the Final Design Concept. The differentiating factors between the applications and markets would lie in the power conversion phase.

The primary market product would consist of the platform structure module along with a turbine and gen erator for generating electricity, which will be supplied by our business partner. The secondary market w ould omit the turbine and generator and circulate the heated oil directly through a network of pipes to he at the home.

[4] (f) Embodiment Design

Since solar thermal power generation is already an existing and proven technology, HelioWorks referred to Luz (predecessor of Solel) and their LS-3 Solar Collector Assembly (SCA). A thermal engineering analysis (see Section 4i) confirmed the dimensional specifications of the LS-3. Thus HelioWorks designed the solar collecting array to consist of modules measuring 10 meters in length and 1 meter in width of the effective reflecting area (resulting in an overall width of 1.67m).

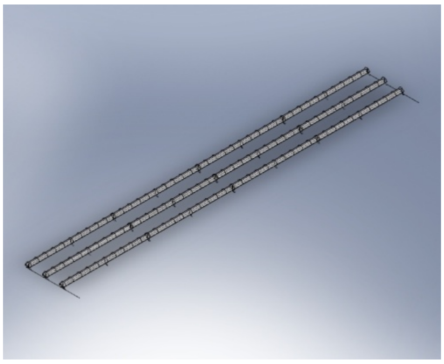
Figure 4.3

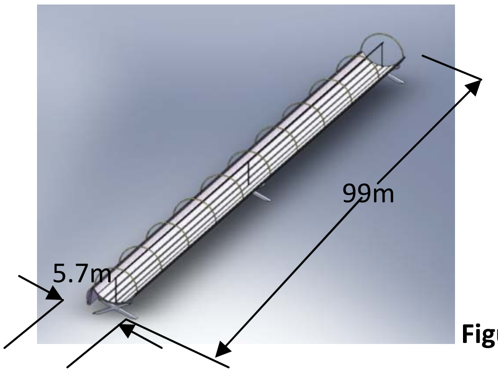

Figure 4.4

Each module consists of a 0.07m diameter pipe running along the longitudinal focus. The pipe carries the oil which is superheated as it passes through the modules and is then pumped back to the boiler. The pipe is supported through each module by three pipe supports. The pipe supports are located at each end of the module and one in the center. The support also serves to support the double mirror located above the heat pipe.

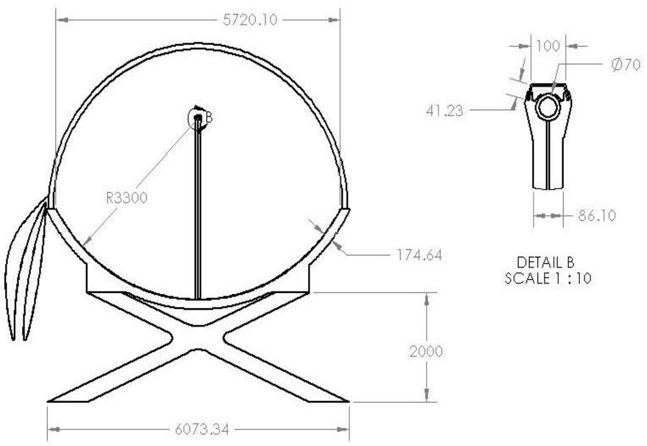

Figure 4.5: Complete CAD front view

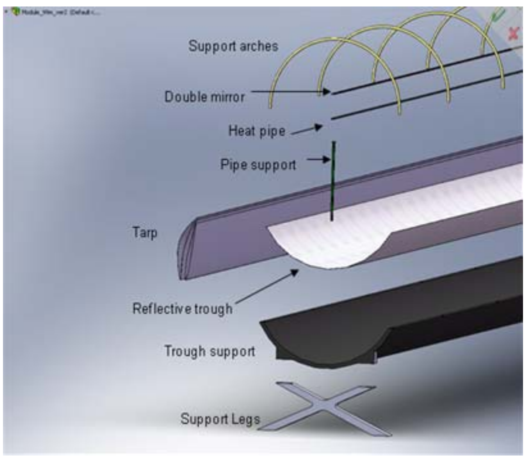

Figure 4.6: Exploded View

Each module contains various sensors to monitor the operation of the power plant. Four low-intensity temperature sensors are affixed to each module, one in each "corner" of the reflective trough. A single high-intensity temperature sensor is affixed to the top of the heat pipe (between the pipe and the double mirror) in the longitudinal center of the module. A photodiode is affixed to the top of the center pipe support.

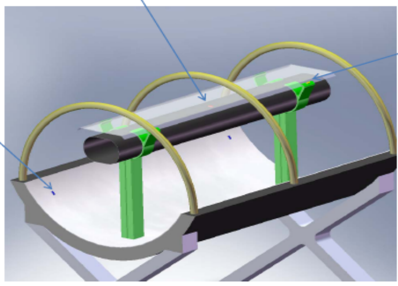

Figure 4.7: CAD model sensor placing

The weather protection is activated by a series of motors located along the support arches of the module. Each module contains 3 support arches (spaced 3.3 m apart). The filament runs along the outside of the arch in one direction and returns through the hollow center, closing the filament loop. Each motor activates the filament which then engages the clips affixed to the underside of the folded tarp.

[4] (g) Critical Parts Of The Design And Justification

The most critical part of the design concept is in fact also one of its key features. The protective shield will, when being deployed, consume a significant amount of energy. Furthermore it has to be robust enough not to defy its purpose and *be* damaged when it in fact should *prevent* the module from being damaged. However, since each module implies a considerable investment to the customer protection from harsh weather conditions is crucial. The customer will therefore benefit from the shield even though it contributes to a substantial part of the total cost of each module. Another critical part are the various sensors which will monitor the module. Fine tuning them would have to become part of a later development phase but would be well worth the effort as the gathered information will allow the module to call for necessary repairs automatically, thereby drastically increasing its own longevity.

[4] (i) Results of Engineering Analysis

Motor specification and Calculation:

The parabolic trough will be covered with canvas pulled by motors on each side of the trough. The motor specification needed is 3.09W and maximum torque of 3.38 Nm at 174.75 rpm

Mass of canvas: m = 139 g/m^2 [http://xdy.en.alibaba.com/product/50398728/51864057/cotton/Canvas.html]

Size of canvas: A = 99,000 (mm) * 9,150 (mm) = 905.75 m^2 .

Total mass of canvas: m_t = 125.8995 kg

Coefficient of friction (between polythene and steel): u = 0.2 [http://www.roymech.co.uk/Useful_Tables/Tribology/co_of_frict.htm]

Friction between the steel beams and the plastic ring: Fr = 0. 2 * 125.8995 * 9.8 = 246.76 N

Pulley radius: r = 0.05m

Torque needed: M_o = Fr x r = 12.39 N

Motor torque: M= (M_o /n) x N = 3.38 Nm

Safety factor: N = 3

Number of motors: n = 11

Time to cover: t = 10 sec

Velocity needed: v = 9.15m / 10sec = 0.915m/s = 18.3rad/s = 174.75rpm

Power needed: P = M x v = 3.09 W

5. PRODUCT MANUFACTURING

[5] (a) Bill of Materials for Product:

The following is the Bill of Materials relating to the team's CAD drawings

No.	Part	Material	Qty
1	Reflective Trough	Stainless Steel (1m x 10m)	2
2	Trough Support	Steel	3
3	Support Arch	Aluminium	4
4	Heat Pipe	Aluminium is used to make the tube. (0.07m OD x 10m)	1
5	Double Mirror	Stainless Steel (0.3m x 10m)	1
6	Pipe Support	Steel	3
7	Support Legs	Steel	3
8	Tarpaulin (henceforth labeled Tarp)	Strong Duty Poly Tarpaulin (1.3m x 10m)	1
9	Tarp Rope	Nylon (1.86m)	4
10	Tarp Clip (Large)	Steel (7mm ID)	1
11	Tarp Clip (Small)	Steel (5mm ID)	1
12	Tarp Clip Ball (Large)	Steel (8mm OD)	1
13	Tarp Clip Ball (Small)	Steel (6mm OD)	1
14	Motor	Model: TransMotec D109175	1
15	Temp Sensor (High Temp)	Specification: Philips KTY84-1 series	1
16	Temp Sensor (Low Temp)	Specification: Philips KTY81-1 series	4
17	Pressure Sensor	Specification: Motorola MPX2010 / MPXV2010G series	1
18	Photo Sensor	Specification: Siemens BPX 61	1
19	Internet Connectivity Kit	Specification: Sena Technologies' HelloDevice	1

Table 6.1: Bill of Materials for Final Product Offering

- 11 motors (~0.5HP each – [0.34kW] – to drive shield over the trough in case of bad weather only.

BRUSHLESS MOTOR DATA								
	NOMINAL VOLTAGE	NO LOAD		AT MAX EFFICIENCY				
MODEL	(VDC)	SPEED (RPM)	CURRENT (A)	SPEED (RPM)	CURRENT (A)	TORQUE (Kg-cm)	WATT (W)	EFF (%)
D109175-12	12	2000	5.1	1680	27.8	16.2	352	74.8
D109175-24	24	1900	2.6	1600	14.3	14.9	339	74.1

Table 6.2: Shield Motor Specifications

The cost of the individual components has not been specified since these are commercially available at all locations and also vary according to design of our Client's downstream equipment. However, we have estimated a very REASONABLE manufacturing cost of $1200 dollars per module as specified in Section 7 below.

[5] (b) Production Process

Our product is more of an assembly process even though we will need a factory for the same. This is outlined in the business case (section 7) with details on the Detailed Financial Analysis Workbook embedded in Appendix A7.

We plan to manufacture in the US – mostly in the Mid-west or south to save on transportation costs (since we will be selling over a million in that market). Our business case has outlined the cost of operating the plant in the US and we believe that it is not cheaper to manufacture this in China and then have the modules shipped from there. [Forbes]

Detailed manufacturing processes for important elements are mentioned below:

- **Pipe:** A thermo-conductive metal such as copper or aluminum is used to make the tube. This is manufactured by simple extrusion methods. We can even buy pipes of specific diameter from outside diameter. Our module uses a Perkins Tube (in which the internal side walls of the pipe have a series of grooves parallel to the tube axis), we eliminate need for inner lining.
- **Steel support** provides stability, while light-weight support arch can minimize overall load on the module as well as provide sufficient bracing for tarpaulin. These are made by stamping.
- **Tarpaulin:** bought in bulk as commercially available material.
- **Motors, Sensors:** also bought in bulk – commercially available.
- **Trough:** Made from stainless sheet steel by stamping in our factory or sub-contracted.

[5] (c) HelioWorks Software Code

For the final version of the monitoring software, which provides the graphical user interface between the plant and personnel, different tools will be added.

For the first frame, which shows the selected plant under service by WIT, there will be multiple HelioWorks-managed powerplants visible to user. They can be selected by tabs provided, which are placed directly on the world map. Furthermore, the error statements of all plants will be listed with the date and time of appearance.

For the second frame, which shows the weather forecast, it will not be simulated manually. The weather will be received from a weather station (internet-connectivity). For the feedback of the status of part-replacement need a data bank will be installed. This will hold all information of replacements that which companies are responsible for the repairing process.

A third frame displaying the exact location of malfunction (problem spot)would be incorporated for power plants with a large amount of modules.

6. PROTOTYPE

[6] (a) Final Deliverable ~Exhibition Prototype

In order to demonstrate the internet-enabled closed-loop functionality of the prototype, HelioWorks conceptualized a complex system with three main components. A parabolic trough has been equipped with a shielding mechanism. The shields can be deployed by three geared DC-motors. Control of whether or not to deploy the shield lies within an external Java program. Interface hardware that enables the software to communicate with the main trough has been designed and built.

Electrical (Sensors and Motor): For the final presentation a total of three separate circuit boards run in parallel within a special console facilitating a number of interactive features which are meant to help illustrate the novel features of the module. A dimmer can adjust the light intensity of a lamp, the information of which's intensity is measured and converted from an analog to a digital voltage and can thus be transferred to the HelloDevice. The same is done with a temperature sensor. Three additional buttons can simulate malfunction of the trough to the control-software. This will assist the audience at the final presentation to understand the benefits of being able to monitor the vital functions of a solar thermal power plant.

At the final exhibition team HelioWorks presents a scaled down prototype of the parabolic trough module. This includes three main components. First, the parabolic trough module itself contains sensors monitoring pipe temperature and sunlight intensity. The module's protective shield can be deployed via the internet. A software program visualizes and monitors a virtual power-plant with respect to the physical module prototype. Imminent malfunction will be indicated and automatic shield deployment will be handled by the software. The third main component is a separate wooden console. With this console a number of errors can be virtually generated by the push of a button. The information of this will be sent to the monitoring software via the HelloDevice internet ready kit. Team HelioWorks hopes to thereby illustrate the modules internet enable closed-loop aspect in a concise way.

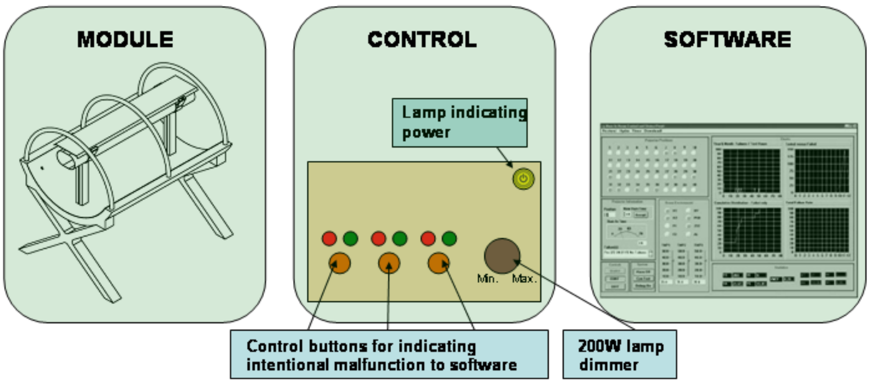

Figure 6.1: Concept platform for final exhibition prototype.

[6] (b) Bill of Materials – Sourcing Strategy and Rationale

Since Kai is the electrical engineer, the console and control circuit was made in Germany. The console was constructed from wood and includes a hinged lid to give access to the internet ready kit and the rest of the electrical wiring. A preliminary drawing describing the console elements as well as an electrical schematic are also given in the Appendix A4. The motor was also bought in Berlin as per the specifications of the circuitry. The module itself consists of its thin stainless steel parabolic trough mirror. The supporting stilts of the module will be made from wood. The sourcing strategy was simple – the parts were sourced where built. Hence the tarpaulin covering, support legs, trough support arches and bearings were sourced in the US while the reflective parabolic trough was sourced from Korea. All of the individual sites accomplished their parts well within the allotted budget of the individual sites.

No.	Part	Material	Qty
1	Reflective Trough	Stainless Steel (1m x .5m)	1
2	Trough Support	Steel	1
3	Support Arch	Copper Coil	3
4	Support Legs	Wood	3
4	Heat Pipe	Steel tube (0.07m OD x 1m)	1
6	Pipe Support	Steel	2
5	Tarpaulin (henceforth labeled Tarp)	Strong Fabric (1m x .7m)	1
6	Tarp Rope	Nylon String (total 1.6m)	3
7	Tarp Clip	Steel (5mm ID)	1
8	Tarp Clip Ball	Steel (6mm OD)	3
9	Motor	Model: TransMotec D1135XE	3
10	Temp Sensor (High & Low Temp)	Specification: Philips KTY81-1 series	(2+2) 4
11	Photo Sensor	Specification: Siemens BPX 61	1
12	Internet Connectivity Kit	Specification: Sena Technologies' HelloDevice	1

[6] (c) Manufacturing, Assembly and Software

6.c.1 Manufacturing For the final Design Review 3 the prototype was built & assembled as per the CAD drawings. The electrical controls were assembled, tested and connected to the software. Machining of the Trough supports, the weather-shield support arches and the tarp-cover stringing was done in Michigan, US by Vazir and Lukasz. Jinki and Taeyong machined the reflective parabolic trough in Korea. The software was programmed by Saskia, while Kai designed and built the electrical console in Berlin. The actual assembly was done in Berlin. Variations from the original project plan include mainly the prototype structure, which was conceptualized to produce electricity. Rather than that, we chose to focus on demonstrating the internet-enabled closed-loop aspect.

6.c.2 Assembly & Exhibition: We constructed a Beta prototype of the module and demonstrate the internet-ready close loop aspect of the same. We **did not** plan to generate solar power within the exposition, but only demonstrate the generic applications of the weather-protection system (the shield and internet-weather report-based actuation) as well as the simulate closed-loop aspects (monitoring of fault/breakdown and timely replacement for the same). The Java /C based program code written by Saskia Zurth runs the electric application constructed by the rest of the team.

6.c.3 Prototype Software Description For the prototype, the HelioWorks program will open up with a View of the world displaying the place where the prototype is located. With a click on the button of the location, a new Frame will open up, showing the parameters of input and output values from o the prototype. Received values will be on one side the sun intensity and temperature and on the other side three status statements if material changes, of tube, panel, or shielding motors are required. Each status of material requirements can be selected individually and to be shown in a separate Frame. If the selected part is damaged, a picture of the damaged part will be shown and the status of ordering has to be entered in the upper text window and will be listed in the text area below with the exact date and time. If no replacements are needed the text area will be none editable. To simulate bad weather conditions four different weather buttons can be pressed, sunny, rainy, cloudy and snowy. These buttons will automatically initiate either a closing or an opening movement of the shield of the prototype.

7. BUSINESS PLAN

[7] (a) Business Strategy:

New opportunities are opening up for solar thermal power as a result of the global search for clean energy solutions. Both national and international initiatives are supporting the technology, encouraging commercialization of production. These and other factors have led to significant interest in constructing plants in the sun belt regions from private-sector project developers and independent contracting firms. In addition, interest rates and capital costs have drastically fallen worldwide, increasing the viability of capital-intensive renewable projects. From a current level of just 354 MW total installed capacity, the rate of annual installation by 2015 will have reached 970 MW, thus reaching a total installed capacity of 6454 MW [Greenpeace Report], thus providing a huge business opportunity for Helioworks.

Our product positioning is as follows in the target segment of the market we want to sell to. We determined that this puts us in a strong position to cater to the needs of the intended customer (i.e., electric utility companies in the primary market, US and housing societies in secondary market, Korea). The figure 7.1 below shows an analysis performed using the Tracy-Wiersema model. For a detailed business potential study, **please refer Appendix 5.1**. There the team has shown the viability of getting into this product development using universally accepted business-case filters.

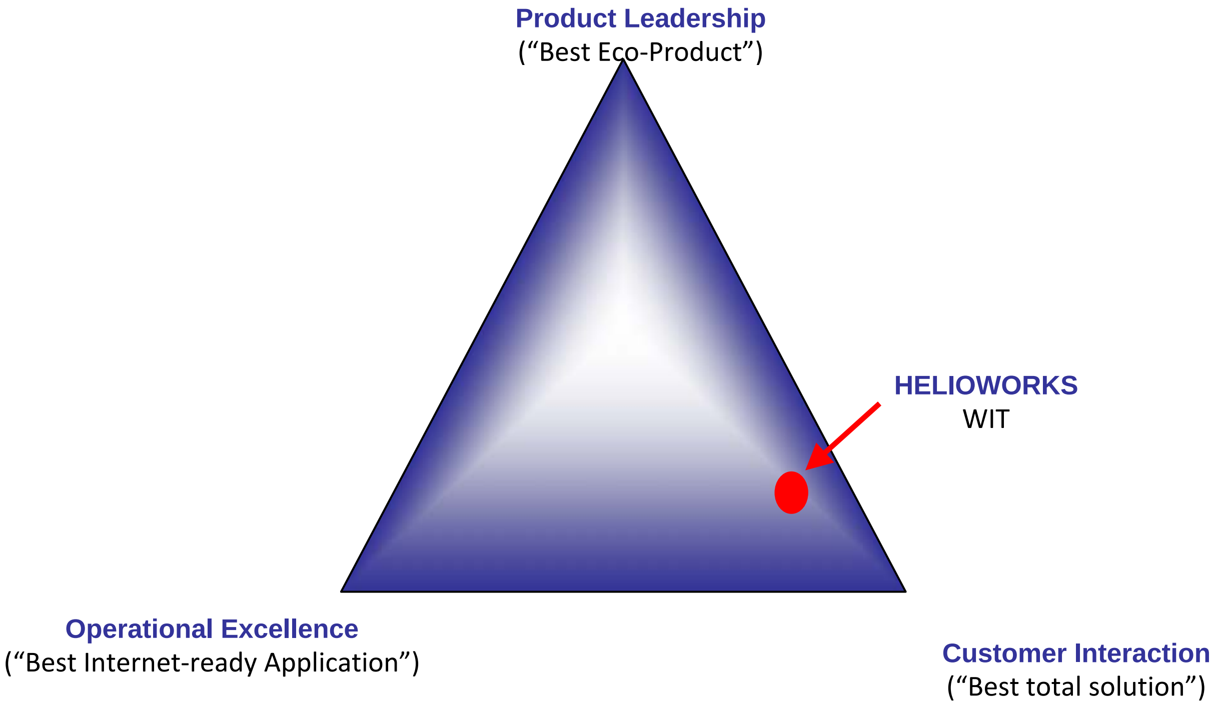

Figure 7.1: Treacy and Wiersema Business Strategy Model

[7] (b) Financing:

Even having defined a technological solution that ideally fits the needs of our specific persona, it is still possible that a business venture in this area cannot succeed financially. In order to determine if our product solution merits further investigation from a financial perspective, we have used a series of financial screens to determine the financial worthiness of the product offering. The three screens used, discussed in detail below, are a static capacity evaluation 15 years in the future, a cumulative cash flow analysis, and a discounted cumulative cash flow [ENGR 599 Lecture titled *Finance Project Valuation Process*].

7.b.1. Product manufacturing costs (both markets)

The **detailed financial analysis model in Appendix 5.2** shows clearly our rationale for calculating manufacturing costs. We have taken realistic rather than optimistic estimates as far as possible for computing these costs and the excel sheet will explain anything not covered here.

We estimate a **manufacturing cost of $1650 per module**. As defined in the product engineering section, a module is one parabolic reflector trough of 10m length, which we will supply along with a tarpaulin cover and sensors, motors and supports. We have specified stainless steel as the reflective material as per our client's technology solution and the supports are made of light-weight mild-steel. Steel is cheap when bought in bulk tonnage. The heat, and light sensors as well as the tarpaulin sheets are weather-proof and we have used the commercially available products respectively to reduce costs and yet maintain reliability. **Labour costs** have been estimated **at $450 per module** (which is a mark-up of actual mass-manufacturing costs), hence we are taking a conservative approach here. The product cost is covered ONLY by direct sales of the product using a **profit margin of 56.25%** (selling price is $2500 - on product manufacturing cost of $1650).

The following sections strive to address how we have analyzed our operating costs in detail. The operating costs are covered separately by charging a service fee on operating the product-system at a client company's solar-power plant. Hence product manufacturing costs are independent of the operating costs allowing World Innovative Technologies more flexibility in scouting for contracts. The product is not only easy to assemble, but also structured in such a way as to dissemble easily for ease of recycling – hence addressing the Recycling and reusability aspects in closed-loop economy in 'Recycle, Repair and Reuse' Eco-triangle, thus reducing end-of-life disposal costs to WIT .

7.b.2 Static Cash Flow Analysis

The static cash flow analysis was developed by estimating the revenue and the costs associated with serving a single client. Office employee estimates were based upon estimating employment of our team of 5 engineers, plus an MBA, two office assistants, and a CEO for which average salaries were used. The medical costs were estimated at the national average for employers per employee [http://www.empyreanbenefits.com]. Additionally, the recurring costs of operating the business outside of directly providing services to customers were factored into this analysis. Included in this calculation were an office lease, office payroll, office employee medical benefits, travel costs, additional indirect equipment, and computer upgrades. The office lease was estimated at the national average for office space [http://www.smallbusinessnotes.com].

The other items are based on much rougher estimates, but are nonetheless detailed in Table 7.1 below.

Item	Price ($)	Time Period	Details
Office Lease	3,733	Month	€20/sqft - 1600sqft (per 200 National Average and this is Berlin)
Payroll	90,083	Month	CS - 85K, 3 ME - 75K, EE - 80K, MBA - 120K, 2 Office Assistants - 38K, CEO - 240K
Employee Benefits	5,250	Month	Benefits (Medical 338/month-person per industry average + Other)
Travel	5,833	Month	Estimated Travel for 3 perons traveling to 3 Plant sites per month
Support Equipment	2,000	Month	Cell Phones, etc
Computer Upgrade	6,000	Month	Computer Upgrades

Table 7.1: Recurring Office Expenses

The costs associated solely with providing the discussed services include leasing hardware through a server provider (Dell or IBM, for example), employing 4 junior engineers with specialties in computer science, electrical and mechanical engineering, medical benefits for these workers, and additional indirect equipment needed to successfully implement our technological solution. The medical benefits were estimated as before. The revenue estimates were calculated based upon a 200% markup in labor costs [ECRC, *Annual Report 2005-2006*] and a 35-55% markup in partnered services; the exact amounts and items are detailed in Table 7.3 below.

Item	**Price ($)**	**Time Period**	**Details**
Server Lease	70000	month	350$/mo 3TB from Dell, 200TB storage x 2 (Redundancy) : 0% DISCOUNT ASSUMED [http://www.dell.com]
Additional Staff	21333	month	4 Junior Engineers or Equivalent
Support Equipment	50000	month	Cell phones, laptops, etc

Table 7.2: Client Service Expenses

The static estimate based upon the above details is a positive operating income of ~ $830 million and is detailed in Figure below. Since this initial screen was positive, our financial analysis moved on to the second screen.

Item	Value in thousand US $
Test Client Revenue	$3,370
Test Client Expense	$184,196
25 True Client Revenue	$5,905,000
25 True Client Expense	$4,423,400
Gross Profit	$1,300,774
Operating Costs	$17,129
EBITDA	$1,283,645
Depreciation	$500
EBIT	$1,283,145
Taxes	$449,101
Operating Income	$834,044

Table 7.3 : Static 15 Year Outlook

7.b.3 Dynamic Cash Flow Analysis

The second screen is dynamic cash flow analysis, and it is implemented by incorporating the fixed initial costs into the reoccurring expenses and revenue. The fixed costs were estimated to include a test server, individual computers, network equipment, furniture, and additional office electronics; which are itemized in Table below.

Item	**Price ($)**	**Details**
Computers	60,000	Test servers, individual computers, laptops, network equipment ….
Furniture and Lab Equipment	7,500	
Electronics	10,000	Phones, Fax, Copier, ……
Plant Cost	10,000,000	One time set-up cost

Table 7.4: Fixed Cost

The adoption rate of our module was examined in order to determine the rate of acquiring clients, which also verified our target customer (electric utilities in US), since the rate is three times higher for new alternate energy systems in very large facilities [US DOE].

A conservative estimate of the cash flow using industry averages was calculated and is shown in Figure below.

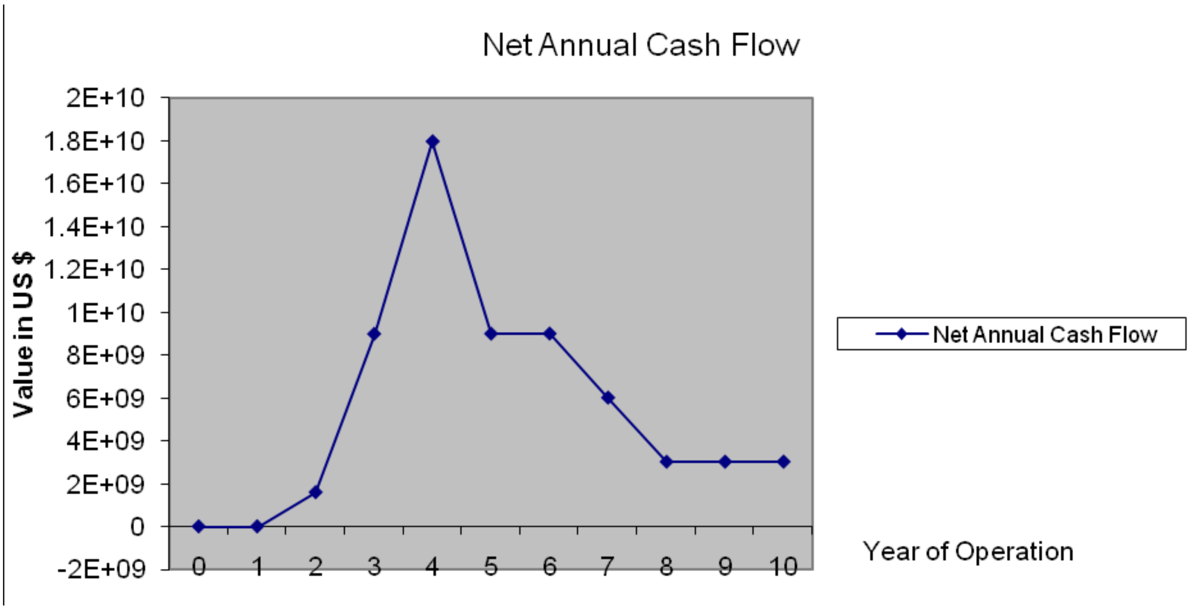

Figure 7.2 : Annual Cash Flow

This was converted into the cumulative cash flow shown in Figure below.

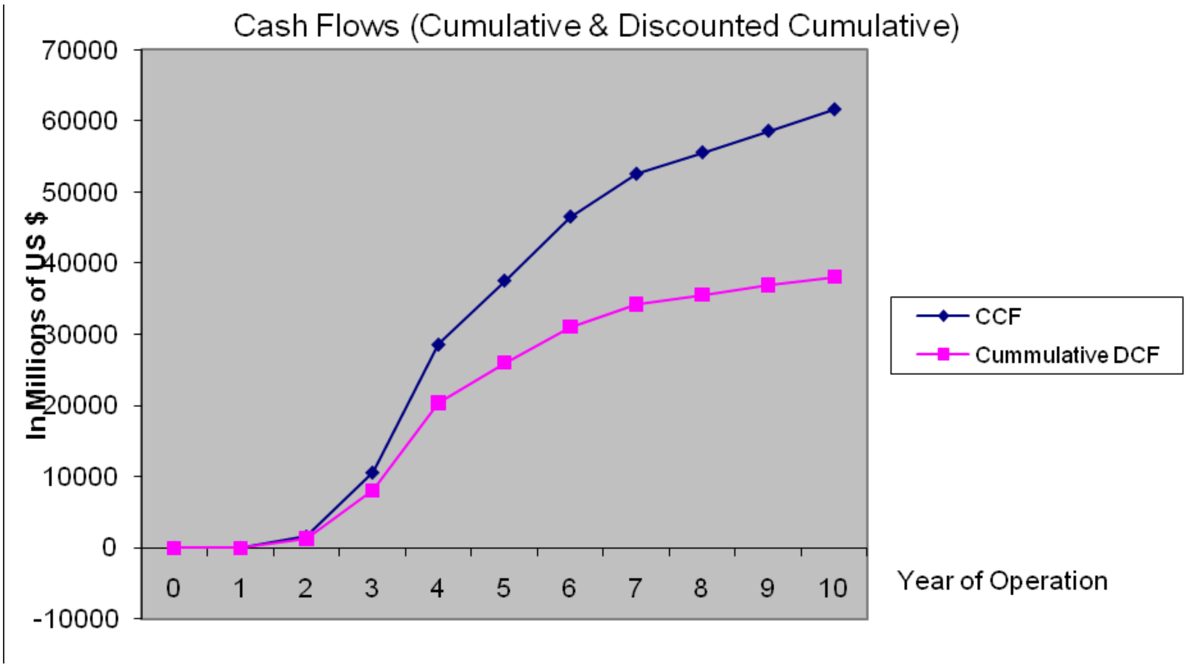

Figure 7.3: Cumulative CCF and DCF

Since our estimate is conservative (we estimate only 5.17% market share for our product), the conservative estimate shows a net present value of $37 billion for the company the analysis was moved forward to the next screen.

7.b.4 Discounted Cumulative Cash Flow Analysis

The dynamic screen was further modified to incorporate the weighted average cost of capital (WACC), which was estimated at 10% [ENGR 599 Lecture titled *Corporate Finance: Cash Flow, Ratio Analysis & Forecasting*]. This DCF was used to estimate the net present value of the company after discounting the cost of the capital needed in the present to make the profits in the future. This applies to the cash flows, shown in Figures above. The net present value at the discounted rate was determined to be $6 billion and $3 billion for the conservative and discounted adoption rates respectively.

7.b.5 Financing Method

Since the business passed the three financial screens, it is feasible to give thought to a method of finance. In order to finance the business, we have structured several rounds of investment by WIT. These rounds were determined using the estimated EBITDA and a multiplier found for a comparable company. In this case we selected SOLEL Solar Systems (Israel) and Pacific Gas & Electric Corporation which had EBITDA multipliers of 10.7 and 28.4 respectively. The multipliers are significantly higher than derived for AMD and Intel and therefore suggests that the energy industry as a whole have higher multipliers than similar companies in other fields. Since we estimated the EBITDA to be $900 million six years out, we applied the more conservative multiplier to reach a financing schedule [One Valuation Method: Methodology by Marcia J Hooper]. We further simplified the schedule by rounding the values to even numbers and reducing the investment to 2 rounds to cover initial operating expenses. The schedule is detailed in Table below.

Round	**1**	**2**
Years post founding funded	1	2-3
Pre Round Valuation	15,000,000	2,750,000,000
Post Round Valuation	1,500,000,000	5,985,591,084
Financing Contributed	1,485,000,000	3,235,591,084
Goal	demonstrate working prototype and acquire development partner (electric utility client 1)	Develop protocols with partner and acquire true clients (electric utility clients 2 & 3)

Table 7.5: Financing Schedule

In addition to the schedule a set of goals that follows our cash-flow dynamic prediction were set for each financing round. Primarily, we want to create a positive cash flow in 3 $^{1/2}$ years, and ensure that the net present value of our venture is positive. Meeting these goals is important for the valuation of the company to increase.

[7] (c) Marketing And Distribution Strategies:

While we focus on our first customers, namely the solar power companies (electric utilities of the south and south-western states in the United States), our marketing positioning statement will read as the following:

"For companies in the solar-thermal power generation business, our internet-ready weather-protection and maintenance system is the best way to ensure long-worklife and trouble-free power generation with minimal downtime because it is designed to interface easily with all systems and equipment, thereby eliminating the need for breakdown maintenance and disparate management locations."

7.c.1 Product Offering

Before we market our product, we must specifically define what our company and product are not. Our company is ***not*** a power generation company, ***nor*** a seller of energy. We cannot produce & sell energy with the same efficiency and economies of scale dedicated companies like Solel have come to enjoy, and thus we will concentrate on the internet-ready closed-loop aspects to make our product function. To this end, we will look to partner with established providers of electric power. We also will not provide inter-corporate communication in at least the first ten years. While we cannot exclude this function as a product feature in the future, we must first concentrate on penetrating the market with our solution, and focusing on nonessential features is not conducive to this endeavor. Also, proprietary technologies are involved, so we would be a supply-support technology provider operation not a technical innovation enterprise.

The product we plan to market is the assembly of our partners' hardware, such as Power generation equipment (transformers, etc), with the software we have written into a data management system and our proprietary weather-protection systems that can be retro-fitted quickly and easily by the client plant at all locations of their plants. Our product offering will include continuing customer support even after the system is online in order to provide continuous monitoring and troubleshooting capabilities to client corporate staff. This will entail having one to four full time staff on site at the solar power-plant in order to provide timely service. In short, our company is a provider of weather-protected parabolic troughs for solar-thermal power-plant hardware as well as plant monitoring data management services and software.

7.c.2 Target sales volume and price (both markets)

Target Sales Volumes

Detailed manufacturing and sales estimates are given in embedded Excel Workbook – Detailed Financial Analysis, Worksheet - Revenue, Table: Sales of Modules. **See Appendix 5.1**. We estimate annual sales of **1 million modules in primary market** and about **100,000 modules in secondary market** annually. The rationale for these is detailed in the Section3: Marketing. The modules that do not go into a new plant would go to existing plants (replacement of existing plants under our contract.

Price Index Context

The module cost represents around 50 - 60% of the total installed cost of a Solar Energy System. Therefore the solar module price is the key element in the total price of an installed solar system. All prices are exclusive of sales taxes, which depending on the country or region can add 8-20% to the prices, with generally highest sales tax rates in Europe (we target only US and Korea).

[http://www.solarbuzz.com/ModulePrices.htm]

Primary Market Price

Following what our customers are willing to pay for a solution comparable to our product, we will price our product at $2500 per 10 m sized module involving an estimated initial up-front payment of $3billion to facilitate implementation at the customer's site. This is based on an approximation of about **800000 modules per plant** (conservative estimate). Also, this is very reasonable in the power industry as the cost of setting up power plants is usually covered by the government/corporate awarded contract. In addition we will charge a monthly service contract fee of $333,333. This price is charged on a monthly basis and covers total maintenance as well as operation. These prices do not reflect discounts a target first customer can enjoy in exchange for helping us establish a beachhead in the market while choosing to implement our product and serve as a product reference.

Secondary Market Price

After considering all aspects of the business case, we decided that we will price our product at the same price for the secondary market, i.e. $2500 per 10 m sized module involving an estimated initial up-front payment dependant on how many modules are installed on the roof of the housing society. Since we are manufacturing in 10m modules, we estimate that a typical apartment block could use between 10-**20 modules per roof** (as per our design plan this translates to a length of upto 100m). These modules would NOT be connected to power-generation equipment, but instead only directly heat water for the building use. The costs to the building society are minimal as it makes maximum use of the rooftop without need for any structural modifications.

7.c.3 Placement – Sales Channels

To successfully market the proposed product offering, we must carefully design our sales channels. To this end we must first understand who is in a position to make the decision whether to purchase our product. In the electric power industry, this means directors of Solar-thermal power companies. The energy utility companies' chairmen (to whom the power producer will sell electric power), however, heavily influence their decision, which is why we propose to also market our product directly to them, given that they may also be more accessible than the primary customer company's director. For maximum chance of a sale, we will concentrate on big companies with an established position in the solar-thermal power business, namely SolarGenix, Abengoa Group, SENER, Stirling Energy Systems, SBP and Partners, New Energy Algeria, Macquarie Generation and Solar Heat and Power, Solar Millennium, Flabeg Solar Int., Fichtner Solar, OADYK, RREC (Rajasthan Renewable Energy Authority), Mapna (Iranian Ministry of Energy), Solel Solar Power Systems, ONE, ACS-Cobra, EHN, Iberdrola, HC-Genesa and Solar Millenium. For them it is most critical to efficiently compile and share comprehensive data on power production for improving generation efficiency, and the chairmen of these companies are most likely to ascertain the benefits of using our product.

For effective sales operations we must provide demonstrations of our product in environment in which it will be used. It is especially important to convince the end users who will be working for the directors, like engineers and plant maintenance personnel, of our product's numerous qualities. Our sales force must show them an improvement in work efficiency and downtime reduction to build a consensus among the staff that our product will benefit the solar-thermal power plant. In this way we can leverage these advocates of our product to generate a sale within the client company. Of course, it is worth noting that our sales operations should take into account the company's receptivity toward an implementation of our product in order to concentrate early efforts on the companies likely to adopt our product.

In summary, including client-company directors and engineering personnel in sales channels will increase the perception of customer value, whereby we create "buzz," articulate the need to the consumer, and demonstrate value.

7.c.4 Promotion

To generate further sales, we will need to promote our product. Initially, this will be done by implementing our product in our first customer's power-plant. In the energy industry one of the most important sales tools is the reference of a customer who is enjoying the benefits our product offers. To this end we may present our first customer with the previously mentioned discount attached to a contract clause that permits our future customers with a similarly sized plant to come in and look at our product in actual operation. In this manner we can show our subsequent customers not only a demonstration system but also one in active use, perhaps to showcase how exactly the power-plant uses our product and which benefits it gains.

In addition we will need to create brand recognition outside the scope of a reference customer. This is best done in the energy industry by publishing and advertising in environmental and technical journals. It would be beneficial to our company to hire a public relations firm specializing in the energy industry to promote our product. Necessary also is our company's attendance at conferences in alternate-energy solution areas with high-technology management needs, like the aforementioned monitoring and maintenance areas. In these ways our product can get maximum exposure in the Concentrated Solar Reflecting technology based power field.

[7] (d) Launching In The Secondary Market

7.d.1 Beyond the Early Adopters

After our first marketing phase of targeting the twelve largest solar-thermal plants using CSR technology is achieved, we enter into the "crossing the chasm" phase [As coined by Geoffrey Moore in *Crossing the Chasm: Marketing & Selling Disruptive Products to Mainstream Customers*]. We will move from targeting the primary market's twelve largest CSR plants to targeting large housing societies in the secondary market. Not all buildings are designed in the same way, however. While our predominant targets, the twelve power-plant sites, tend to be visionaries and hence early adopters, it is important to understand that private housing societies tend to be pragmatists by first requiring a working system before they consider our product. These customers create more difficulty in a refusal to reference the large-scale power-plants we will target first.

Therefore, for our product to take hold in this market we must at first target a segment most likely to adopt our product. This is referred to as the beachhead segment; the process of addressing this segment "is to target a specific niche market as your point of attack and focus all your resources on achieving the dominant leadership position in that segment" [Geoffrey Moore in *Crossing the Chasm*]. Large private apartment complexes wishing to lower their tax bills by adopting green buildings present themselves as an ideal beachhead segment, as in this area there is a very high need for efficient heating. In this case, a product tailored to expertly handle the specific data generated in the field of solar-heating could increase the likelihood of adoption within this segment. Once the "chasm" is crossed with this segment, we will branch out to other large housing societies in general having already sold to pragmatist customers that can be referenced.

7.d.2 When and Why

For our product to gain acceptance and technological dominance in the market, we plan to launch the product in the secondary market **in the sixth year** of operations. This is because of several reasons. Firstly, it is possible to achieve economies of scale in manufacturing only when we are building large number of modules and are able to sell of them. Also, cash flow (see finance section) does not get positive until the end of 3rd financial year of operations, which means valuable resources used in marketing to our primary consumers will take first priority. Initially, WIT will have to bear all costs of operations and set-up of manufacturing, distribution and marketing facilities, which will involve full-time responsibility of our team-members (HelioWorks Group) within World Innovative Technologies business operations. Thirdly, we will use the primary market as both a technology demonstrator as well as experimental/proving ground for perfecting our own product solution. This is essential, because adoption by more discerning secondary market is dependent on proving benefit to the building and currently the technology in CSR-type solar-powerplants is skewed toward efficiency when there are a larger number of modules. When energy o/p per module increases as a result of further research and progress, it will allow the product to be far more suitable and viable for use in lower numbers (such as on housing societies' rooftops in Korea).

8. PROJECT SUMMARY

HelioWorks' main focus has been the detailed design of the solar module as a result of a product redefinition. Initially, the broad scope of the project encompassed the design of the entire power plant. Upon a more critical examination, it was determined that such a broad scope would be unfeasible in the time allotted for the project and a strategic decision was made to narrow down the project scope and concentrate the efforts on the solar collecting module itself. More importantly, the efforts were centered on the internet enabled aspects, as well as value-addition, i.e., the weather protection system.

We were able to create a product solution that addresses a need and thereby present a viable case for World Innovative Technologies to get into a new market-space. The product is a solar-power module consisting of a parabolic trough that concentrates heat onto a pipe carrying heating fluid (oil). This transfers heat to water and creates steam – outside of our module. That steam can either be used to drive a turbine generating electricity (primary market), else directly be used for heating applications (secondary market).

The business case and financial analysis shows that investing into this business would pay rich dividends for WIT. Even after estimating a conservative market-share of 5% over 10 years, profitability is assured.

The Internet-Enabled Closed-Loop Aspect

Each array module comes fully equipped with a set of critical sensors which monitor the operation of the power-plant and orchestrate the data through a central server. Sensors monitor the temperature within the parabolic trough and along the heat pipe and compare this data against that recorded by a photodiode to ensure proper solar ray harnessing and focusing. Pressure sensors monitoring the pressure within the water/steam pipe would ensure the safe operation of the plant.

The data collected at each plant by the aforementioned sensors would be transmitted to a central server at HelioWorks. This server would monitor each plant's processes and allow for early detection of any anomalies. When a component is deemed as not performing properly, a technician would be dispatched to fix or replace the component. If a replacement is necessary, the faulty component would be sent back to HelioWorks for refurbishment or salvage. The internet connectivity would also allow for real-time inventory tracking across all HelioWorks plants and in case a parts shortage occurs at one location, parts from a neighboring plant can be sent over to assist in a timely conflict resolution.

The malfunction incident and replacement-cost data would be stored on the central server for each individual plant as well as a collaboration of all the plants. This would allow for a fast and accurate cost and quality analysis to aid in any redesign efforts to ensure proper distribution of engineering resources to the most critical areas.

The internet connectivity would also allow for remote control of the power plant. Using weather forecasts, the central server would send a signal to the power plant when a cloudy forecast exists. This would initiate the automatic covering of the power plant to prevent damage. Not only is downtime reduced in this way, but HelioWorks can also ensure the recycling or repair of those parts. Research indicates that this is not the case currently. Large-scale solar-thermal plants are adversely affected by scratches on the surface of a reflective trough, which has a multiplier effect, reducing the efficiency of the entire plant. Since it is not possible to detect exactly where the problem may have occurred, the entire faulty 'row' of parabolic troughs is replaced with new ones.

With HelioWork's solution, a replacement is necessary, **only** the faulty component would be sent back to HelioWorks for refurbishment or salvage. The internet connectivity would also allow for real-time inventory tracking across all HelioWorks plants and in case a parts shortage occurs at one location, parts from a neighboring plant can be sent over to assist in a timely conflict resolution.

9. LESSONS LEARNED

The team is satisfied with our accomplishments within the scope of the course. We were initially a bit optimistic regarding the amount of technical capability available with the individual members, which is why we chose to do this project for submission to World Innovative Technologies. However, as the course progressed and we took stock of our capacity to actually develop a working model, we rationalized the scope of our project.

Thus we went from attempting to develop a mini solar power-plant, to a weather-protection and monitoring device for concentration solar power plant troughs. We chose to concentrate our efforts to addressing the internet-ready closed-loop aspect of the problem prevalent in the solar-power industry, rather than compete with established market leaders like Solel and deep-pocketed industry giants like Siemens. Instead, we were able to successfully make a case for profitable manufacturing under sub-contracting from these companies already involved in projects of a huge scale. After the revision of the project scope, we would rate our achievement at 80% of initial objective, leaving only solar-power generation out of the final product delivered.

We take back with us lots of lessons from this course. Firstly ofcourse would be the fact that it is not very easy to produce solar-energy using concentration solar technology at a small scale. Secondly, all of us learnt about working with colleagues from different countries and diverse technical backgrounds. Thirdly was the course lectures themselves which opened our minds to product lifecycle management and manufacturing strategies. We also learnt about international product development – i.e., about designing for markets not familiar to us, as well as differences in designing and measuring units.

The softwares used were Visio and MS Power Point for the presentations, SolidWorks for the CAD, Java/C and Adobe Photoshop for the graphical user interface and the Steam System Scoping Tool Suite – available free from the Dept. of Energy, USA.

One of the things that would be construed as critical learning from this course but not highlighted is how innovation within a company could be fostered and carried out. (The entire course was structured around a fictional company who employed the team). Then how to present the proposal and business plan to the directors of the company, to compete with rival teams within the company to get budget sanctioned for further research and development and champion an investment in a direction which you believe the employer should take.

Last, but not the least, all of us learnt communication skills – something that engineers take for granted since they are easily able to get their ideas across to co-engineers - and hence are not very good at in real-life. Communicating with each other through internet applications like VOIP, video conferencing and Instant Messaging gave all of us a new perspective to dealing with colleagues working on the same project at different sites across the world. We used all of the aforementioned communication mediums.

10. ACKNOWLEDGEMENTS

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Also, a website of the Dept. of Energy with a software package for steam system analysis (see references).

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APPENDIX A1

The following were the top 5 ideas out of a pool of over 20 that were proposed by members of HelioWorks Group.

1) Camping Tent:
   - **Manufacturability:** Easy to make. Made of canvas, this internet ready device would be a boon for campers and emergency rescue personnel (even having military frontline first-aid applications).
   - **Internet-Ready:** The internet connectivity would enhance the safety of a camping group – would give them a readout of (i)temp, (ii) GPS location, (iii) weather conditions **and** have ONE emergency button that could report all this (location, etc) to Park Authorities in the event of an emergency (bear attack, natural disaster, other emergency like injury, etc) when pressed.
   - **Cradle to Cradle:** the canvas could be used for several applications depending on where the tent was used – for example:
     - if the tent was used on a jungle safari in Africa, then the campers could simply leave it with the local tribals so they could use the water-proof canvas for use as water-porting containers
     - if the tent was used for camping in a developing country like India, the canvas could be re-used as water-proof clothing or rain-proofing of homes (the famous Indian monsoons)
     - if the camping was in a place like the south of France, the canvas could be left for struggling artists to paint on.

2) Modular Furniture:
   - **Manufacturability:** Also easy to make. Made of a basic wooden skeleton with hinges and covered with soft foam-filled outer resin skin. Would consist of one chair with a lamp and folding table and possibly a heater/cooler.
   - **Internet-Ready:** The internet connectivity would allow this chair to be set (for example, from office before returning home) to one of 3-4 pre-adjusted memory settings depending on person's mood.
     - If he were sleepy, the contraption could be set to sleep setting, which would open it out to full length (airline first class chair/bed) with lamp off and table folded in.
     - If he were tired, setting would open chair to semi-recline, open lamp to dim setting (soft lighting) and keep table partially open for remote control. Cooler would come to full power for ……… lemonade?
     - If he wanted to work, setting would keep back-rest upright, lamp turned fully on and table set out for reading. Heater would come to full power for ………… coffee?
   - **Cradle to Cradle:** The wood can be used for planks, etc in any application when furniture is dismantled, while foam can be used for packing, etc. Resin cover can be used as curtains, car-cover, etc.

3) Greenhouse:

- **Manufacturability:** Again, easy to make. Made of wooden frame and glass sheets (like a normal greenhouse)
- **Internet-Ready:** The internet connectivity means that constant monitoring of temperature, plant moisture content, humidity, amount of oxygen and CO_2, etc. This is sent to the central information control of the farm or household.
- **Cradle to Cradle:** All materials are re-usable – wood can be used for making furniture, dog-kennels, whatever, while the sheet glass can be used to make French-windows of a house, etc. The soil can be put in any garden or field.

4) Thermal Solar-Power plant:
(Sustainable renewable energy mini-power plant)

- **Manufacturability:** A circular area of corrugated iron sheeting should cover an area of about 25m². This should hover about 0.8 m from the ground and be cone-shaped. In the middle is a tall chimney containing a generator attached to a fan. In a sunny environment, the heat created underneath the corrugated iron sheeting would create a draft within the chimney that powered the generator.
- Cheap, easy to manufacture and therefore, in extremely poor & far out regions, an alternative to expensive and fragile solar cells. Also, the plant would be easy to fix in which also is very important.
- **Internet-Ready:** To make the thing internet ready a few sensors would be attached to the mini-plant. Heat sensors, rotation/vibration sensors for the fan, power-meter, and dust-sensor indicating surface cleanliness and so on. Transmitting the information to a central web-site would enable the plant to call for help automatically. A company distributing the plant could manage its maintenance with minimal manpower. Performance statistics for a number of plants would be generated automatically.
- **Cradle to Cradle:** After reaching its End-Of-Life status the plant could be disassembled. The metal can be used for housing, water storage or fencing in chickens if there are any :). The fan and generator could be put on a flag pole and serve as a secondary plant. Building an air-con from the thing is another option. Maybe the material from the plant could even be used to build a bridge.

5) Treadmill

- Design a new treadmill (workout equipment that allows the user to essentially run in place).
- **Internet-Ready:** (1) Can monitor your workout online, track progress, analyze heart rate, etc.. (2) Can connect with other treadmills and compete against other online (races, distance running, a "virtual marathon", etc.).
- **Cradle to Cradle:** Two pieces of the treadmill can be reused:
    - The **belt** can be reused for either (1) a grocery store checkout lane (where the consumer loads their goods onto the belt and the cashier advances the belt toward the register); and (2) a warehouse where the belt would serve as a conveyor belt but with the added functionality that the internet-ready device would monitor throughput, process activity, etc..
    - The **frame** of the treadmill can be reused for use as a wheelchair or low-cost bicycle.

All of these proposals were analyzed for their feasibility in manufacturability, as well as their suitability in addressing the given project brief – i.e., an internet-ready closed-loop product where the web enabled feature enables the Reuse-Recycle-Repair cycle for minimum environmental impact.

APPENDIX A2: MARKET ANALYSIS

Appendix A2.1: Patents

There are few patents in the field of solar power generation that use technology similar to that of HelioWorks. Concentrated Solar Thermal (CST) technology has not been proven to be very efficient until recently with innovations in materials and technology with research still ongoing in the field. CST systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. CST technologies require direct insulation to perform properly. This requirement makes them inappropriate for significantly overcast locations. PATENTS in the field of Concentrated Solar CSR Technology:

1.) Apparatus for concentrating solar energy – Hein
2.) Concentrating solar receiver-Dorfeld
3.) Directing and concentrating solar energy- Kauss
4.) Integrated Solar thermal energy collector-Garrison
5.) Solar Thermal Collection System- Frank
6.) Solar Thermal Power System Employing ADJ-Kaplan

Appendix A3.2: Feasibility of Korea Market

To show the feasibility of our modules fitted on roofs in Korea market, we've found some pictures to show you all about the apartments in Korea. Those are the typical "concrete jungle" in Seoul. Other cities are also similar, maybe a bit smaller. Our point is that these are the TYPICAL apartments in Korea, and it makes our market search REASONABLE.

Long buildings with flat roofs that are basically a waste of valuable square meters of real estate


Hi Seoul

Looking at the photos above, we feel a lot more confident in the feasibility of a module like this for that application, albeit the length could vary if partner-companies like Solel came up with more efficient energy per-unit-length modules which we could build.

APPENDIX A3: ALTERNATIVE DESIGN CONCEPTS

Appendix A3.1: Highlighted Concept Proposals:

Alternative Concept 1 is very similar to the final concept selected in that it employs the parabolic trough with a single wide pipe running along its longitudinal axis with a shield affixed in close proximity atop the pipe. The differentiating factor with this concept is the protective shiled. The shield is still a durable tarp but is now pulled along the longitudinal axis of the module. The tarp is permenantly affixed at points to the support arches which run along the side rails. When the rails are activated, the arches pull the tarp over the module.

Alternative Concept 2 also utilizes the parabolic trough for reflecting the sunlight. The water/steam pipe is now a series of smaller pipes in order to increase surface area for heat absorption and reduce the amount of water per pipe that needs to be converted to steam. The top of the module consists of the one-way mirror to allow for solar rays to penetrate into the module but not escape should they be reflected not directly at the pipe. The shield would be a series of rigid telescoping modules running along the side rails.

Alternative Concept 3 uses a parabolic trough with a glass sheet on top to help trap the heat inside the module while serving to protect the reflective surface from external factors. The water/steam pipe is in the form of a sine wave to extend the time it takes the fluid to tranverse the reflective area to aid in superheating the steam. The shield is a durable tarp that is pulled directly over the glass sheet via the rails running alongside the module.

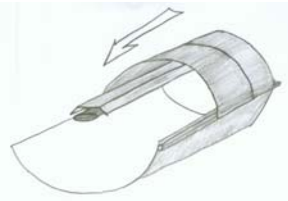
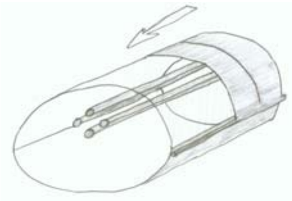


Figure A3.1. Alternative



FigureA3.2 Alternative

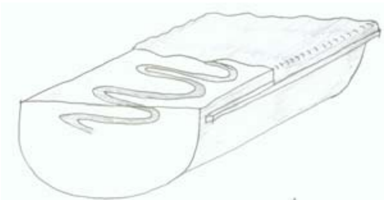


Figure A3.3. Alternative

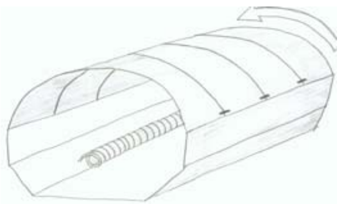


Figure A3.4. Alternative

Alternative Concept 4 uses a series of long flat elements oriented in a parabola-like manner to form the reflective surface. The water/steam pipe is a longitudinal coil running the length of the module in order to maximize the length of time the fluid is exposed to the solar rays. The shield of this plant configuration is a series of modular rigid parabolic structures which are interconnected. By activating the first in a series of these structures, the entire network of shield modules is put in motion.

The HelioWorks team ranked the 5 design concepts using following categories to arrive at the optimal design selection: (1) solar energy collection, (2) sustainability, (3) manufacturability, (4) market price, & (5) set-up.

							
Item	**Details**	**Weight**	**#1**	**#2**	**#3**	**#4**	**#5**
Solar Energy Collection	How efficient?	3	5	5	2	1	3
Sustainability	Long-lasting?	2	4	5	4	2	3
Manufacturability	Ease of manufacturing?	2	5	4	3	2	2
Market Price	Cost?	3	5	4	2	3	2
Set-up	Easy Set-up?	1	3	3	1	5	3
	Total		51	48	27	25	28

Table A3.1. Pugh Design Selection Matrix

Appendix A3.2: Alternate Design Process:

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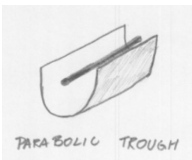
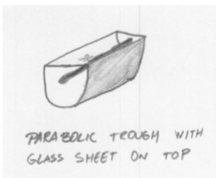
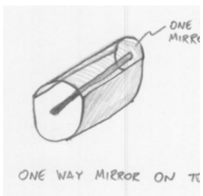
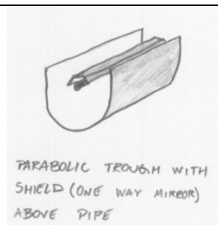
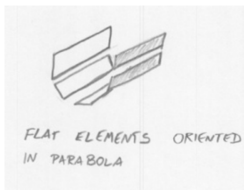
<tr><td rowspan="2">Heat Focusing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td></tr>
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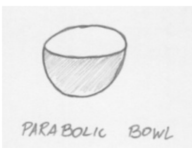
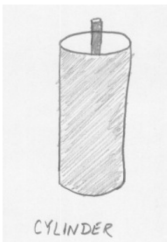
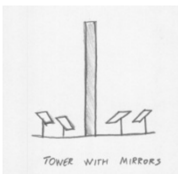
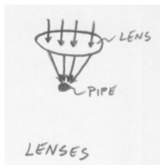
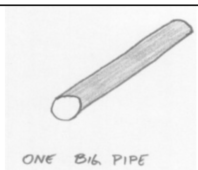
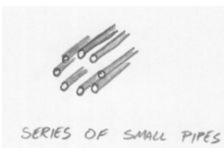
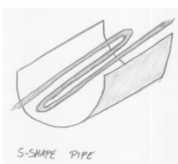
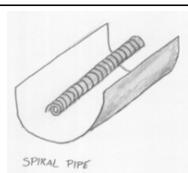
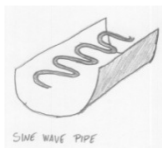
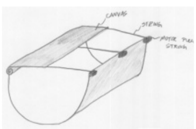
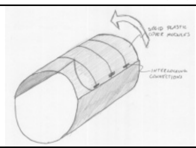
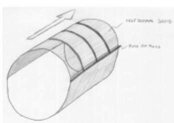
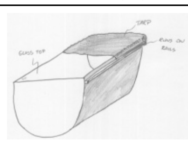
<td></td>
<td></td>
<td></td>
<td></td>
<td></td></tr>
<tr><td>Pipe Configurations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td></tr>
<tr><td>Heat Transfer</td><td>Black steel pipe</td><td>Black aluminum pipe</td><td>Black brass pipe</td><td>Ceramic pipe</td><td>Fiberglass insulation</td></tr>
<tr><td>Shield</td>
<td></td>
<td></td>
<td></td>
<td></td>
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Table A3.2: Morphological box illustrating the alternative design process.

Appendix A3.3: CAD Drawings:

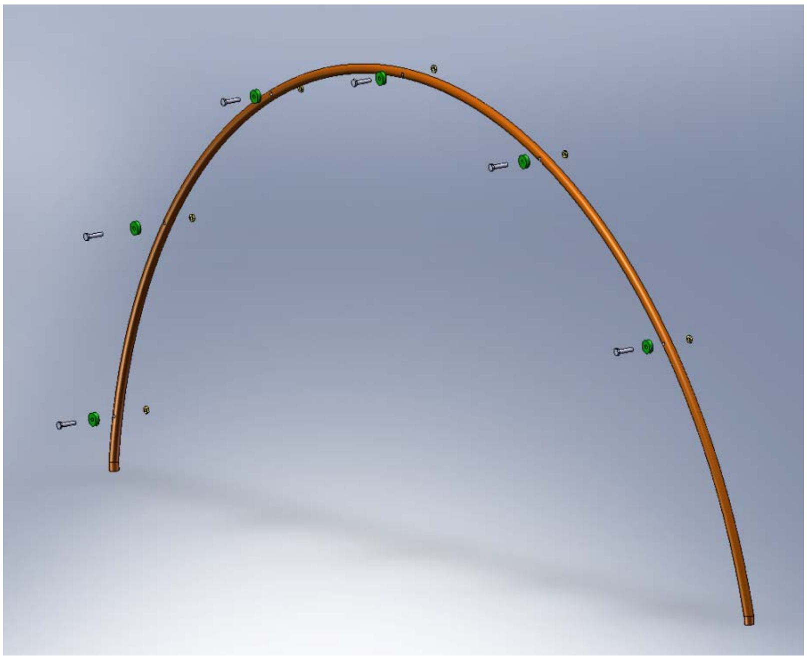


Figure A3.3: Support Arches

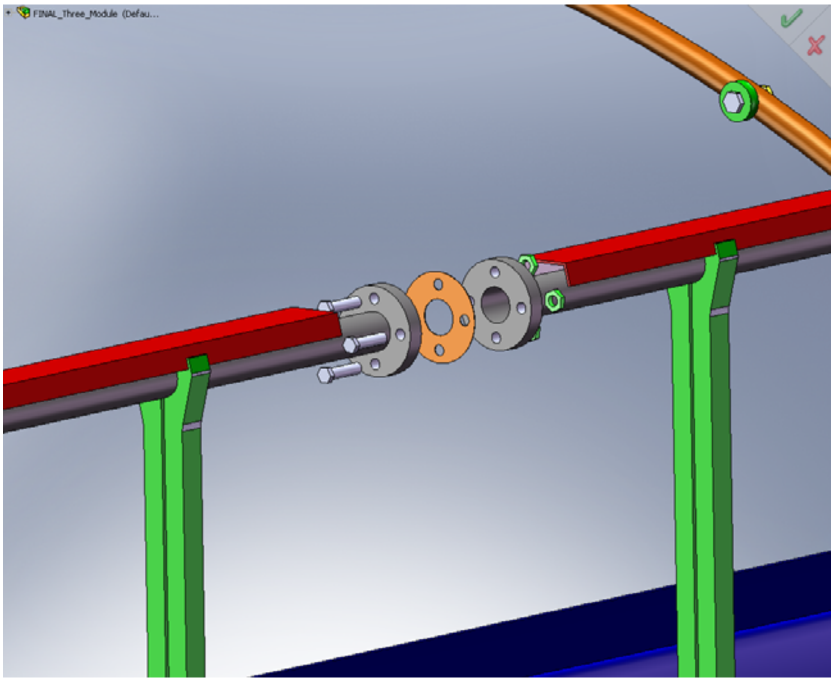


Figure A3.4: Oil Pipe Detail

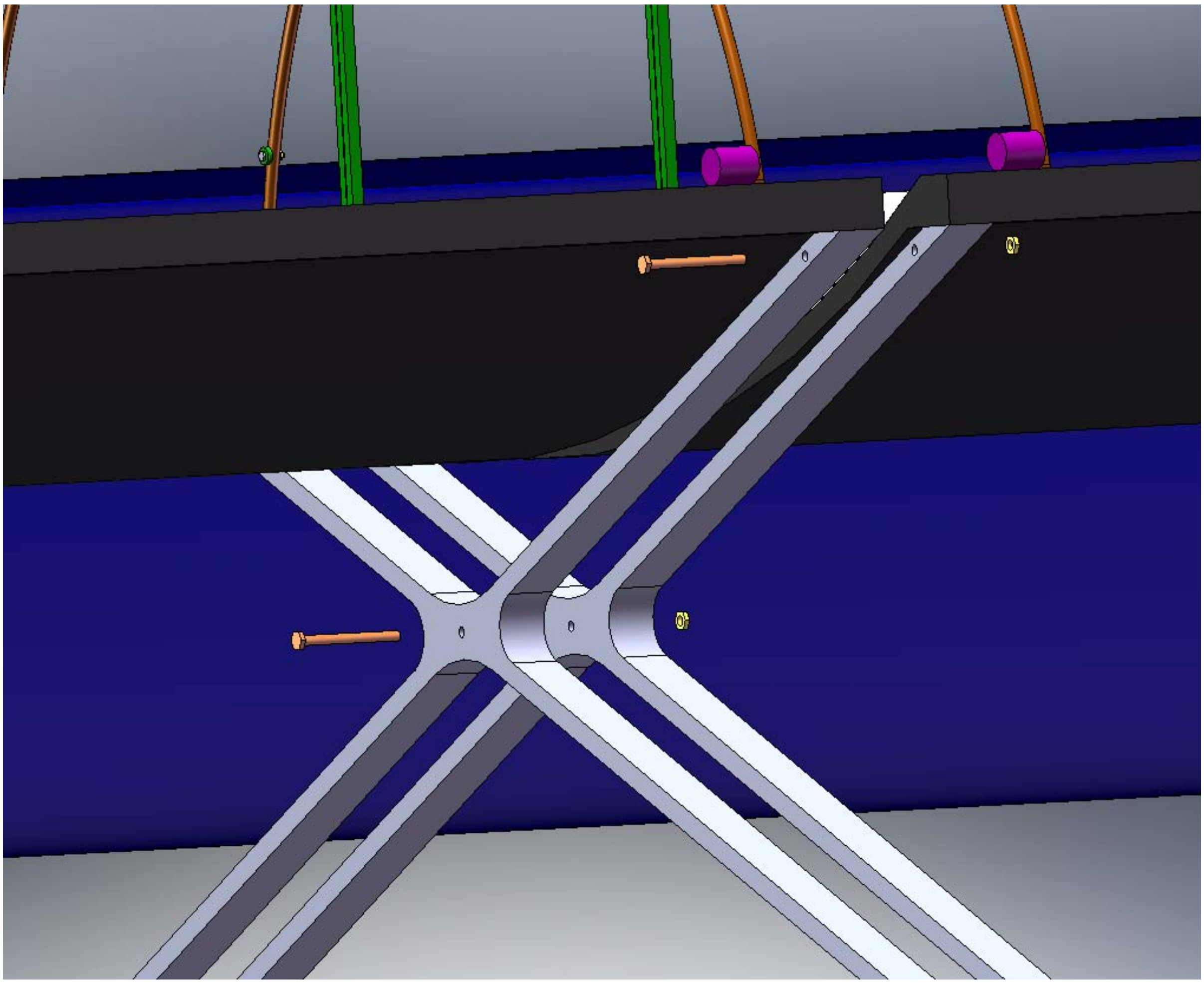


Figure A3.5: Support for Trough

Appendix A4: Prototype

Appendix A4.1 : Design for Prototype Console Box

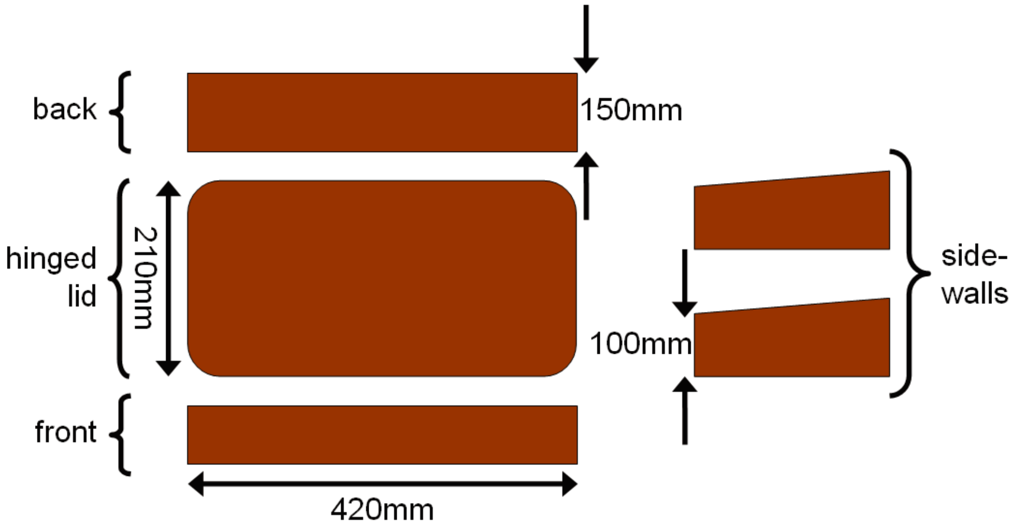


Figure A4.1 : Dimensions for manufacturing the wooden prototype console.

Appendix A4.2 : Prototype

Figure 4.2: Assembled Prototype

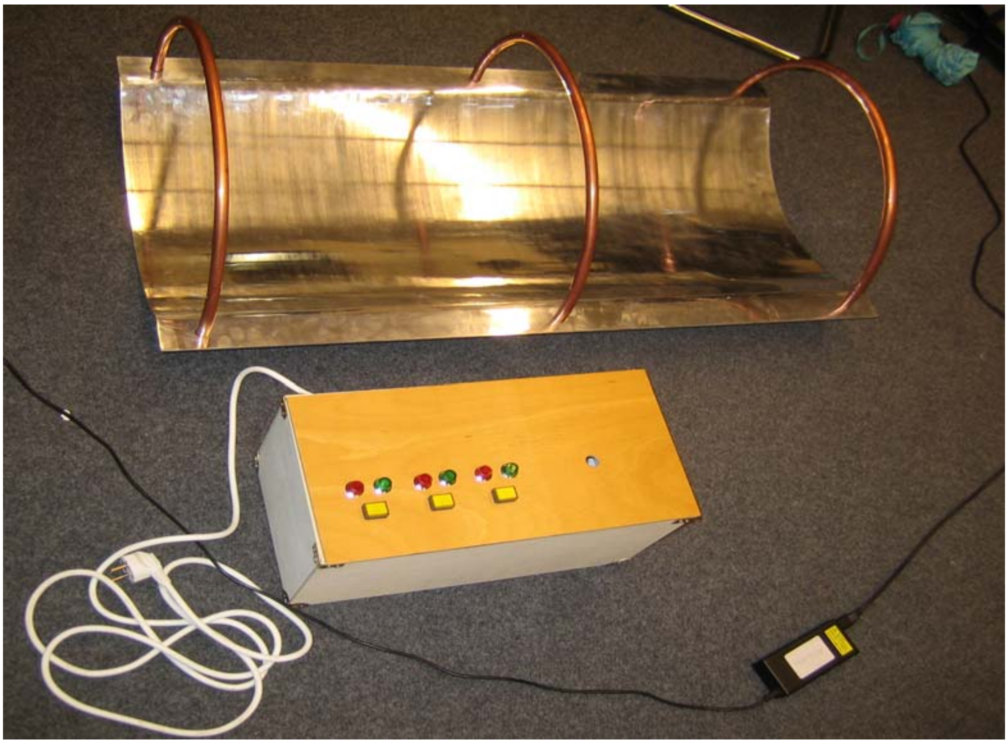


Figure A4.3: The Parabolic Reflecting Trough and Electrical Console

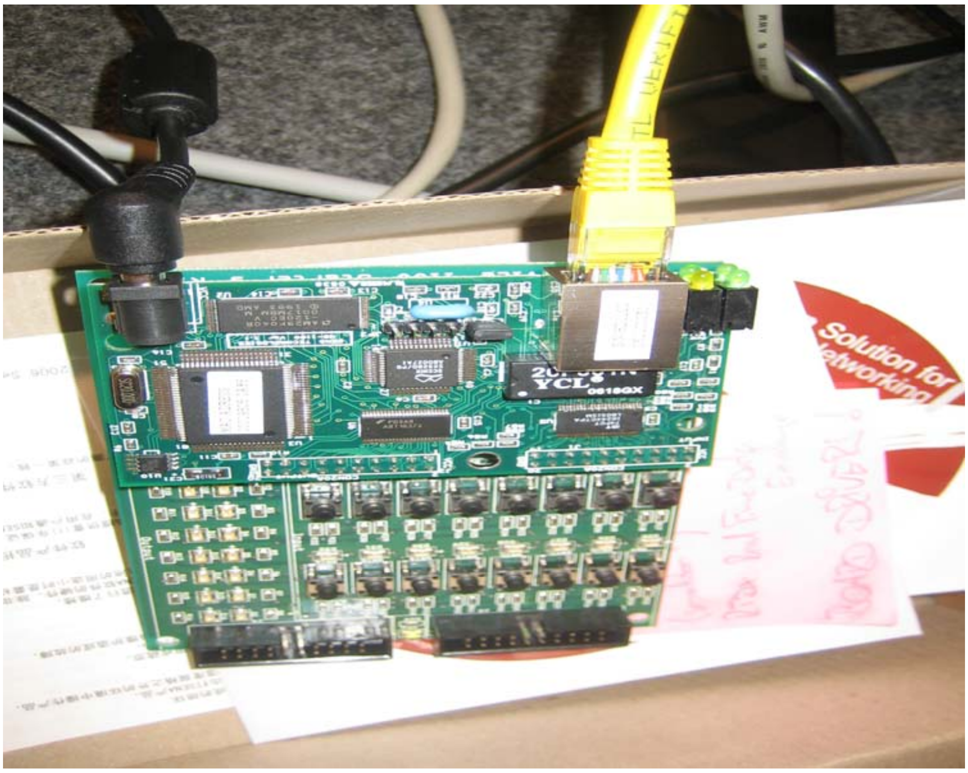


Figure 4.5: Electrical Control Circuit

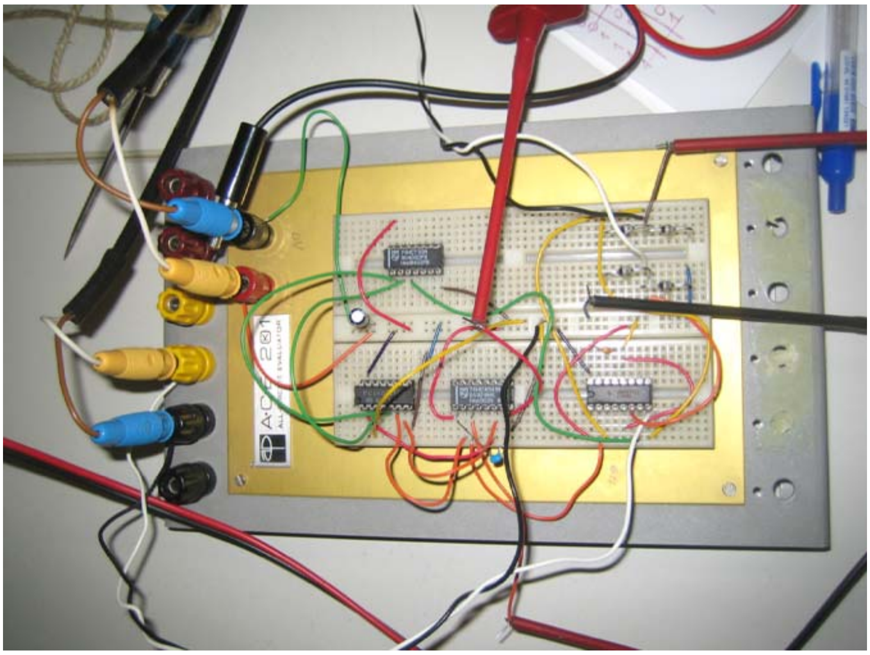


Figure 4.6: Electrical Circuit Board

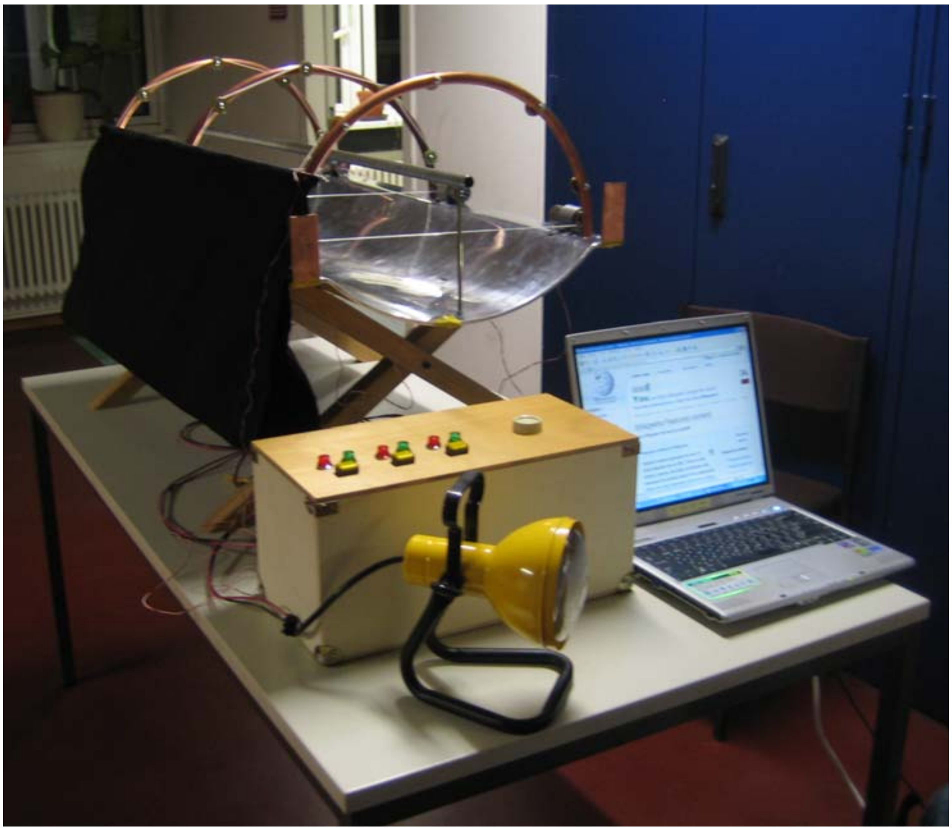
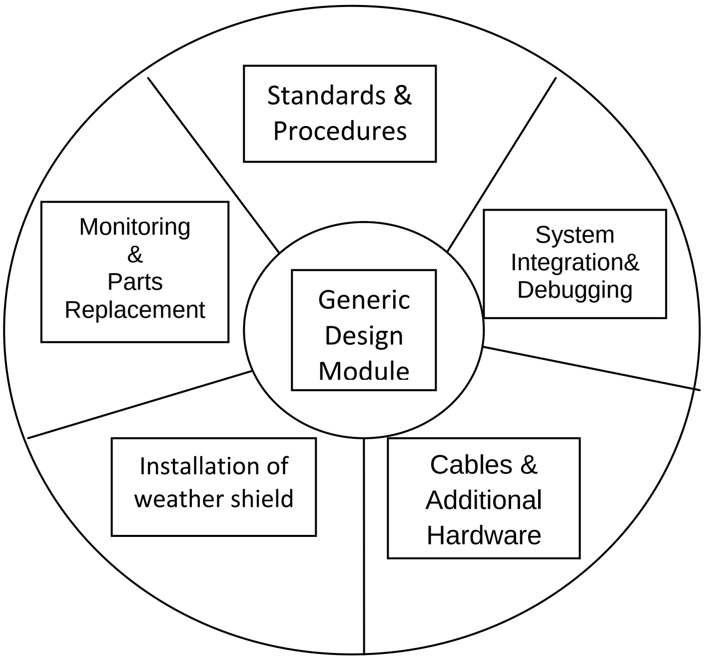


Figure 4.7: Demonstration Prototype

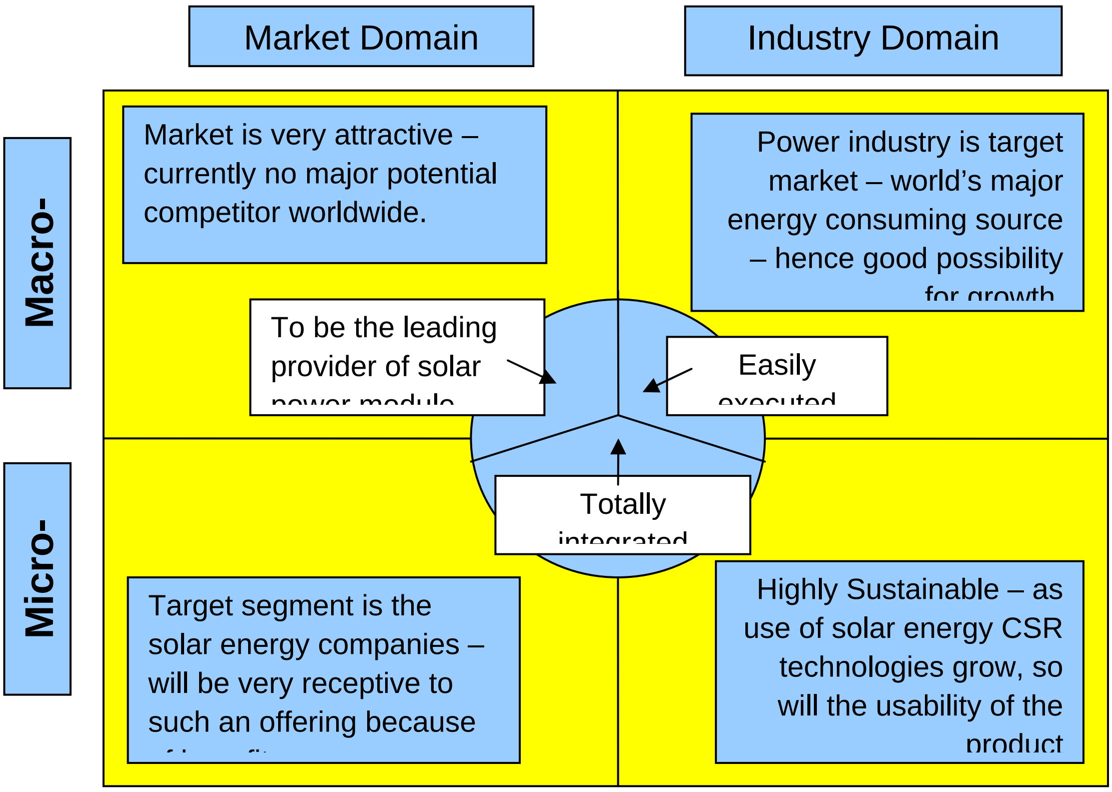
APPENDIX A5: BUSINESS CASE

A5.1. Assessing The Business Potential:

1.) HelioWorks' **Product offering** for electric utility companies



2.) **Mullin's Assessment Framework** for Product offering: Team Domain – Power Infrastructure



3.) **Defining the Opportunity Space:**

Using communication technologies combined with the personnel and integrating components that provide a long-term platform to solar energy arrays used for power generation, HelioWorks' product offering is also a kind of framework on which a solar-energy utility company can develop any solar arrays for. The resource is an integrated network that links power distribution and monitoring as well as several provides a fast data sharing concept model.

The team estimates that there is a latent demand in the solar energy provider market for protection of delicate solar system arrays in Concentration Solar Reflector (CSR) panels/troughs from weather elements and a simultaneous method for early fault detection so that the latter can quickly be remedied before causing total breakdown. In the event of breakdown, it would provide data for pre-determining the faulty part and help in replacement. Thus it would also enable closed loop economy by allowing only that part to be replaced/reused instead of total replacement.

4.) **Determining the optimal value-capture vehicle for the team's product offering**

Defining Intellectual Assets as something that the company (WIT) will possess as a direct result of its employees' intellectual property shared under employment and complementary assets as those that would be required to sell products (factory infrastructure, distribution capability, etc., Team HelioWorks has determined the following for its product:

Complementary Assets Position:

	Specialized	**Generic**
Intellectual Asset Position: **Strong**	**Partner with Complementary Assets holder** (such as power companies whose solar power modules would require the internet-ready weather protection and fault detection for closed-loop economy)	**Strong New Business Potential** (as demand for clean energy grows and Solar CSR Technology improves)

Ref: Intellectual Asset Strength Summary – T. Faley, 2007

A5.2. Project Finance Methodology Summary:

There are three steps to the financial analysis of your projects:

- Cost Assessment
  - Steady-state analysis
  - Make sense / seem reasonable?
    - Yes – move on to cash flow look
    - No – revise or kill the project
- Cash Flow
  - Dynamic analysis
  - Need to add cash flow line for the DEVELOPMENT costs for our technology/product. How much money over how much time. This will help create the "cash flow hole." (Without such a up-front investment, the project looks suspect.) The costs in the "cost assessment" look are the on-going maintenance, continuous improvement, etc. costs.
  - Break-even analysis (when does cumulative cash flow cross zero—undiscounted basis)
    - 3-5 years for software
    - 5-7 years for hardware
  - Seem reasonable?
    - Yes – move on to "Valuation" look
    - No – revise or kill the project
- Valuation—Financial Return Assessment
  - Corporate projects
    - NPV (Net Present Value); discounted at WACC
    - Calculate WACC
      - WACC= (% Debt*Cost of debt*(1-tax rate)) + (% equity*Cost of equity)
      - Look at Debt-to-Equity of our company or other similar companies in the same technology space to get an estimate for this value
      - Get estimate of corporate tax rate (from other similar companies in our space, or guess timate and markup by 45%)
      - Cost of Debt.
        - 10-year Treasury bond is a decent estimate of this. Wall Street Journal reported this to be 4.6% on 4/3/07. But this is near historic lows…. Can boost it to 5%. Rationalize the guesstimate.
        - Return on Equity. Two methods to estimate
          - Best method. Look at shareholder return for other public companies in our field for the last five years. Use this (or a deviation of this) figure.
          - Okay method. Stock market generally returns 7% above the long-term debt number. Stable-performing commodity companies may be lower, "riskier" businesses may be slightly higher. (This has to do with the stock "beta," but this is beyond the scope of this course.) Rationalize our estimate.

- Valuation—Financial Return Assessment (Contd.)
    - Startup assessment
        - IRR (Internal Rate or Return) for investors
            - Find comparable public companies
                - Determine Equity Value
                - Calculate Enterprise Value
                - Discount by 30% (since we are comparing a public company to a private company)
                - Calculate the EBITDA-to-Enterprise Value ratio
                - Calculate our companies estimated EBITDA in year five of operation
                - Calculate our company's enterprise value in year five using this ratio
                - Plug this Enterprise value into the spreadsheet to calculate the pre-money values of our company.
                - Based on the investment needed, calculated the funding schedule of the company (WIT).
                - Based on this % ownership and the exit value of our company (year five enterprise value), calculate the IRR for the investor.
                - Note if multiple investments are required (likely), then use venture capitalist- Jim Price's cap table spreadsheet. The intermediate pre-money values can be determined from the intermediate values of the pre-money valuation table spreadsheet.
                - NOTE: Clearly VCs have other methods (largely experiential-based) which we are **simulating** with the evaluation table spreadsheet. We understand that NO one actually uses this method (more of a post-valuation reality check).

A5.3. Project Detailed Financial Analysis Workbook:

Detailed Financial Analysis is embedded in the following file (Double-left click to Open):

Team3-Detail
Financial Analysis-GPI

Team3-Detail Financial Analysis-GPD2007.xls

The analysis is prepared from learnings in the course :UMICH COE, ENGR 599: Entrepreneural Business Fundamentals for Engineers and Scientists