SILICA ADDED VALUE & APPLICATION IN SOLAR CELLS MANUFACTURING

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PART I
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APPLICATION IN SOLAR CELLS MANUFACTURING

PART I
VALUE ADDED TO SILICA-SAND AND QUARTZ

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1- GENERAL INTRODUCTION

Why Silicon Technology is a Must for Egypt !

Silicon Technology is the back bone for most electronics including photovoltaic solar cells and micro electronic components used for telecom, automotive electronics, military equipments, and others.

Row Materials (silica-sand and quartz) are available, with very high purification, in Egypt.

Strategic Planning for future expansion in manufacturing micro electronics, with application in several industrial developments.

Huge Market is available in Africa and Middle East.

Minimizing Technology Gap with western countries.

International Recognition with ability to cooperate world-wide in "high-tech" electronic's applications.

Enhancement of Egypt Economy and Employment.

Educate New Generations on state-of-the-art technologies and enhancement of higher education to world wide.

Egyptian Society of Engineers- February 19, 2017
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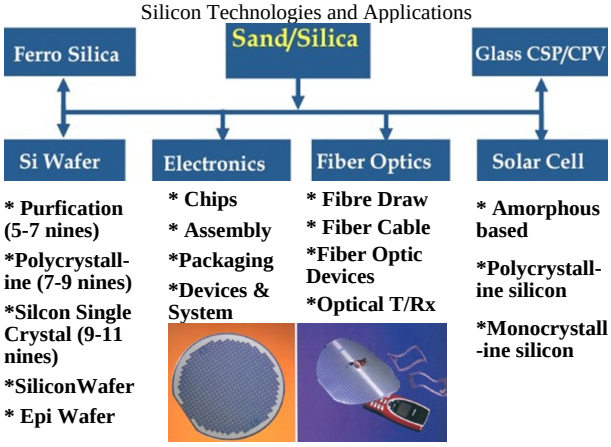
Silicon Technologies and Applications



Application of Silica-Sand and Quartz in Generating Electricity

• During the past half century, advances in application of silicon as light detectors has stimulated interest in using such detectors in transferring solar light/energy into electricity.

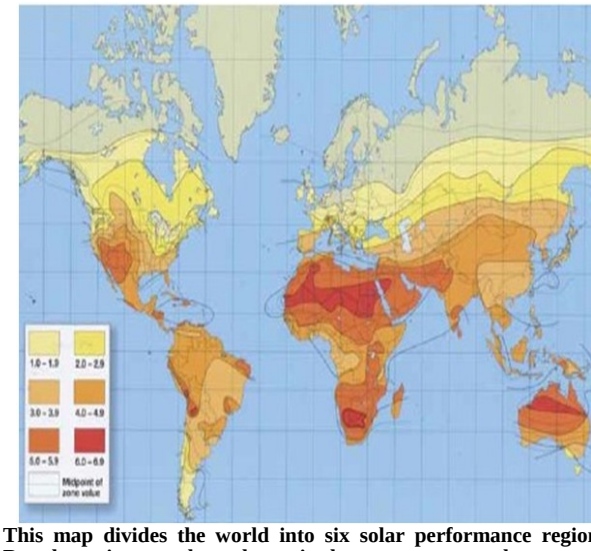
• It is known that silicon is mainly extracted from silica-sand and quartz, which are available with high degree of purification in some middle east countries, mainly Egypt.

• Also, it is known that by year 2050 the production of electricity from gas and oil will not be enough to cover more than 30-40% of the energy needed worldwide.

• Recent innovation in silicon technology has resulted in simple and cheap processing techniques for manufacturing solar cells.

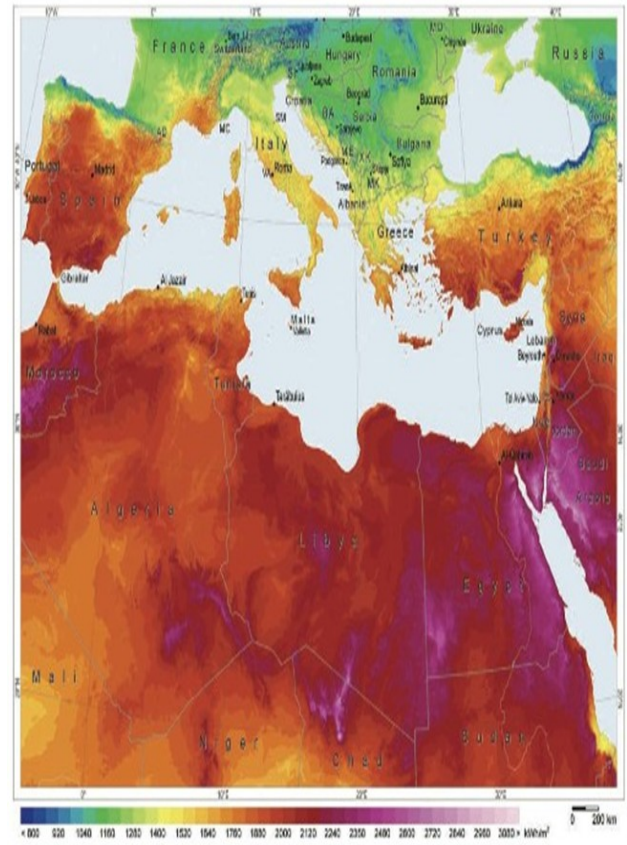
• Based on what mentioned above, the manufacturing and application of solar cells to generate electricity in Egypt is a must, because of the available valuable free resources; sun energy and pure silicasand/quartz.

Winter Peak Sun Hours



This map divides the world into six solar performance regions Based on winter peak sun hours in the worst case month.

Direct normal irradiation potential (KWh/m^2) for the Mediterranean area (http://solargis.info.



The Impact of Silica-Sand and Solar Energy on Egypt Economy

• Electricity generated by silicon solar cells can be much cheaper than that generated by oil or gas, and even cheaper than electricity generated by atomic power stations, because of the expensive maintenance fees for atomic power station.

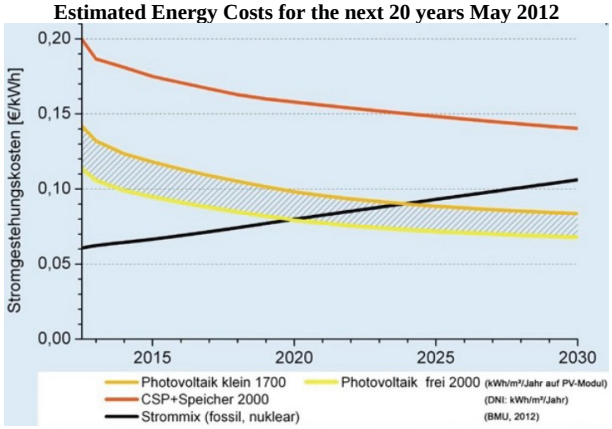
• Also, because of the solar irradiation in Egypt is the highest worldwide, and can be double the irradiation in Europe, the generation of electricity using solar cells in Egypt will be much cheaper (about 50% less) of that generated in Europe, using the same type of solar cells.

• We can not imagine that the sale price of one ton of silica-sand, which is exported for less than $20 USD, will be sold after treatment, purification, and processing in silicon wafers for about $2000 USD, before used in manufacturing solar cells or electronics.

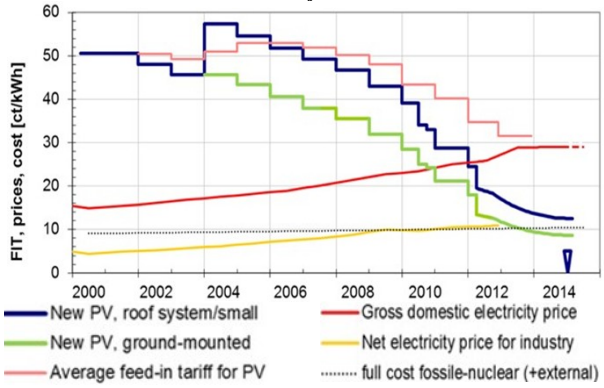
• The manufacturing of solar cells and using them in large size solar farm in Egypt can also enhance

the national economy by massive generation of electricity and exporting it to Europe.

Estimated Energy Costs for the next 20 years May 2012

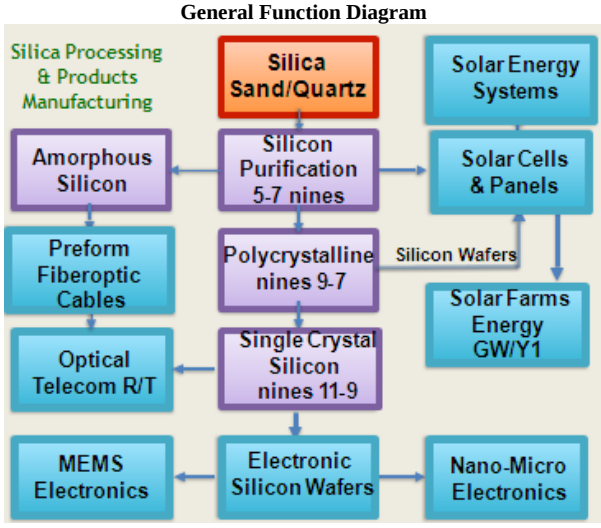


Actual Energy/Photovoltaics Cost Analysis for Past 15 years January, 2015



2. VALUE ADDED PROCESS TO SILICA-SAND AND QU0QUATRZ

General Function Diagram



How to Add Value to Raw Silica-Sand and Quartz !!!

A- ***Washing, Crushing and Milling,*** then purification can be conducted after that.

B- ***Silicon Extraction*** of low grade silica quartz (which has high impurity levels) by mixing it with carbon and other ingredients then heating the mixture to 3000°C in a melting furnace to produce low-grade **metallurgical grade** (MG) silicon metal (98%-99.99% pure metal).

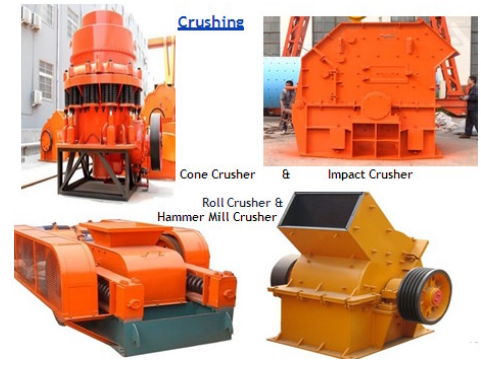
C- ***Silicon Metal*** is then further purified via an expensive, complicated process **(Siemens method)** to create **poly-silicon** metal (99.99999% pure metal) used to make photovoltaic cells used in solar panels. The Siemens process is used for the production of poly-silicon, by **gasification of metallurgical-grade** ***(producing trichlorosilane = HsiCl3),*** distillation, and deposition of ultrapure silicon.

D- ***Multi-Crystalline Silicon*** is made by melting poly-silicon in a large square quartz crucible. When it is cooled an ingot of **multi-crystalline silicon** metal is produced. Depending upon requirements these ingots can weigh up to 1200 kilograms.

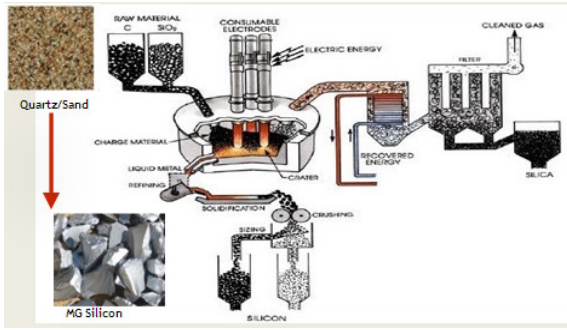
E- ***Mono-Crystalline Silicon*** is made by melting poly-silicon in a round crucible. A small piece of silicon metal is dipped, as a seed, into the molten poly-silicon and withdrawn slowly while rotating. This process is the Czochralski Process.It produces a large round cylindrical ingot that is a **single crystal** of silicon.

A- Washing, Crushing & Milling

Sandwashing

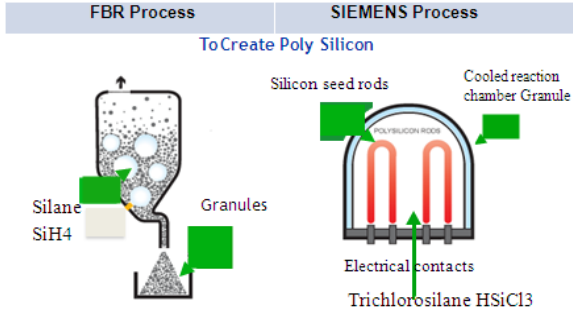


B- Silicon Extraction



Metallurgical Grade Silicon Factory

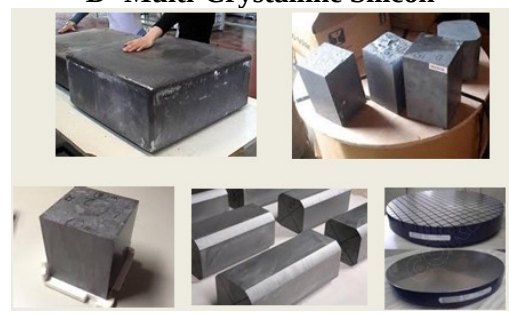
C- Silicon Metal



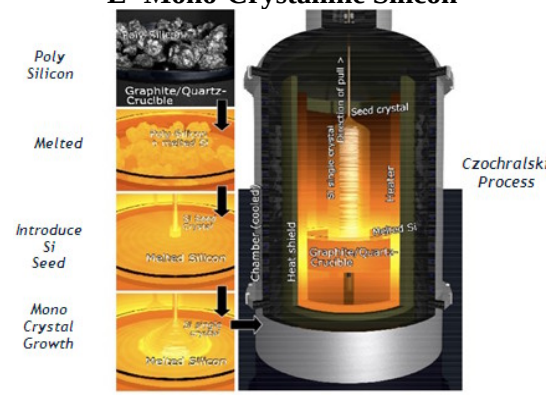
Schematic diagram of the traditional Siemens and the modified Fluidized bed reactor (FBR) purification process

The Siemens process, which is used by most of the industry canbasically be described as superheating silicon gas and seed rodsinside a giant refrigerator. In this method, a **gasified siliconcompound**, being either silane gas (SiH4) or trichlorosilane(SiHCl3) is released into a superheated chamber that containsseed rods of silicon. The **heated gas deposits pure silicon** onthese heated rods, and at the same time the chamber walls needto be cooled in order to avoid silicon deposition on them.Obviously, this process has a large fraction of "unproductive"energy consumption per unit of silicon produced.

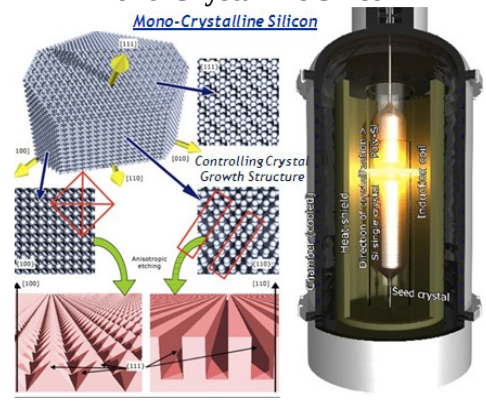
D- Multi-Crystalline Silicon

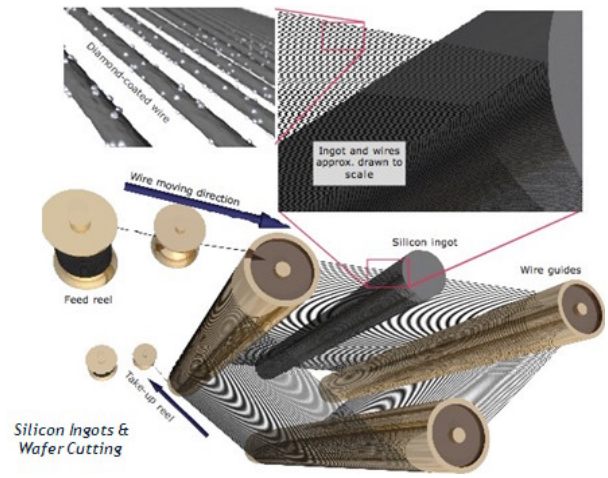


E- Mono-Crystalline Silicon

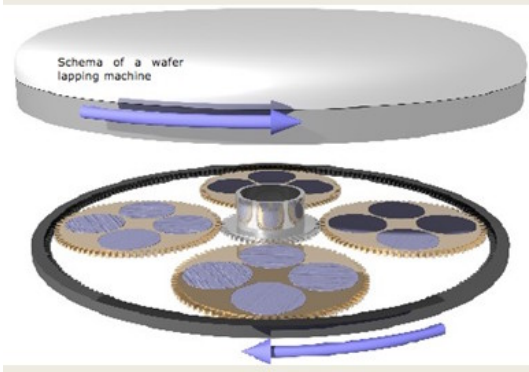


Mono-Crystalline Silicon





Wafer Preparation and finishing



3. IMPORTANT FACTORS TO SILICA ADDED VALUES

• Value added can be maximized through the transfer of state-of-the-art technologies in collaboration with worldwide leading companies in this field, in a joint venture and/or partnership.

• It is important to use advance value added to silica-sand/quartz in order to maximize the benefits to the country' economy and for future developments

• Value added can improve ROI by at least 300-500%, with minimal expenses.

• It is intended to process very large quantities of pure silicon for daily export and for local manufacturing of silicon photovoltaic solar cells

• In latest phases of value added process, very high purification of silicon wafers can be processed for manufacturing micro/nano electronic.

• Maximizing the value add to silica-sand and quartz for broad spectrum of applications would be a major focus, to maximize the investors ROI.

4. SUMMARY ON VALUE ADDED PROCESS

The proposed value added process has five major phases:

Phase I:

Mining and extraction of Silica-sand and Quartz Ore

Washing and Crushing to different sizes based on the application Milling of high percentage of the crushed quartz silica to various particle size.

Phase II:

Processing of crushed silica quartz to Metallurgical-Grade Silicon at 3000^{o}C and with purification up to 99.99%.

Phase III:

Processing of metallurgical-grade silicon to Poly-Silicon metal (99.9999% pure metal – by Siemens method) used to make photovoltaic cells, used in solar panels.

Phase IV:

Processing of poly-silicon to Multi or Mono Crystalline silicon ingots, by melting then casting or by Czochralski techniques, respectively, then wafer dicing and preparation.

Phase V: (Application to PV -WHICH IS PART II OF THIS PROJECT)

Application to solar cells and microelectronics manufacturing.

Purification requirements for solar cells and electronics applications:

Element	Metallurgical-grade silicon (ppm)	Poly-Solar-grade silicon (ppm)	Multi-crystalline solar-grade	Electronic grade (ppm)
Si content	99	99.9999	99.999 99	99.999 999 999
Fe	2 000–3 000	<0.3		<0.01
Al	1500–4 000	<0.1		<0.0008
Ca	500–600	<0.1		<0.003
B	40-80	<0.3		<0.0002
P	20-50	<0.1		<0.0008
C	600	<3		<0.5
O	3000	<10		
Ti	160-200	<0.01		<0.003
Cr	50-200	<0.1		

Common types of quartz are typically sold for USD $20 – $50 per tone, and by little more value added they can be sold for USD $20-50/kg (not tone) and more.

High purity quartz, which has purity of greater than 99.7% silica (SiO2), is a very rare form of quartz, but, it is available in Egypt's quartz ore.

Based on the proposed phases, for a comercially viable ROI,the processing capabilities for each phase can be as follow:

1 Quartz Crushing/Milling (tons/yr **out**) 150000

2 Metallurgical Silicon (tons/yr **in**) 15000

3 PV Silicon Refinement (tons/yr **in**) 10000

4 Ingot/Wafer Processing (MW/yr) 2000

5 Cell & Modules Processing (MW/yr) 2000

• A new company can be established focusing on the first and second phases.

• The capital needed is $15 million USD.

• A full "Execution Plan" has to be prepared including all fab designs, equipments, supplies, technical and operation teams, staff training,daily operation regulations and costs. The "**Execution Plan**" has to be executed in collaboration with a first class organization in the field.

• A highly qualified team of expert would be selected in collaboration with the foreign company, in a joint venture or partnership

5. OVERVIEW OF A VALUE ADDED BUSINESS PLAN

Until an accurate "Business Plan" is completed, we can explain the economic benefits of the value added on ROI in a simple way by a comparison of the market prices before and after the value added process is completed, as follow:

• PV process requires quartz nuggets in a size of 10-80 mm, as resulted by crushing - prices are **$25-40 USD per ton.**

• Metallurgical Silicon prices are about $2 USD per kg (**$2000 per ton**)

Quartz powder is used for different applications such as glass production etc:

• Prices vary from $40.00 USD/ton to **$3000.00 USD/ton (for nano particles)** depending on final grain size after milling.

• A typical value would be **$500 USD/ton for a 30-40 micron** grain size.

To maximize the value added to silica quartz, the material has to be processed all the way to manufacturing of solar cell panels.

This is an example on value added by establishing a solar cells manufacturing plant, having annual production capacity of 200 MWp

• This requires processing 2000 ton of silica quartz ore, which is sold as raw material for about total $60k USD.

• The Plant is used to establish 200 MWp solar farm every year.

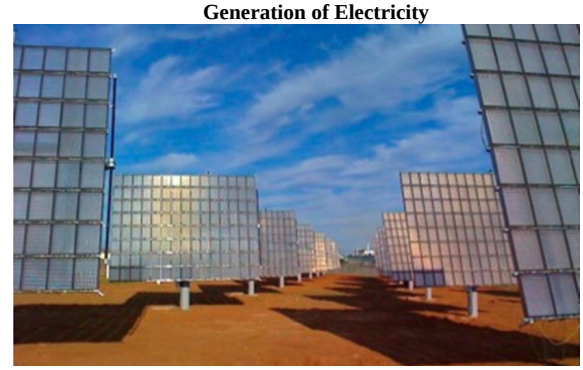
• This farm produces 200 MW electricity every hour exposed to sunlight

• Total number of sunlight' hours per year in Egypt >3000 hours.

• Therefore, the total generated electricity per years is 600 GW.hr

• Annual revenue of the generated electricity **$60-70M/Y (for 30 years)**

Solar Cells and Solar Modules Used in Solar Farms and Generation of Electricity



PART II
APPLICATION IN SOLAR CELLS MANUFACTURING

PART II
SOLAR CELLS MANUFACTURING

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1. EXECUTION PLAN OF MANUFACTURING FACILITIES

• Time Required for the execution of the plan to

establish all the solar cells manufacturing facilities is 2.5 to 3.0 years.

• Advance technologies will be transferred by a world class industrial company, through a joint venture agreement.

• Total capital investment, for the full execution of the plan, for the Solar Cells Manufacturing from sand to electricity, is about **$200M**, with annual production capacity of 200MWp solar modules, as well as the establishment of a turn key Solar Farm as a model with energy 10MWp.

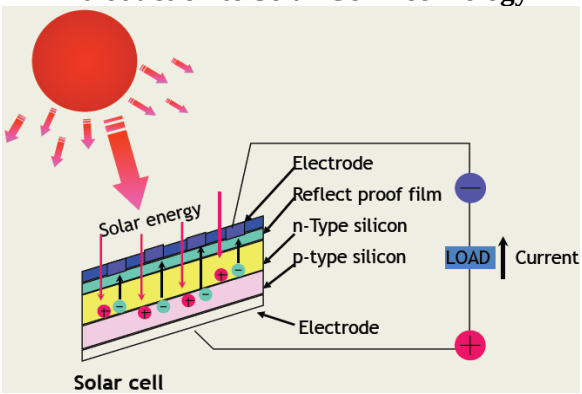
• Authorized Capital is **$20M**, and the Start-up Capital **$5M**.

• Fund raising after that will continue by offering shares at a price **$1000** USD per share, for local and abroad Egyptian and Arab investors.

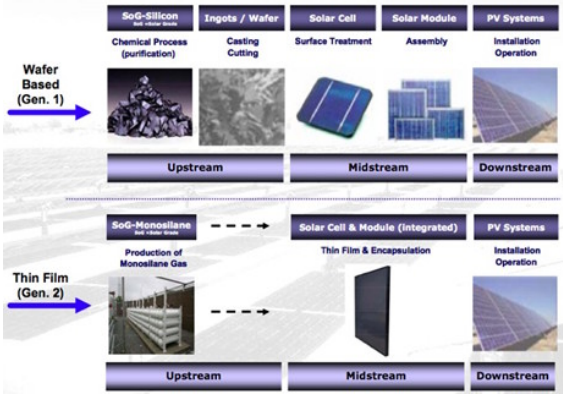
• Total land required for all the manufacturing plants is about **30- 40 acer**,and the land required for the Solar Farm of 10MWp is in the range of **20 acer**.

2. SOLAR CELLS MANUFACTURING AND SOLAR ENERGY APPLICATION

Introduction to Solar Cell Technology



COMPARISON WAFER BASED & THIN FILM PV VALUE CHAIN (Gen. 1 &Gen. 2)



3. WORK PLAN

SOLAR CELLS MANUFACTURING

The Plan is aiming to establish five major manufacturing plants:

1. Plant for silica/quartz milling and Metallurgical Silicon and purification up to 5-7 nines.

2. Plant for ingots and wafers processing.

3. Plant for mechanical and chemical wafer treatment.

4. Plant for manufacturing of solar cells and modules.

5. Plant for production of solar energy units

This is in addition to the establishment of a 10M Wp solar farm.

The Work Plan is designed in **three major phases.**

Phase I

For the establishment of a **10MW** solar farm, to be used as the energy/electricity source for all the manufacturing plants, as follow:

Phase IA: Install a 1MWp solar farm on a turn key contract with a world class company (industrial partner), for transfer of know-how.
Time 4 months, Budget $1.20M, land 2 Acer.

Phase IB: Training the Egyptian team members within the industrial partner's facilities.
Time 4 months, budget $300k (overlap with Phase IA).

Phase IC: Install the 9MWp (balance for the 10MWp) solar farm, by the trained Egyptian team, under the supervision of the industrial partner.
Time 10 months, budget $8.50M, land 18 Acer.

Phase II

Establishment of the plants 3, 4, 5, for the manufacturing of solar cells and modules, with annual production capacity 200MWp. This Phase includes; civil construction, ordering all equip-ments, training of the teams, and establish-ment of the quality control and testing facilities. Selected members of the team will be trained in the industrial partner's facilities.
Time 18 months (can overlap with Phase I), Budget $50 M, and land 15 Acer

Phase III

Establishment of the plants (1&2) for silica/ quartz milling of 2000MT, and metallurgical

silicon & purification up to 5-7 nines, with annual produc-tion capacity of wafers for 200MWp solar cells. This Phase includes; construction, ordering all equipments, training of the team, establishment of the quality control and testing facilities.

Time 24 months (can overlap with Phase II), Budget $140 M, and land 20 Acer

On-Grid PV Systems
2-D and 1-D Tracking


THE BREAKEVEN FOR ALL MANUFAC-TURING FACILITIES RANGES FROM OM 2 TO 3.5 YEARS.

Annual production capacity is 200MWp of solar energy modules and units ready for application in the field

• Total Capital for all manufacturing plants **$190 M USD.**

• Total land is about **40 acer** for all manufacturing facilities.

• Total land for solar farm of 1**0MWp** is about **20 acer** and total cost is about **$10 M USD.**

• Total time for full execution of the Plan including overlapping between projects **30-36 months.**

4. SUMMARY ON SOLAR CELLS MANU-FACTURING (BUDGET AND LAND)