STEPS Summer Interdisciplinary Team Experience

Solar and Wind Energy Three-Week Review

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CSUN College of Social and Behavior Sciences[3]

Overview

- Intro to Renewable Energy
- Economic Trends in Solar Energy
- Solar Power Conversion
- Solar Tracking Systems
- Solar Simulations and Testing
- Field Trip to Photovoltaic Plant
- Field Trip to SolarWorld Industries Factory

Overview

- Economic Trends in Wind Energy
- Wind Power Conversion
- CSUN Wind Generator and Testing
- GIS (Geographic Information System)
- Urban Planning Project (Solar Powered Bus Stop)
- Conclusion and Q&A

Renewable Energy

- Human beings need energy.
- All energy and matter on earth came from and is coming from the sun or something it created.
- All accessible energy comes from
  - Within the Earth: Geothermal Energy
  - The Moon: Tidal Energy
  - The Sun: Radiation, Wind, Hydro-mechanical, Biomass (Coal, Oil, Natural Gas, Plants and Animals)

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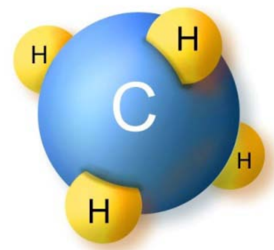
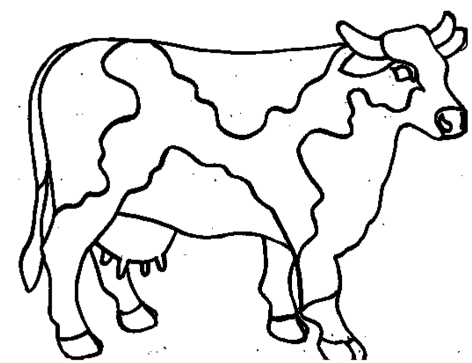
Renewable Energy



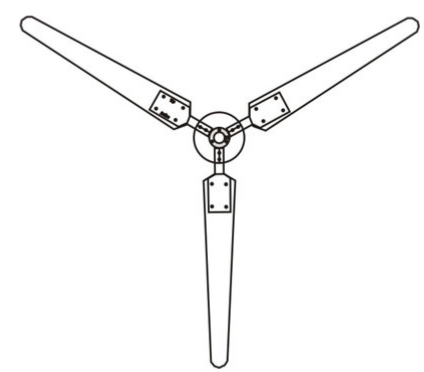
CARBON BASED FUELS



Biomass (Coal, Oil, Natural Gas, Plants and Animals)

Renewable Energy

- There are several ways to generate energy sustainably, without damaging the environment.
- The two that are predominant in the renewable energy market, and the two that this project has focused on, are Solar Energy and Wind Energy.



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Economic Trends in Solar Energy

- Advantages
  - Completely renewable and will not run out for billions of years.
  - No physical, chemical, or noise pollution.
  - Driving material is silicon, which is extremely abundant.
  - Very little maintenance.
  - Very cheap power.
  - Compared to other power generation methods, it is very simple and straightforward to implement.

Economic Trends in Solar Energy

- Disadvantages
  - Conducting material is silver, which is costly.
  - Does not generate at night, which usually requires expensive batteries.
  - Generates DC current, which usually requires expensive inverters.
  - Industry-wide maximum efficiency is only about 18%

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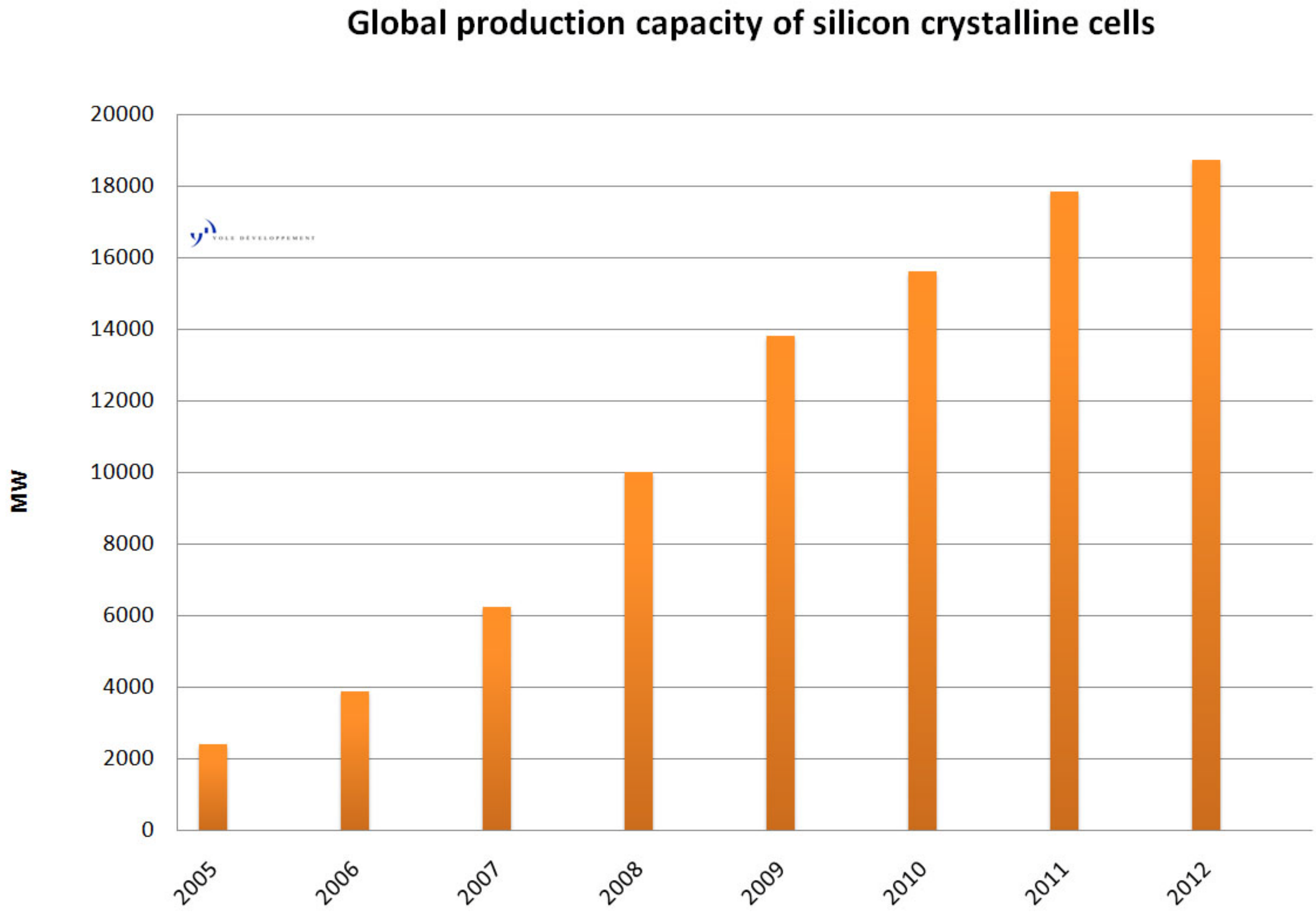
Economic Trends in Solar Energy



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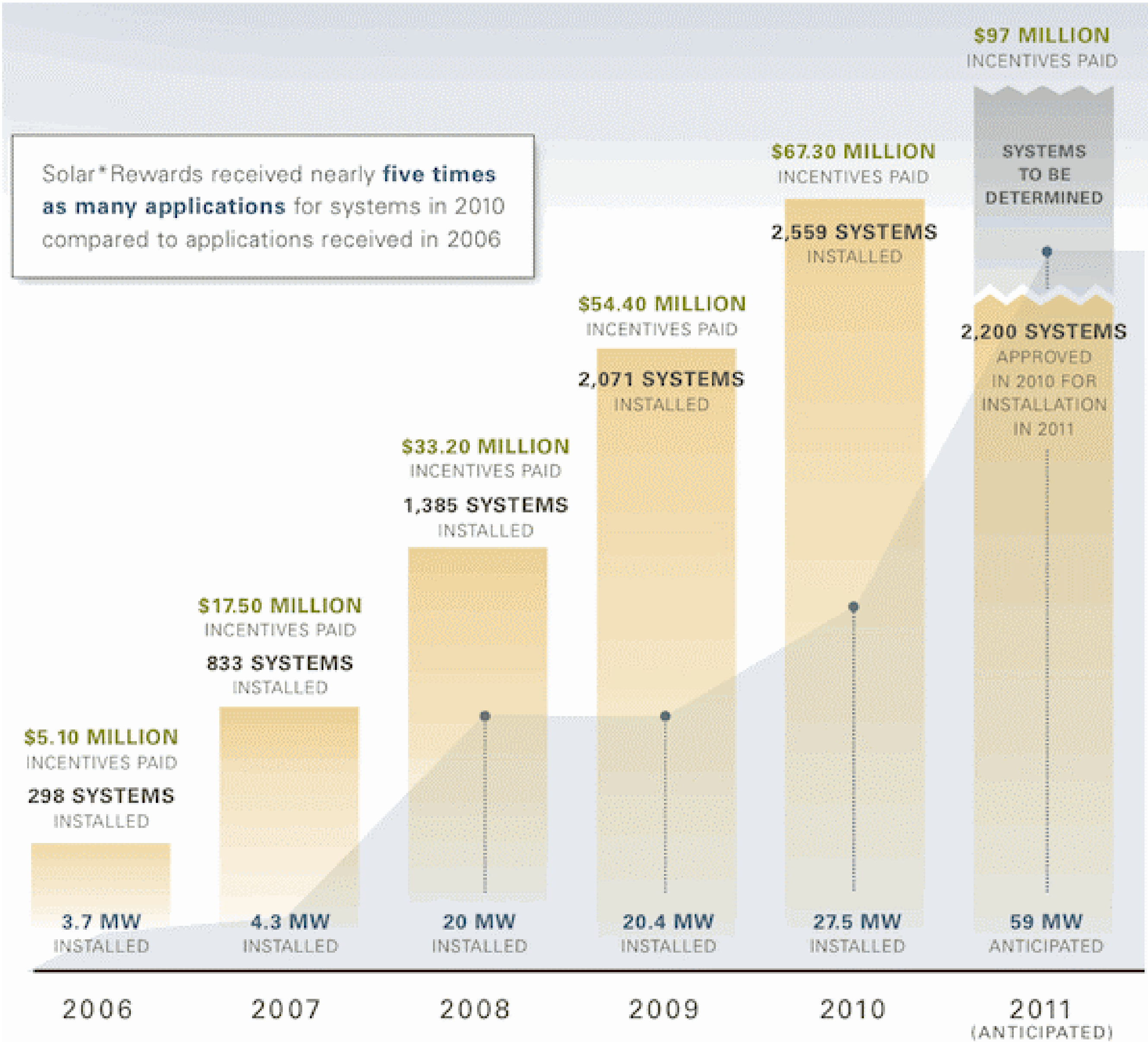
Economic Trends in Solar Energy



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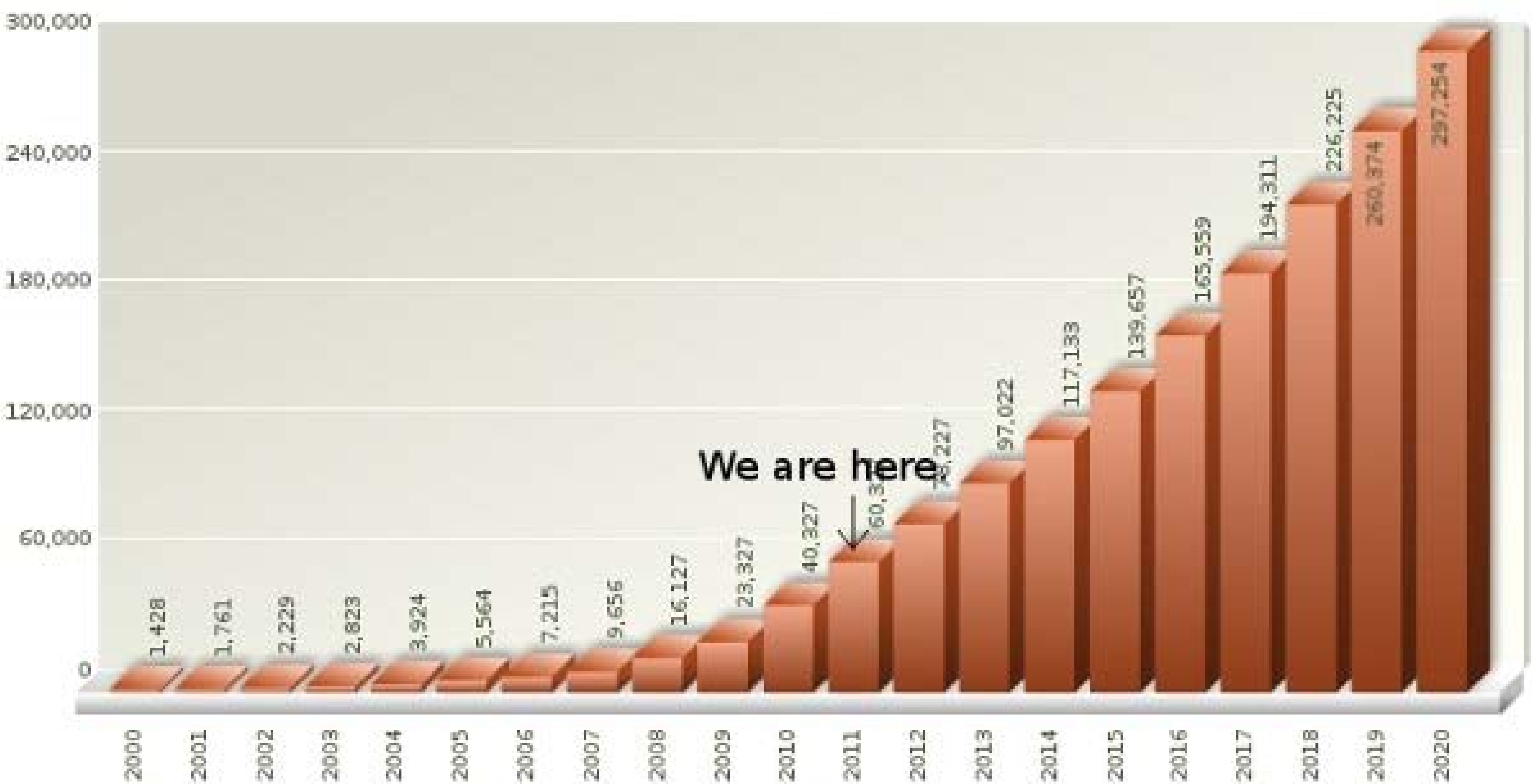
Economic Trends in Solar Energy

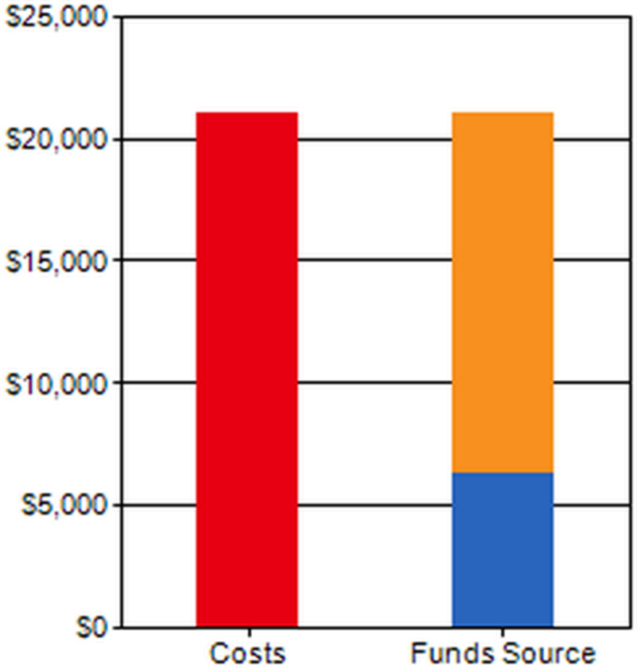
Cumulative Installed Photovoltaic Capacity (MW)



Economic Trends in Solar Energy

Method	Operation	Result	Unit
Average monthly kilowatthours used	Initial Value:	750	kilowatthour
Multiply by 1000 for watthours in a month	*1000=	750,000	watthours
Divide by 30 for total kilowatthours used in an average day	/30 days=	25000	watthours per day
Subtract watthours you will eliminate with conservation and energy efficiency	-6400=	18600	watthours per day
Multiply by percent of home to power with system	*100%	18600	watthours per day
Divide by maximum (June) solar insolation	/7.62 kWh/m^2/day	2441	watts
Multiply by 1.2 to cover system inefficiencies	*1.2	2930	watts
Divide by the peak wattage of the panel	/240 peak watts	12.2	panels
Round up to a whole number	round up	13	panels

Economic Trends in Solar Energy



Net system cost after incentives: $14,700

30% saved by Incentives from Total System Cost

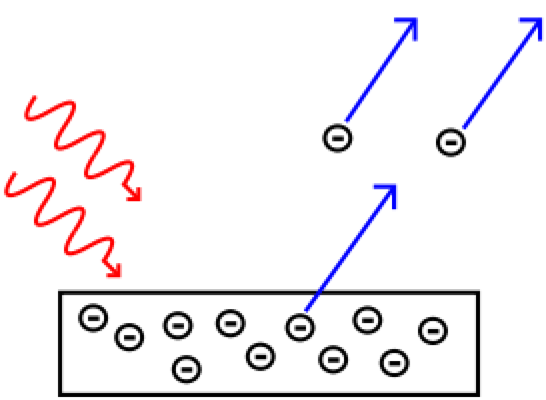
Total System Cost	$21,000
Rebate	$0
Tax Credit *	$-6,300
Net System Cost	$14,700

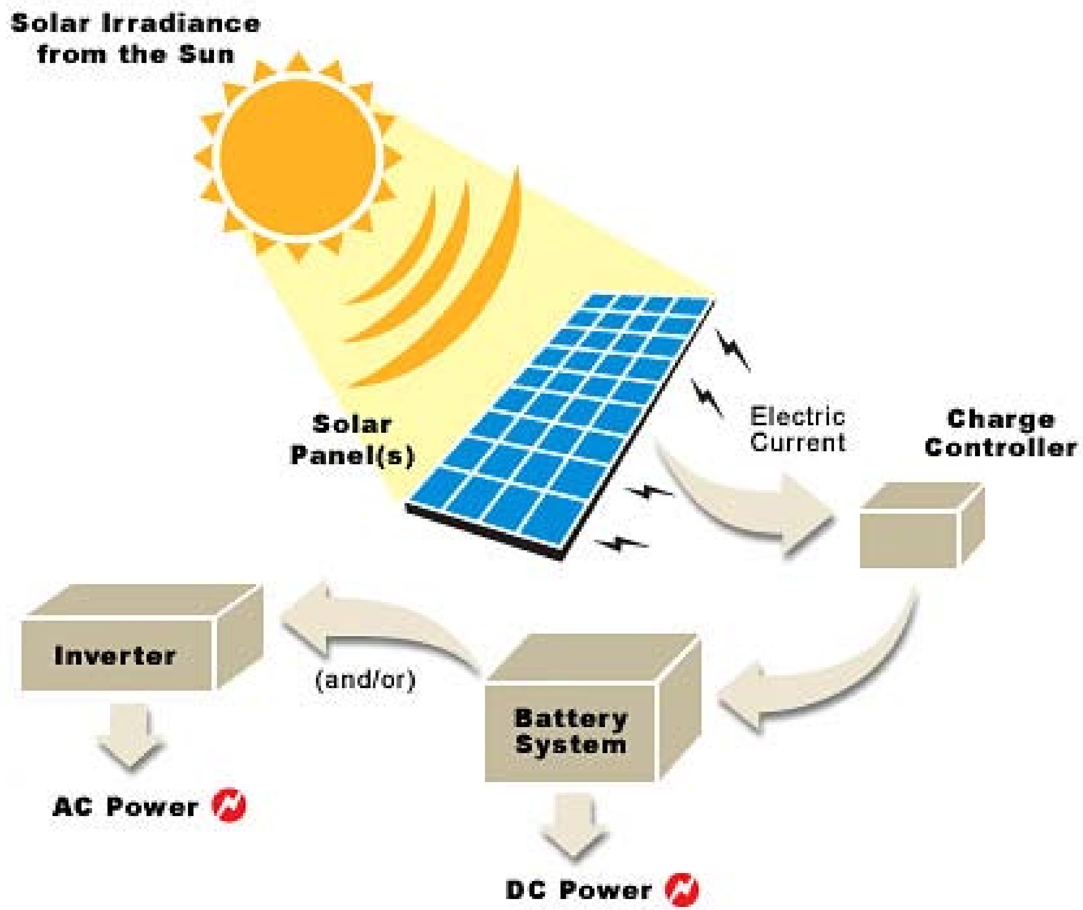
** This includes the Federal Investment Tax Credit (ITC). If your state offers a state tax credit, this amount is included in the Tax Credit amount. Please note that federal and state tax credits are calculated on the system cost minus any applicable rebate. Please contact a tax professional if you have further questions.*

ESTIMATE SUMMARY	
Net System Cost	$14,700
Monthly Cash Flow	$23/month cost
1st Year Electric Bill Savings	54% cost savings
Daily Output	11.8 kWh
Average Monthly System Output	358.7 kWh
Monthly Electric Bill	$46.04
Payback Period	14.0 years

Solar Power Conversion

Photoelectric Effect:
Energy from the sun in the form of electromagnetic radiation (photons, alpha particles, etc.) makes contact with electrons in the semiconductor material, which displaces them from their atoms. Photons decrease in their energy levels, and electrons increase in their energy levels.





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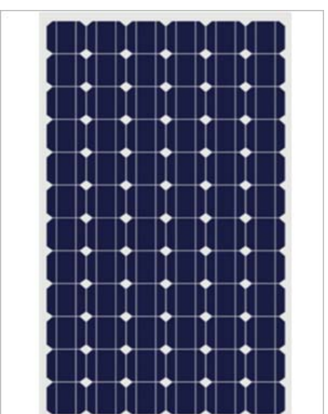
Solar Power Conversion

Different materials behave differently when exposed to photons, and most materials do not produce a voltage.

- Crystalline Silicon
  - Monocrystalline[1]
  - Polycrystalline[2]
- Amorphous Silicon[3]
- GaAS[4] (Gallium Arsenide)
- CIS[5] (Copper Indium diSelenide)
- CIGS[6] (Copper Indium Gallium Selenide)



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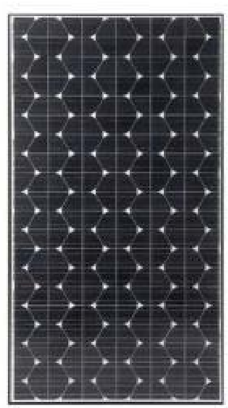

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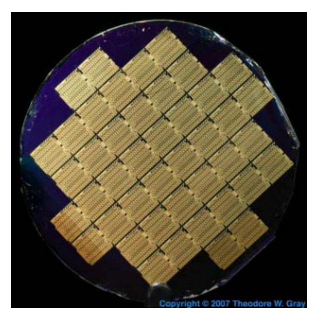

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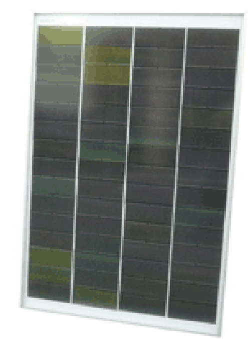

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Solar Power Conversion

A specifications sheet for a 235W solar panel manufactured by SolarWorld Industries, for commercial sale.

Sunmodule™

SW 235 mono / Version 2.0

PERFORMANCE UNDER STANDARD TEST CONDITIONS (STC)*

		SW 235
Maximum power	P_{max}	235 Wp
Open circuit voltage	V_{oc}	37.5 V
Maximum power point voltage	V_{mpp}	30.3 V
Short circuit current	I_{sc}	8.19 A
Maximum power point current	I_{mpp}	7.77 A

COMPONENT MATERIALS

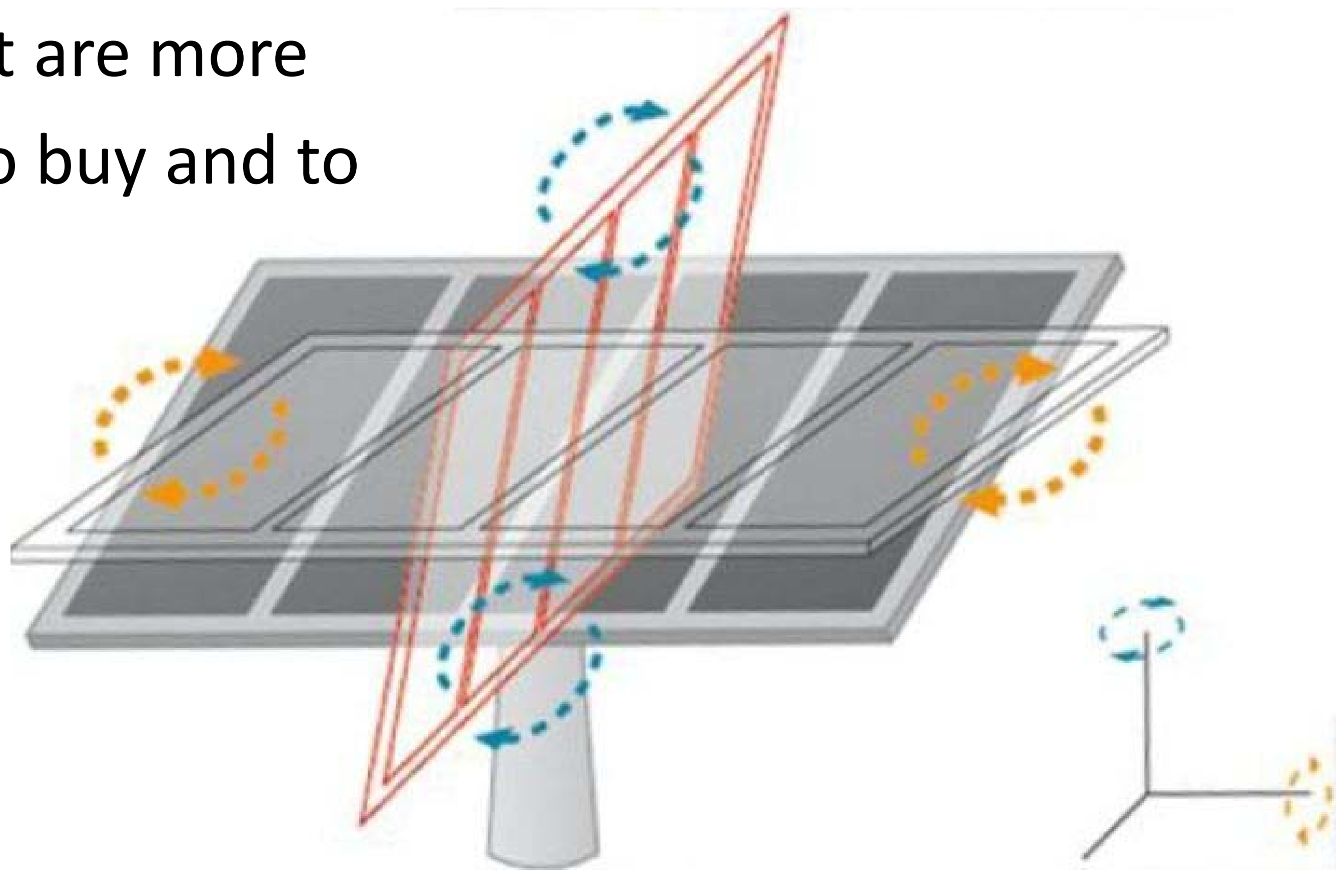
Cells per module	60
Cell type	Mono crystalline
Cell dimensions	6.14 in x 6.14 in (156 mm x 156 mm)
Front	tempered glass (EN 12150)
Frame	Clear anodized aluminum

Solar Tracking Systems

- A solar panel achieves maximum power when it is faced perpendicularly to the sun's rays.
- In order to achieve constant maximum power, solar tracking methods are used to keep the angle between the panel and the sun at 90^o constantly, through daylight hours.
- Trigonometric algorithms are used to calculate how solar panels should be positioned at any given moment, and that data is fed real-time to motors underneath the panel.

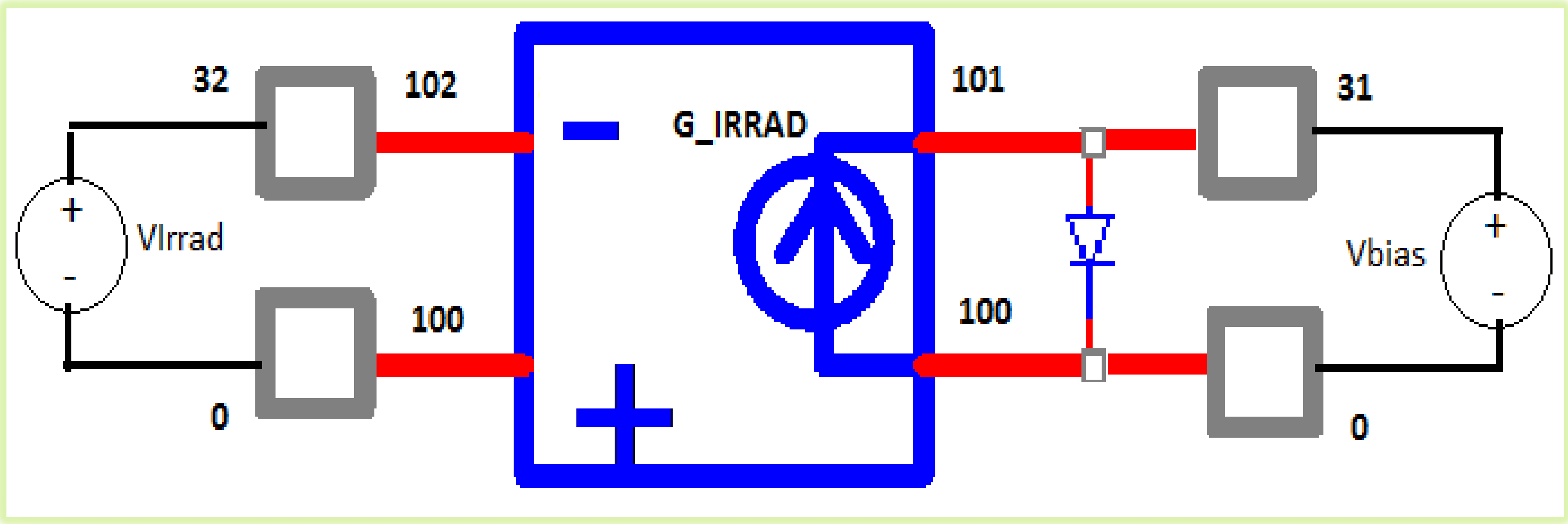
Solar Tracking Systems

- Trackers can be single-axis or dual axis.
- Dual axis trackers provide efficiency that single-axis trackers, but are more expensive to buy and to maintain.



Solar Simulations and Testing

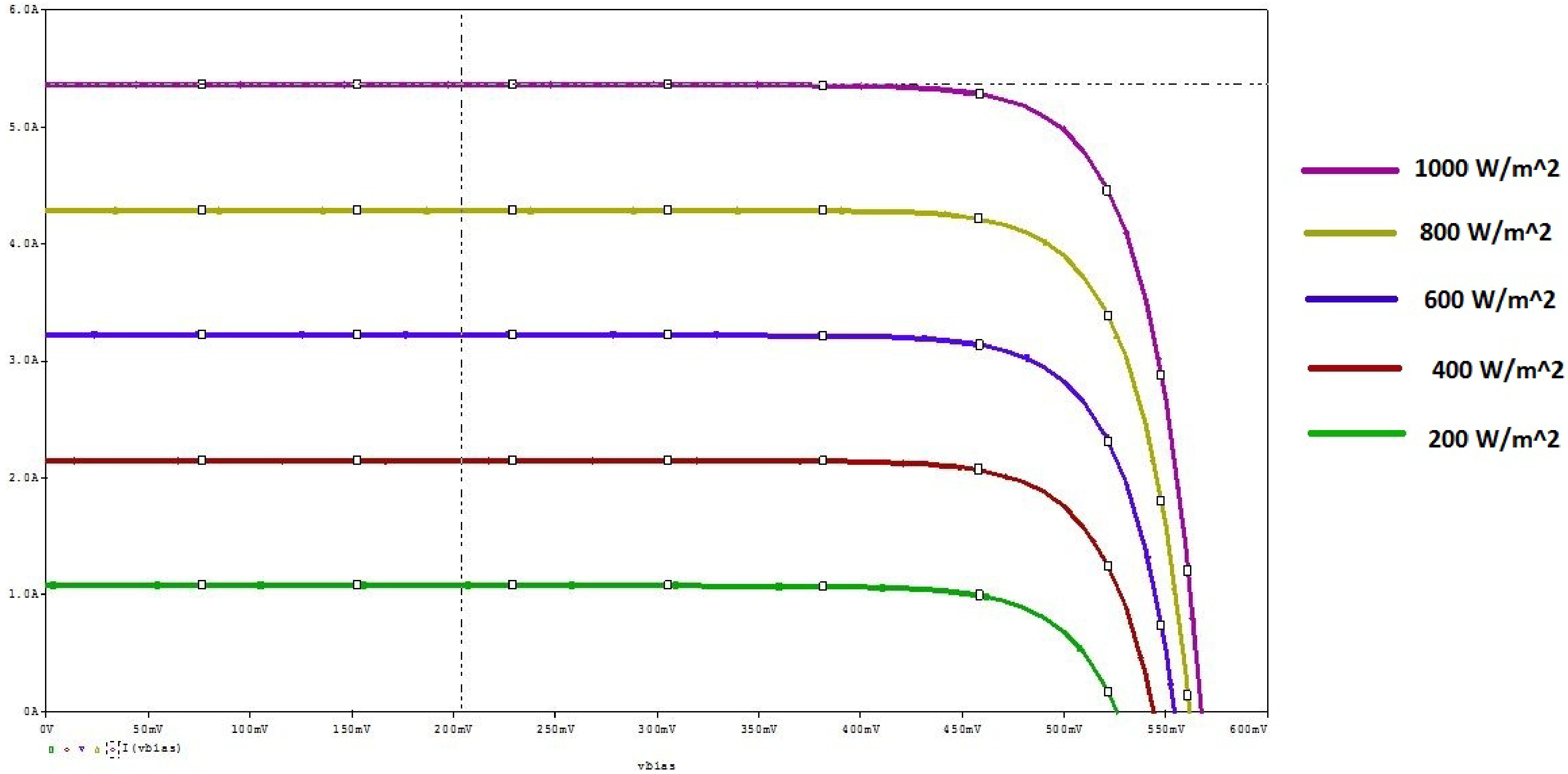
- PSpice simulation of a solar panel and Load.



Solar Simulations and Testing

IV Curves for varying Solar Irradiance Levels of a Simulated Solar Panel

Current (A)



Voltage (V)

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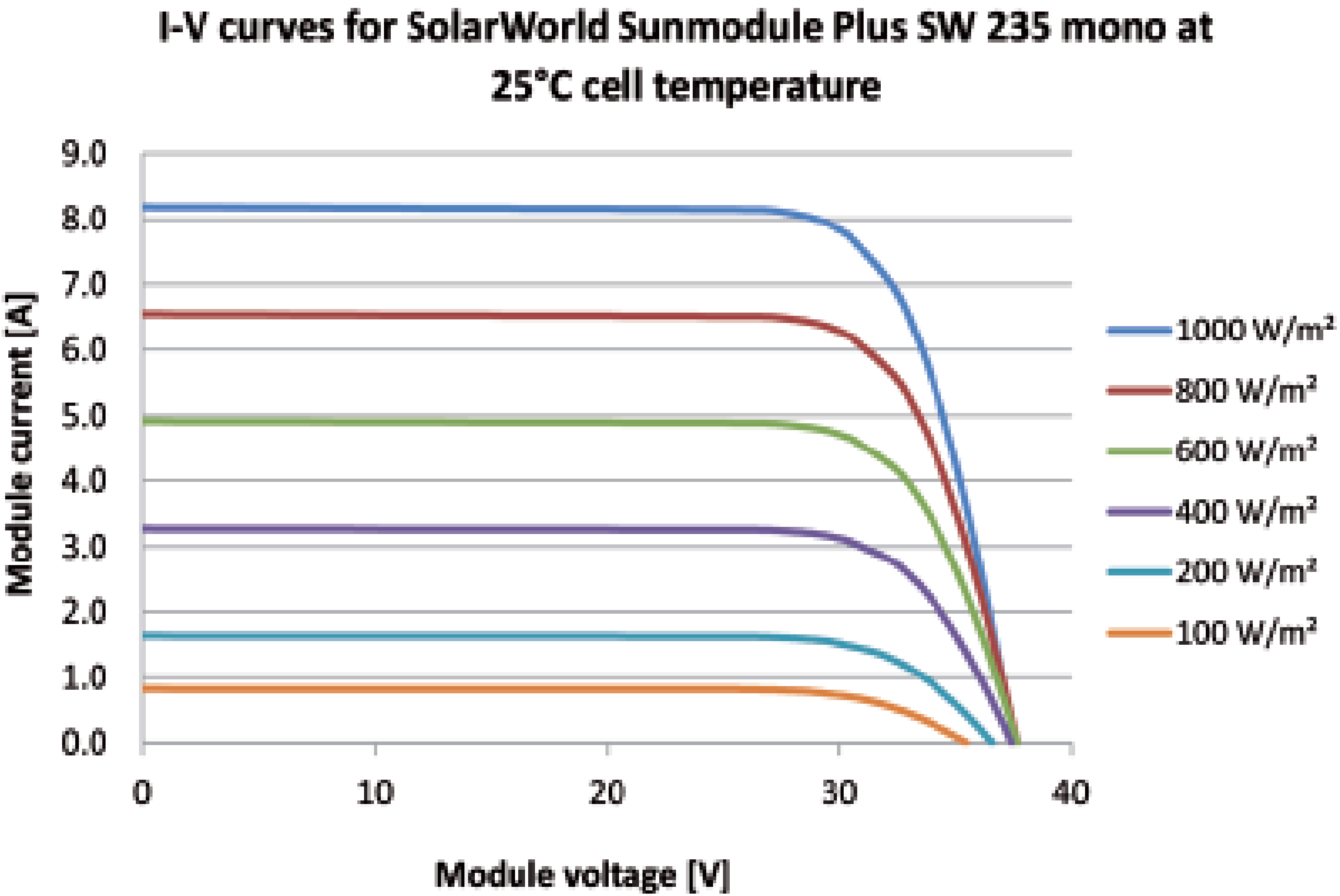
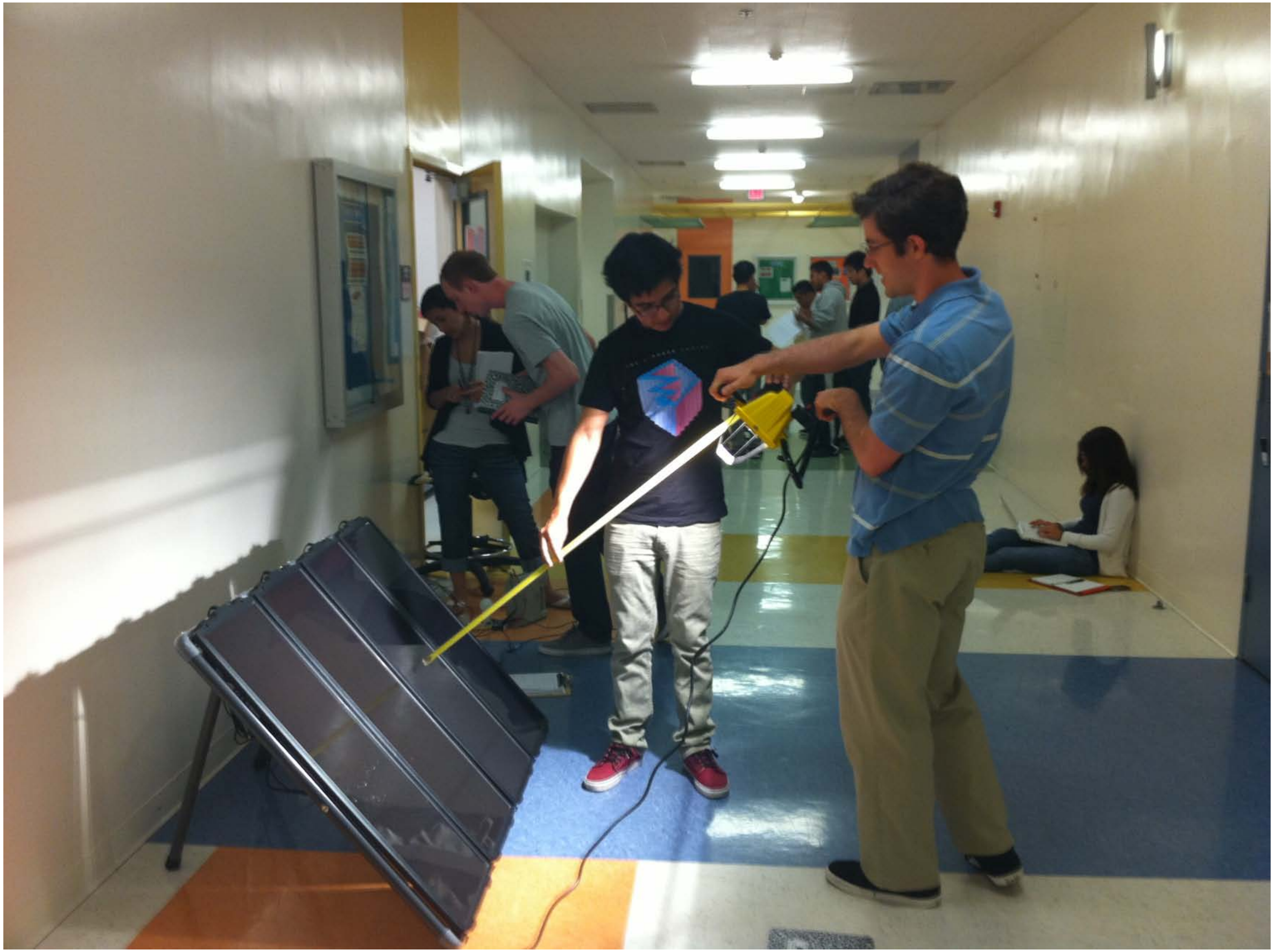
Solar Simulations and Testing



Solar Simulations and Testing



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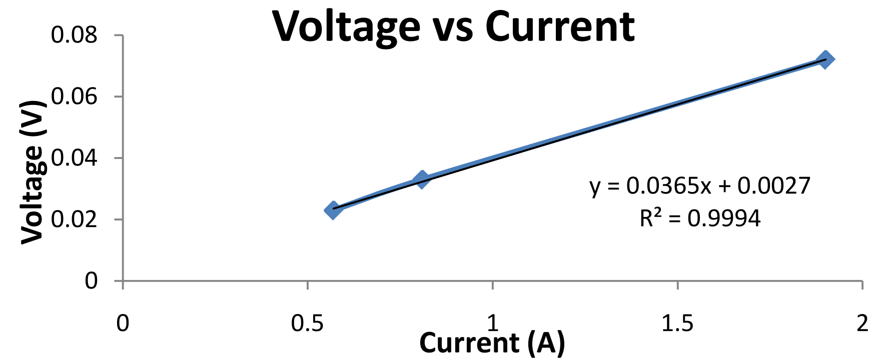
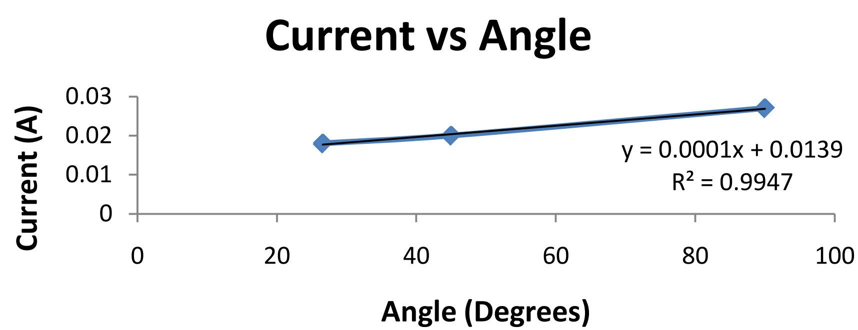
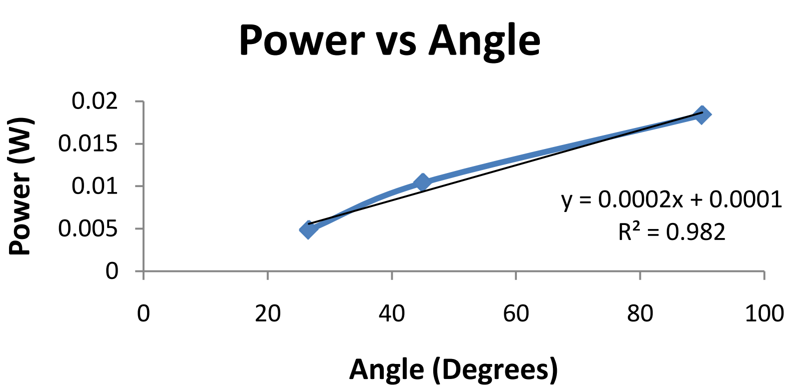
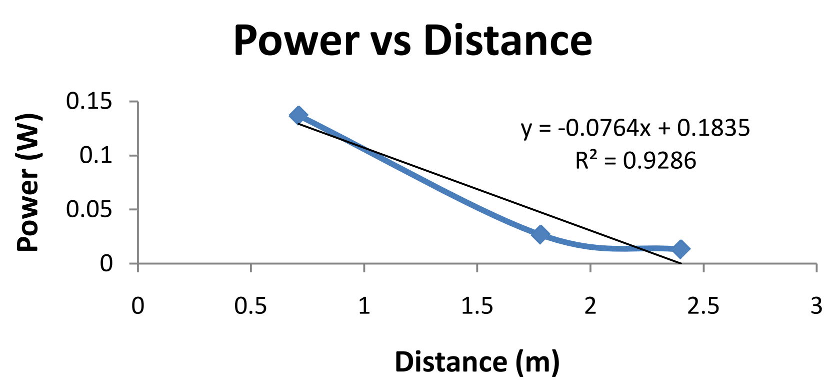
Solar Panel Testing

Distance (m)	Voltage (V)	Current (A)	Power (W)
0.71	1.9	0.072	0.1368
1.78	0.81	0.033	0.02673
2.4	0.57	0.023	0.01311
Angle (degree	Voltage (V)	Current (A)	Power (W)
26.6	0.27	0.018	0.00486
45	0.52	0.02	0.0104
90	0.68	0.027	0.01836









Field Trip to Photovoltaic Plant

- On CSUN land
- Hardware and equipment owned by Boeing.
- Contract specifies plant will eventually be owned by CSUN.
- Purpose: A Proof of Manufacturing of Concentrated PV Power (using focal mirrors to concentrate light onto a solar cell).

Peak Power Output	Number of Arrays	Tracking
75 kW	29	Dual-Axis

Field Trip to Photovoltaic Plant

9-panel Arrays

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Field Trip to Photovoltaic Plant

6-Module CSP Array

Ke

Field Trip to Photovoltaic Plant

Dual-Axis Tracking Motor

Field Trip to Photovoltaic Plant

- Inverter
- Converts DC to AC

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Field Trip to Photovoltaic Plant

9-foot Ground Rod

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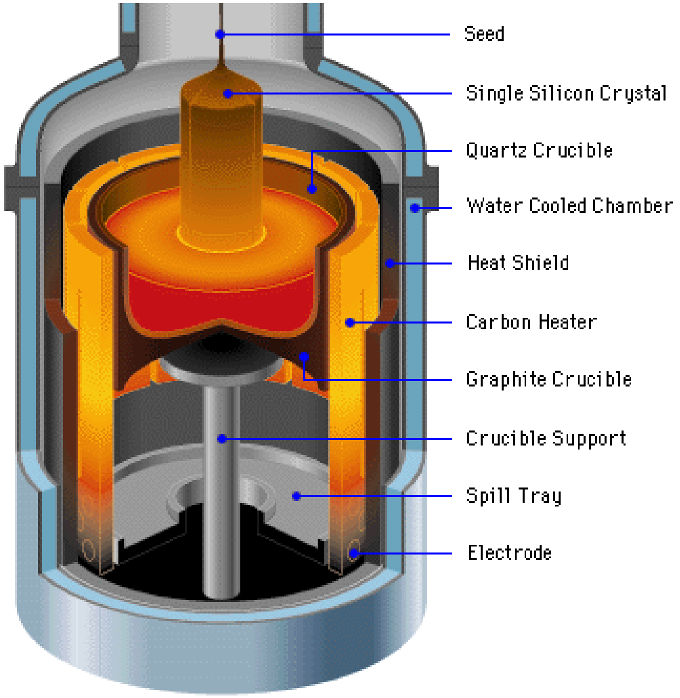
Field Trip to SolarWorld Factory

- Headquartered in Germany, SolarWorld is responsible for 10% of all yearly capacity of solar cells Sold.
- 1.4GW of Solar Power produced a year.
- Assembly plant in Camarillo, CA, receives solar cells and assembles them into panels.

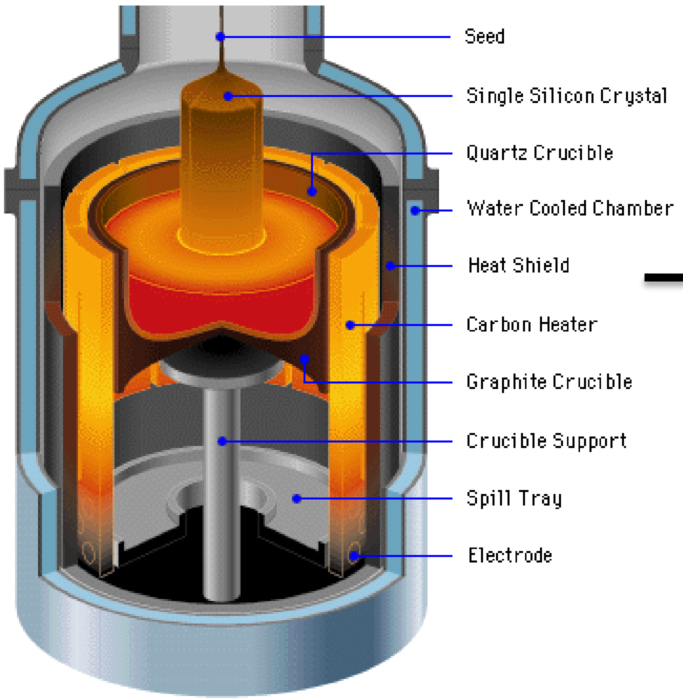
Field Trip to SolarWorld Factory

- Silicon rocks are melted down to liquid.



Field Trip to SolarWorld Factory

- Liquid is dipped with a seed crystal.
- Silicon attracts silicon, and the crystal is drawn upward, causing a vertical crystal to form at the end of the seed.



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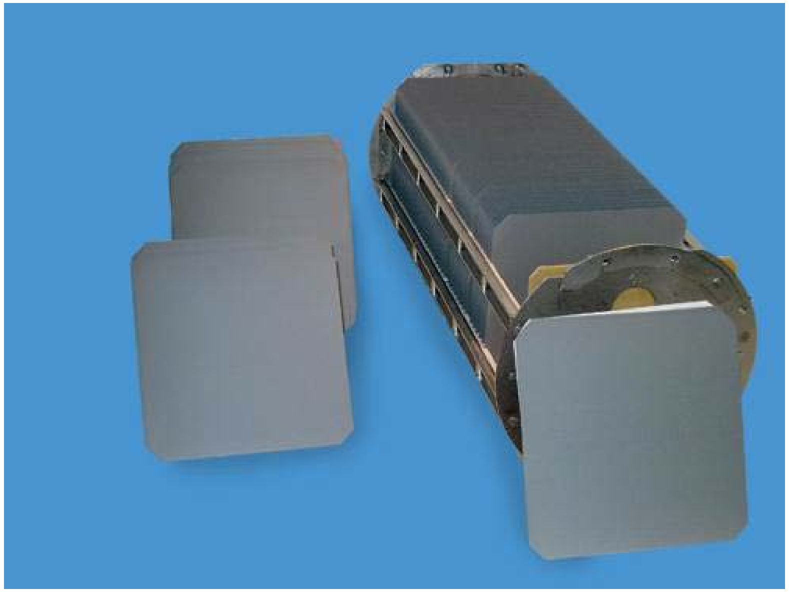
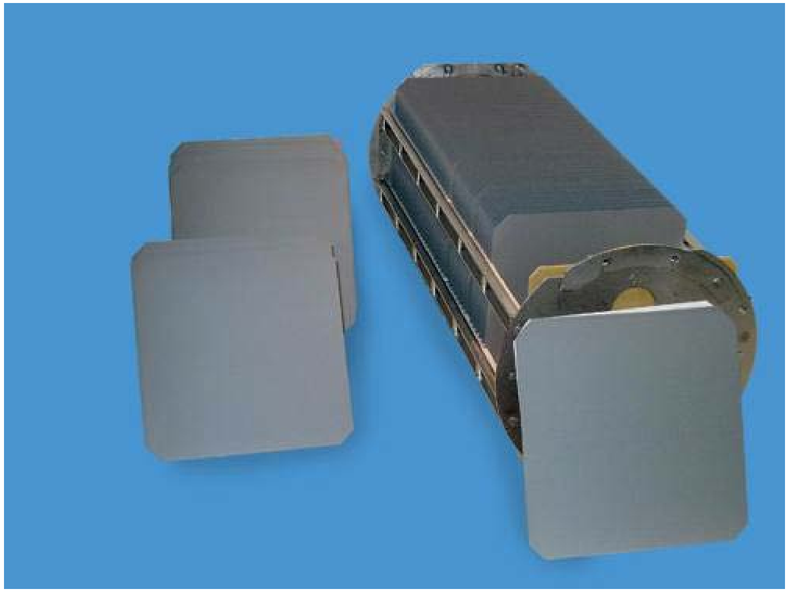
Field Trip to SolarWorld Factory

- Cooled solid crystals are inspected for imperfections.
- Crystal cylinders are cut into the desired shape using Wire-EDM cutting (thin wires with millions of volts running through them).



Field Trip to SolarWorld Factory

- Wafers are sandwiched with other necessary layers of material.
- Silver ribbon is attached to each cell for eventual assembly and packaged for shipping.



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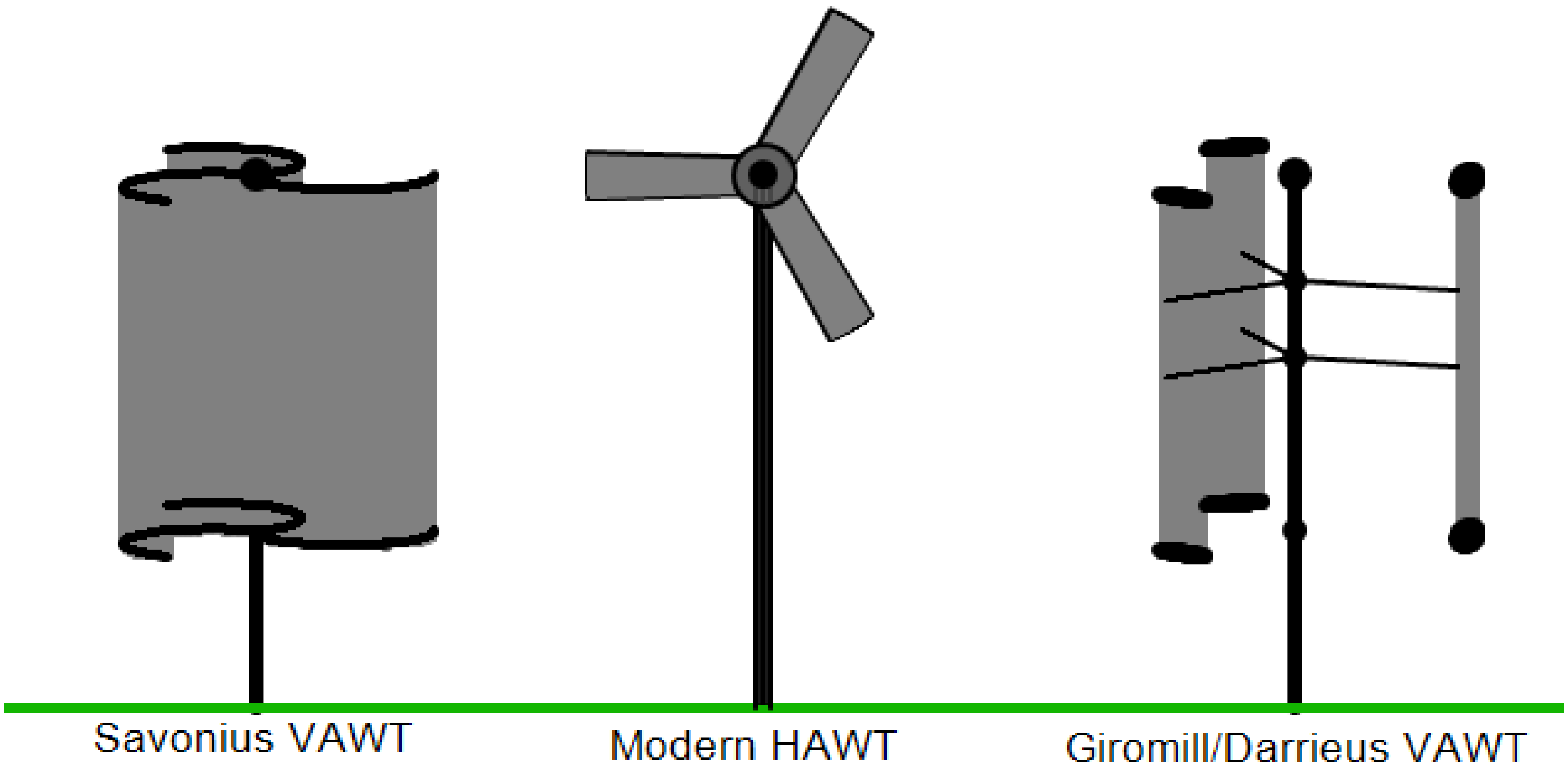
Field Trip to SolarWorld Factory

- Solar Cells are inserted as “cartridges” in an assembly line operated mostly by large robotic arms.
- Several cells (in this case 60) are assembled into a panel.

Economic Trends in Wind Energy



Horizontal-Axis/Vertical Axis Wind Turbines

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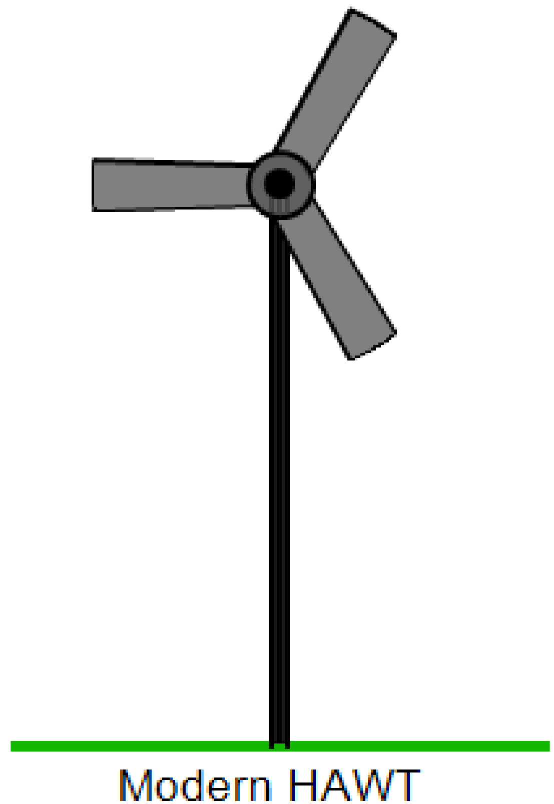
Economic Trends in Wind Energy



Horizontal-Axis/Vertical Axis Wind Turbines

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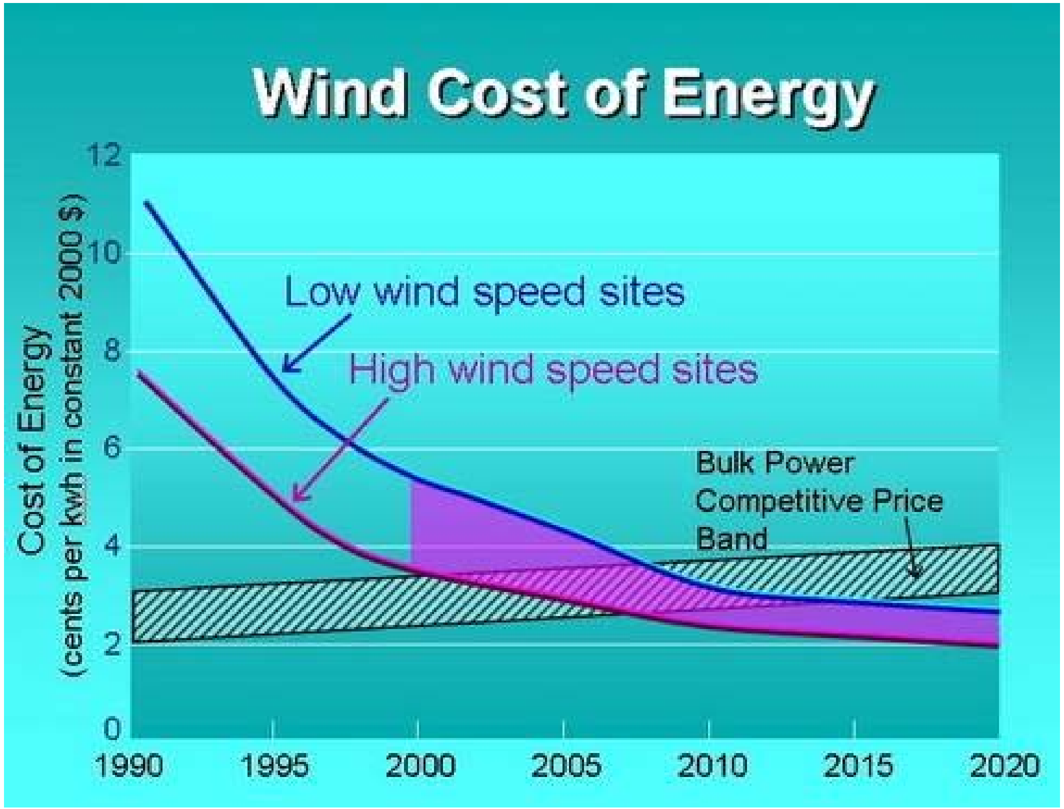
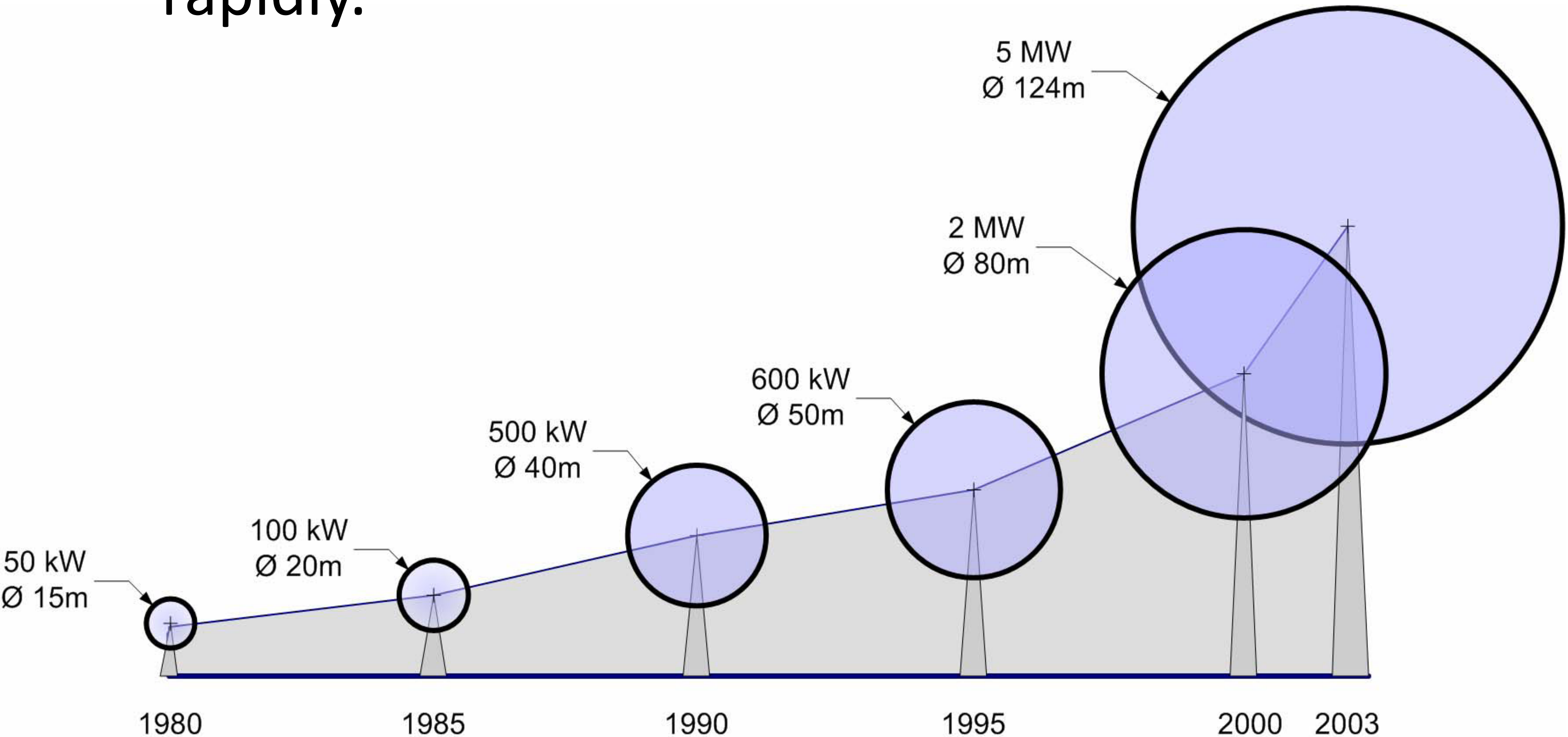
Economic Trends in Wind Energy

- The costs of implementing wind energy are decreasing rapidly, and predicted to continue.
- This is driven largely by the increasing size of turbines, and economics of scale, as more and more generators are installed.



Economic Trends in Wind Energy

- Average turbine size and power has increased rapidly.



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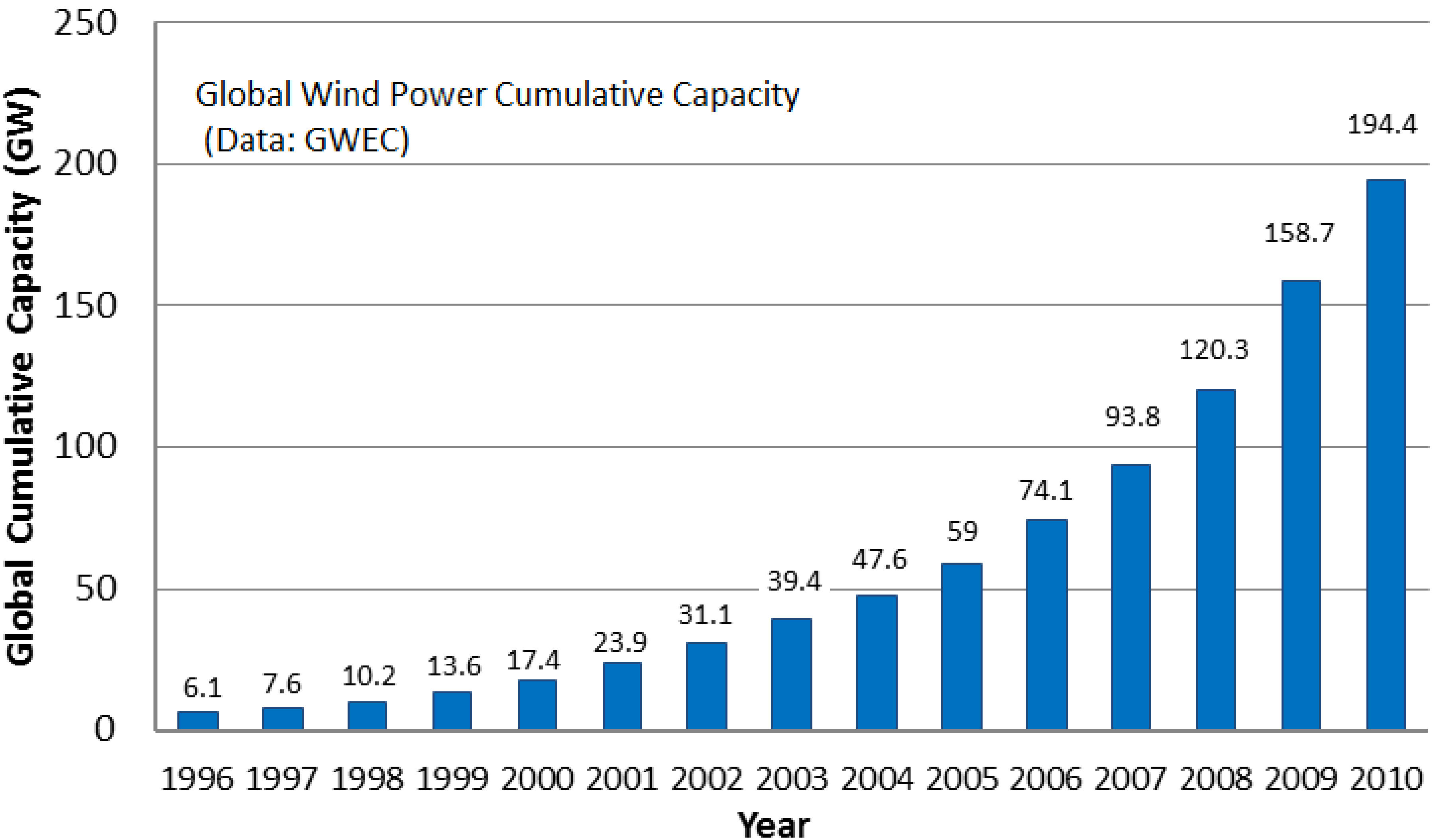
Economic Trends in Wind Energy



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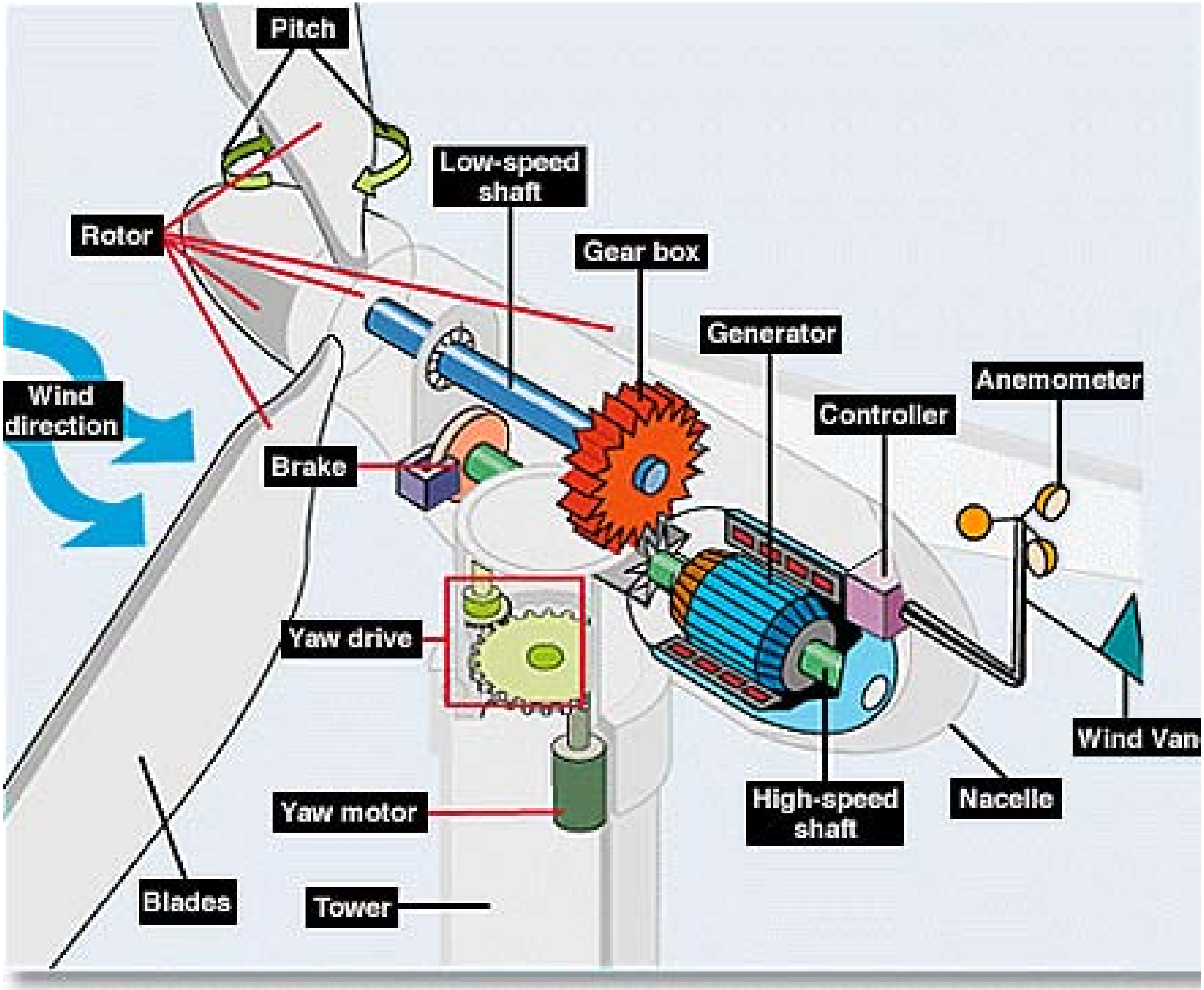
Wind Power Conversion



Wind Power Conversion

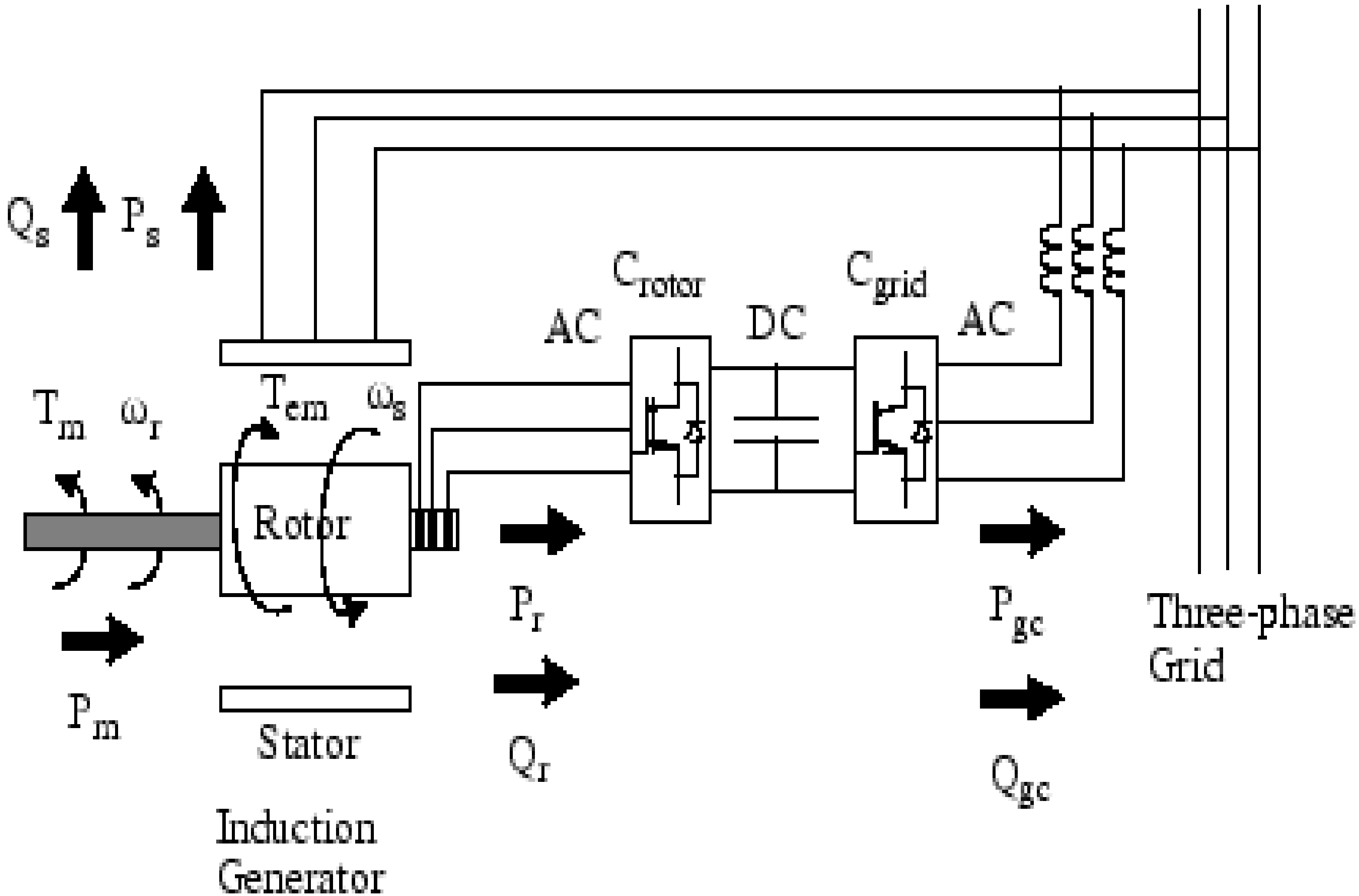
- The wind's kinetic energy is converted to electrical energy by an electric generator.
- The power produced is given by

$$P_m = (½)C_p\rho AV^3$$

where C_p is the Power Co-efficient of a turbine, ρ is the air density, A is the swept area, and V is wind-speed through the swept area.

- The generator uses magnetic fields and coils to produce electricity from the rotation of the turbine, based on principles of Faraday's law.

Wind Power Conversion



Doubly-Fed Induction Generator

Dependence of Power on Wind and Turbine Speed

- Power output increases with increasing wind speed.
- Maximum power production shifts to higher turbine speeds as wind speed increases.

D

Dependence of Power on Wind and Turbine Speed

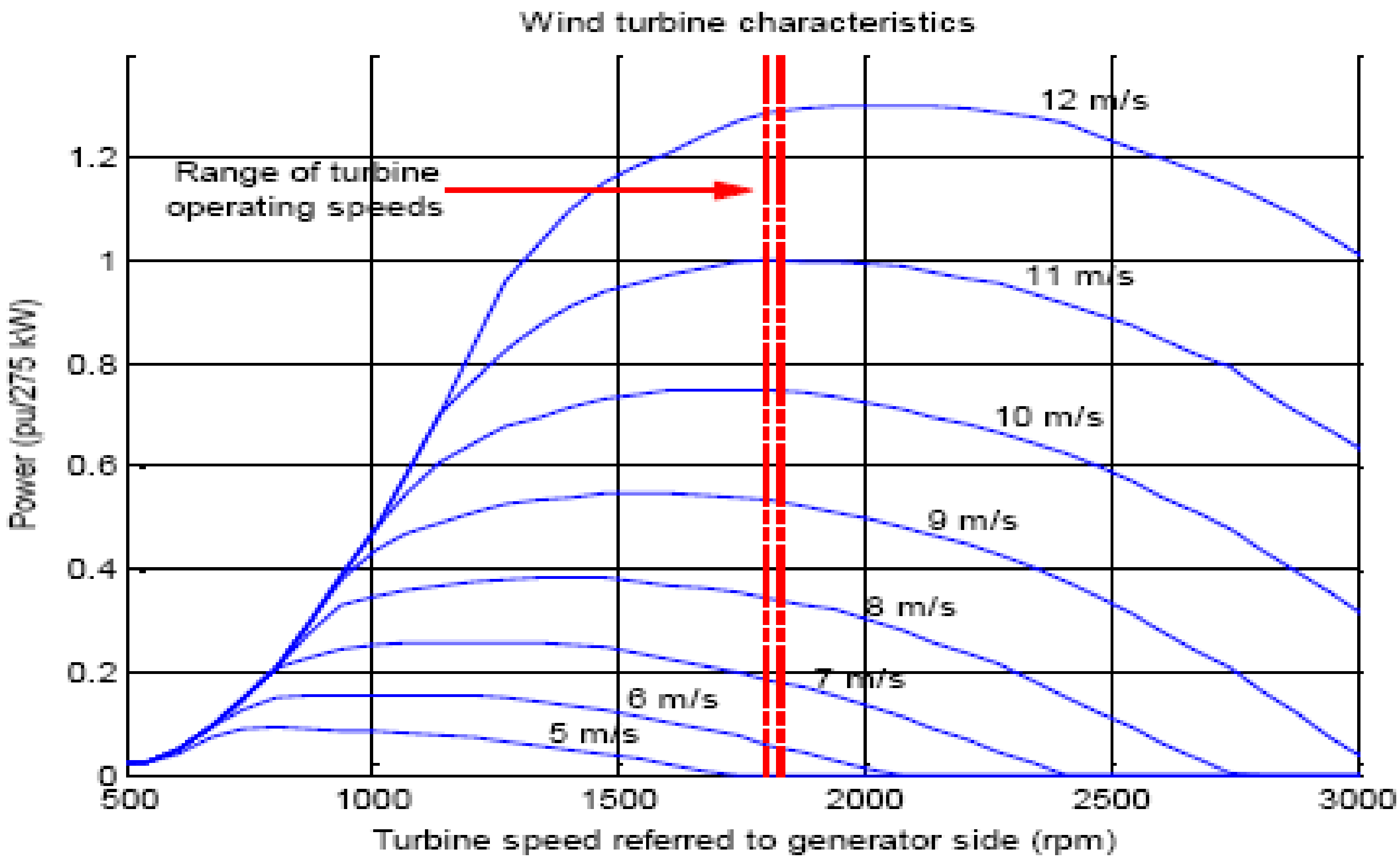


Figure 1. wind turbine charactaristics

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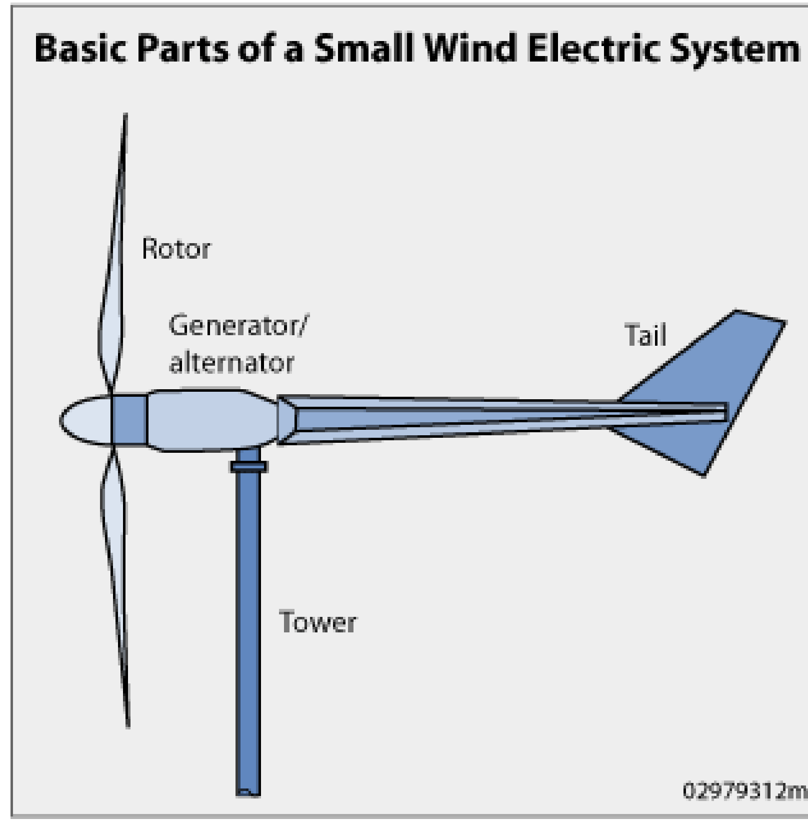
CSUN Wind Generator and Testing

- 600W
- 12 or 24VDC
- Minimum speed 4.5 MPH (minimum to achieve 12V)
- Nominal speed 28 MPH
- Height: 14 feet
- 2.1 ft rotor diameter



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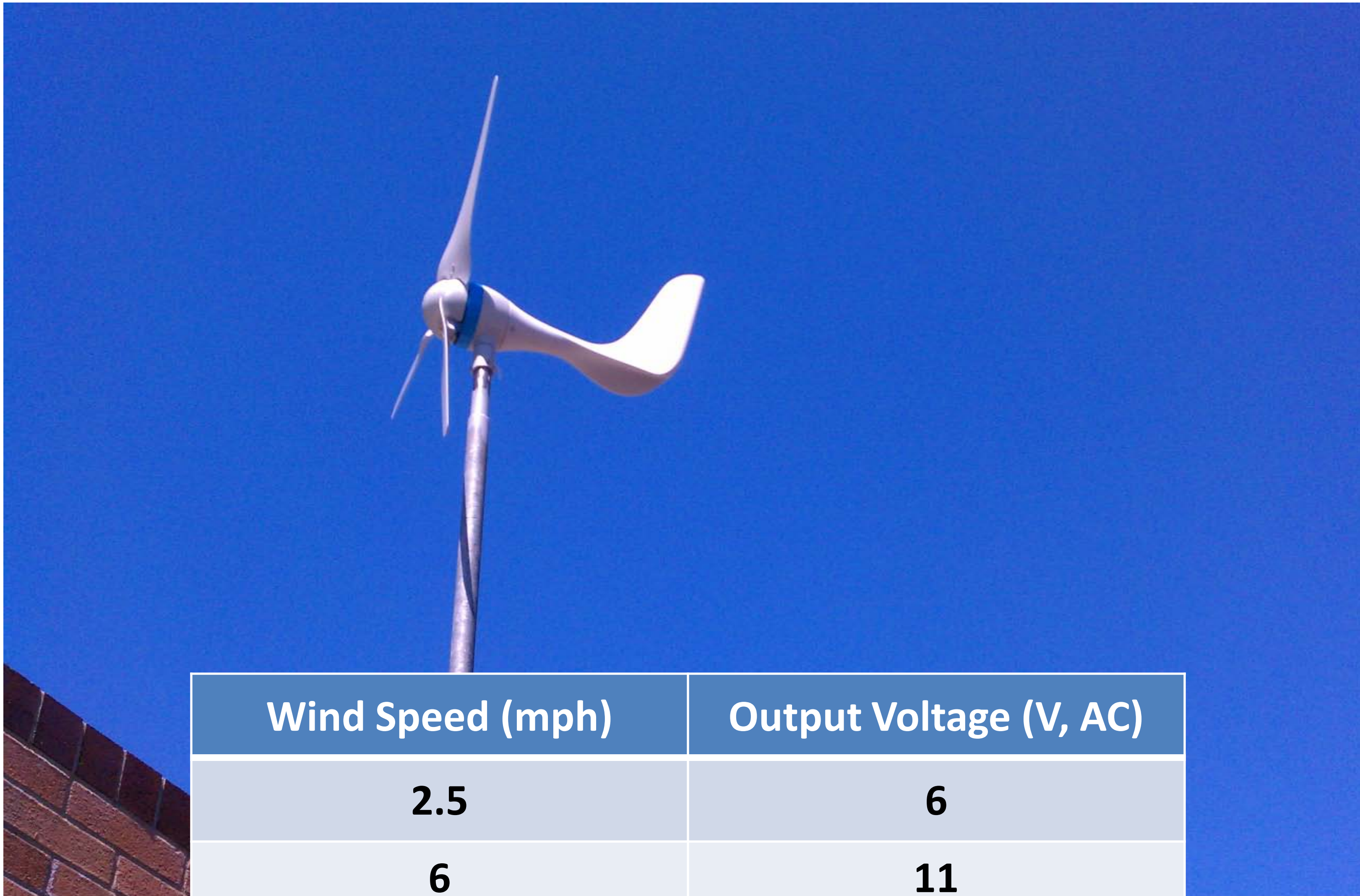
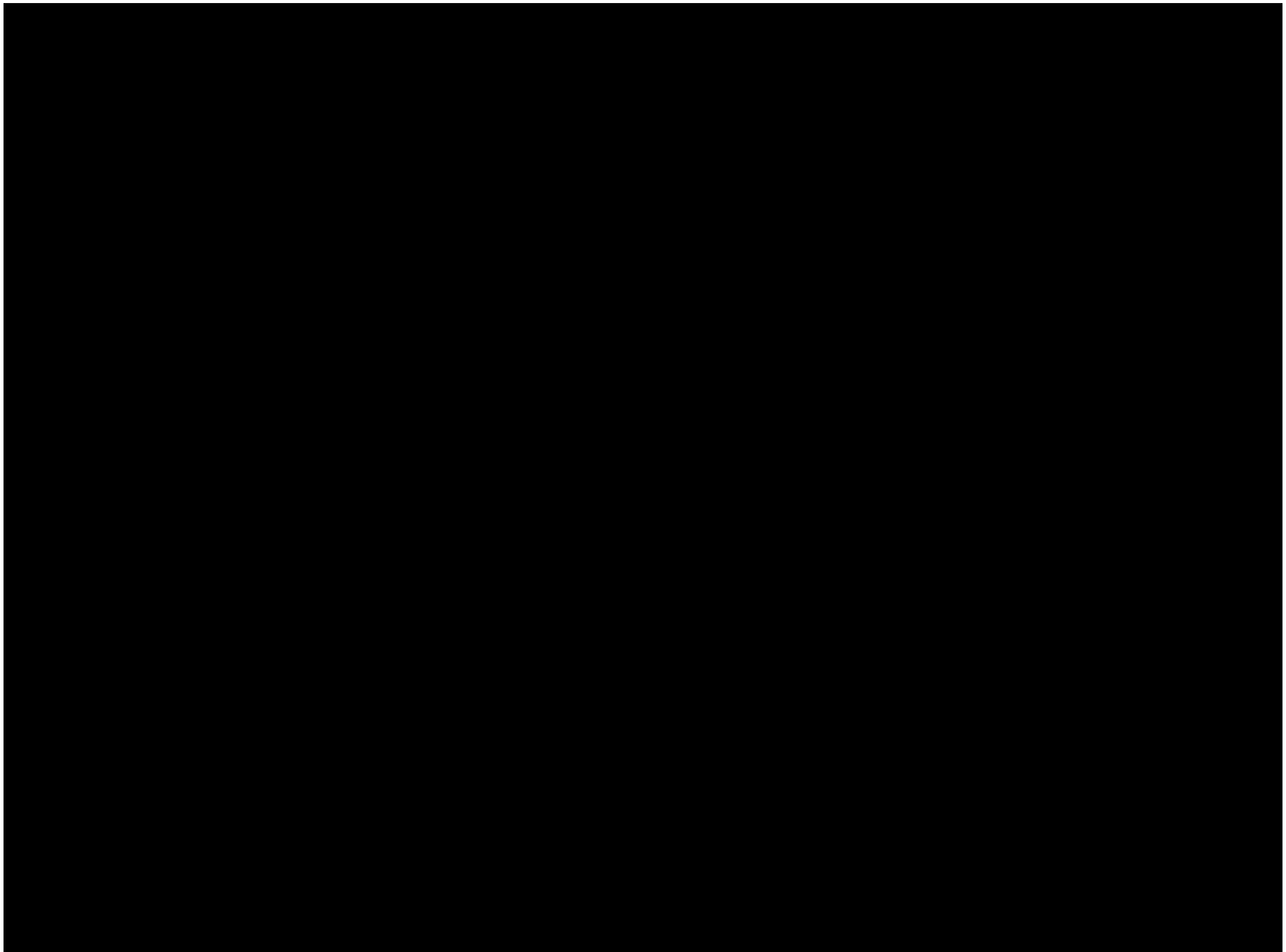
CSUN Wind Generator and Testing



Wind Speed (mph)	Output Voltage (V, AC)
2.5	6
6	11

CSUN Wind Generator and Testing



GIS

GIS (Geographical Information System) helps us:

- Manage assets and data
- Plan and analyze
- Isolate specific demographics and interests
- Operate business
- Improve situation awareness

Decision Factors

Team A

- Population Density
- Insolation (Irradiance)
- Frequency of Pedestrian Collisions
- Frequency of Non-Pedestrian Collisions
- Density of Restaurants
- Income Closest to Middle Class

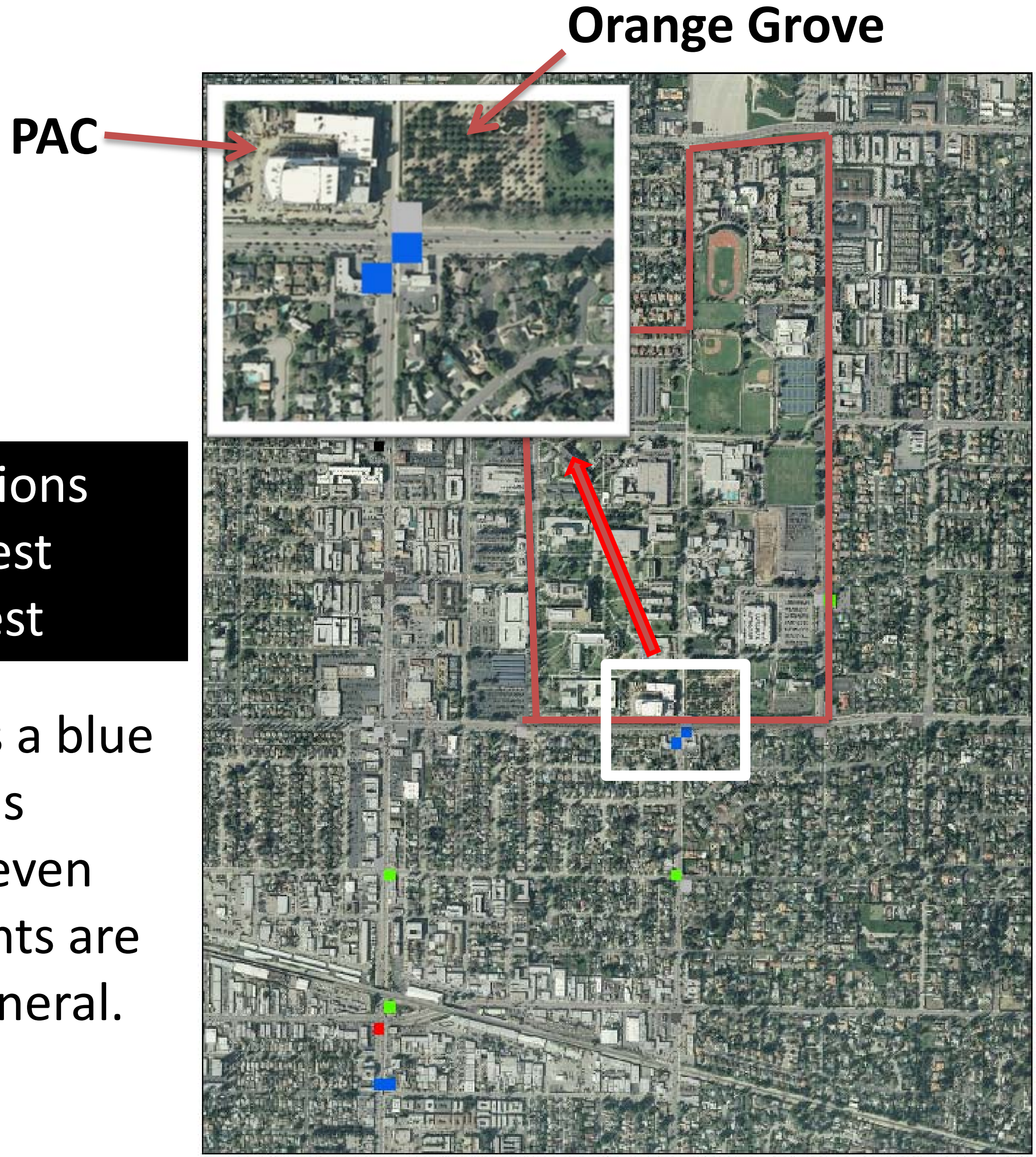
Team B

- Population Density
- Insolation (Irradiance)
- Frequency of Pedestrian Collisions
- Frequency of Non-Pedestrian Collisions

* The results of the models should be very similar, because the decision factors in the models are very similar.

L

Team A Bus Stop Location



- Red: Best Locations
- Blue: Second best
- Green: Third best

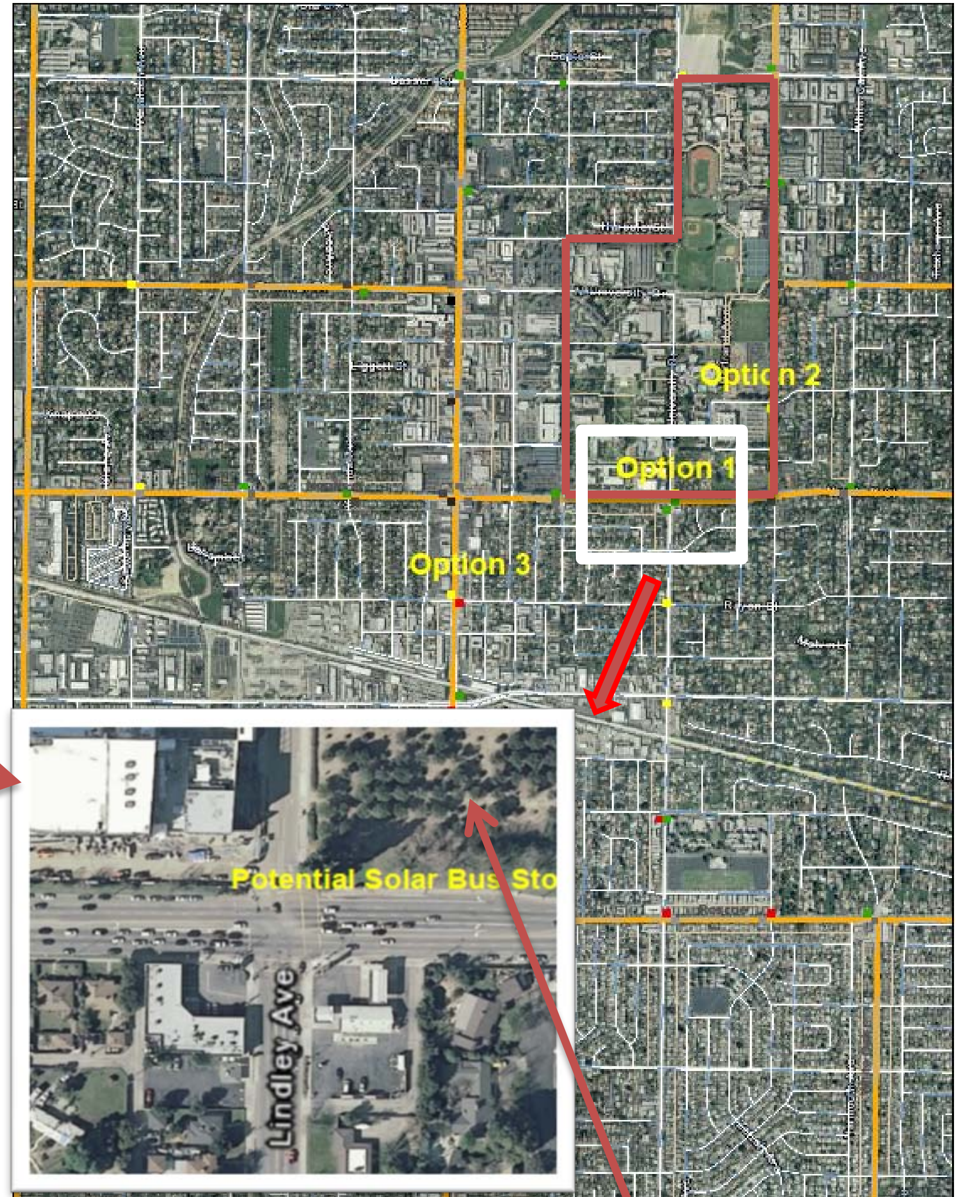
* Team A’s pick was a blue point because it was adjacent to CSUN, even though the red points are more suitable in general.

L

Team B Bus Stop Location

- Red: Best Locations
- Green: Second best
- Yellow: Third best

*Team B's pick was a green point because it was adjacent to CSUN, even though the red points are more suitable in general.



Urban Planning Project
(Solar Powered Bus Stop, Team A)

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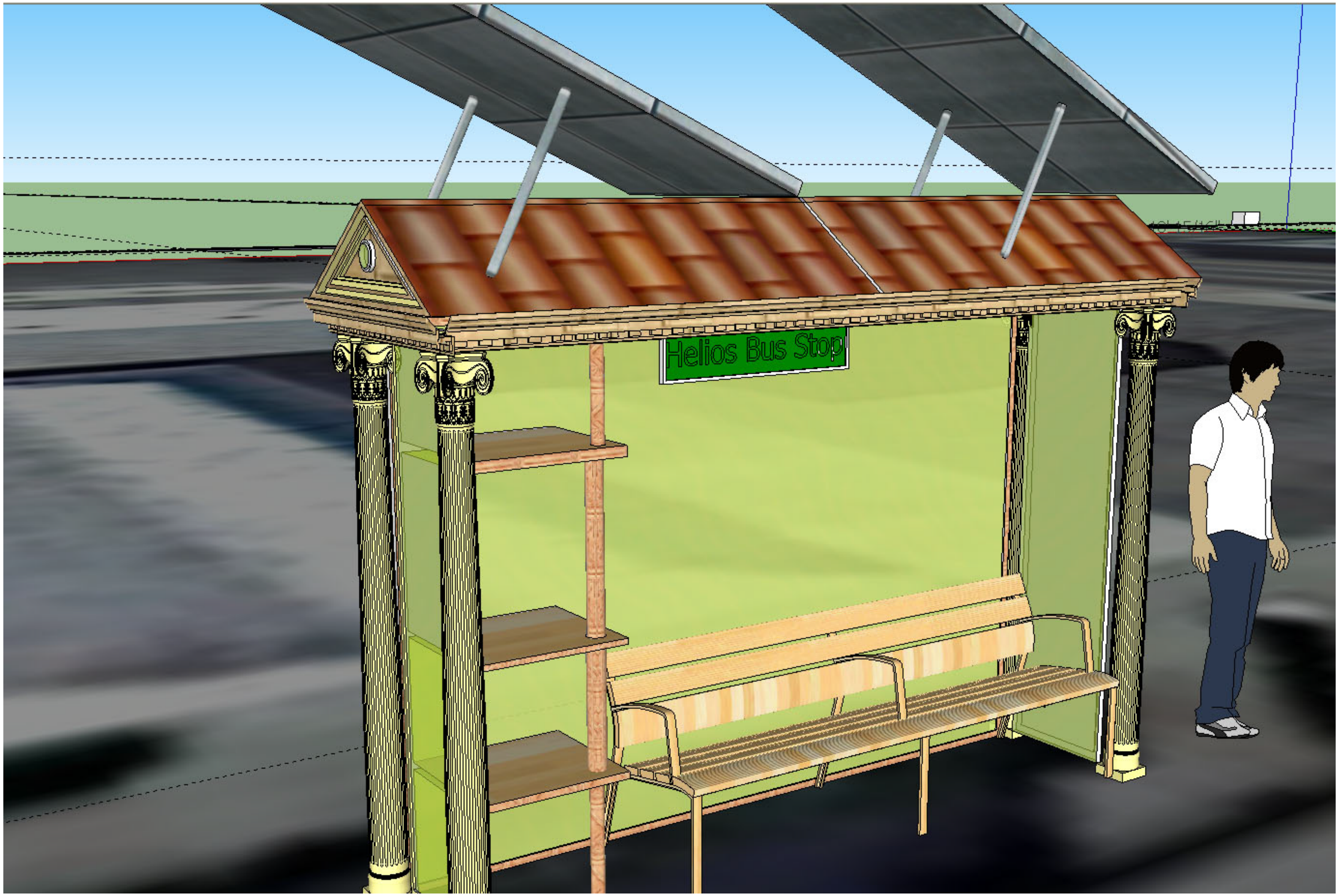
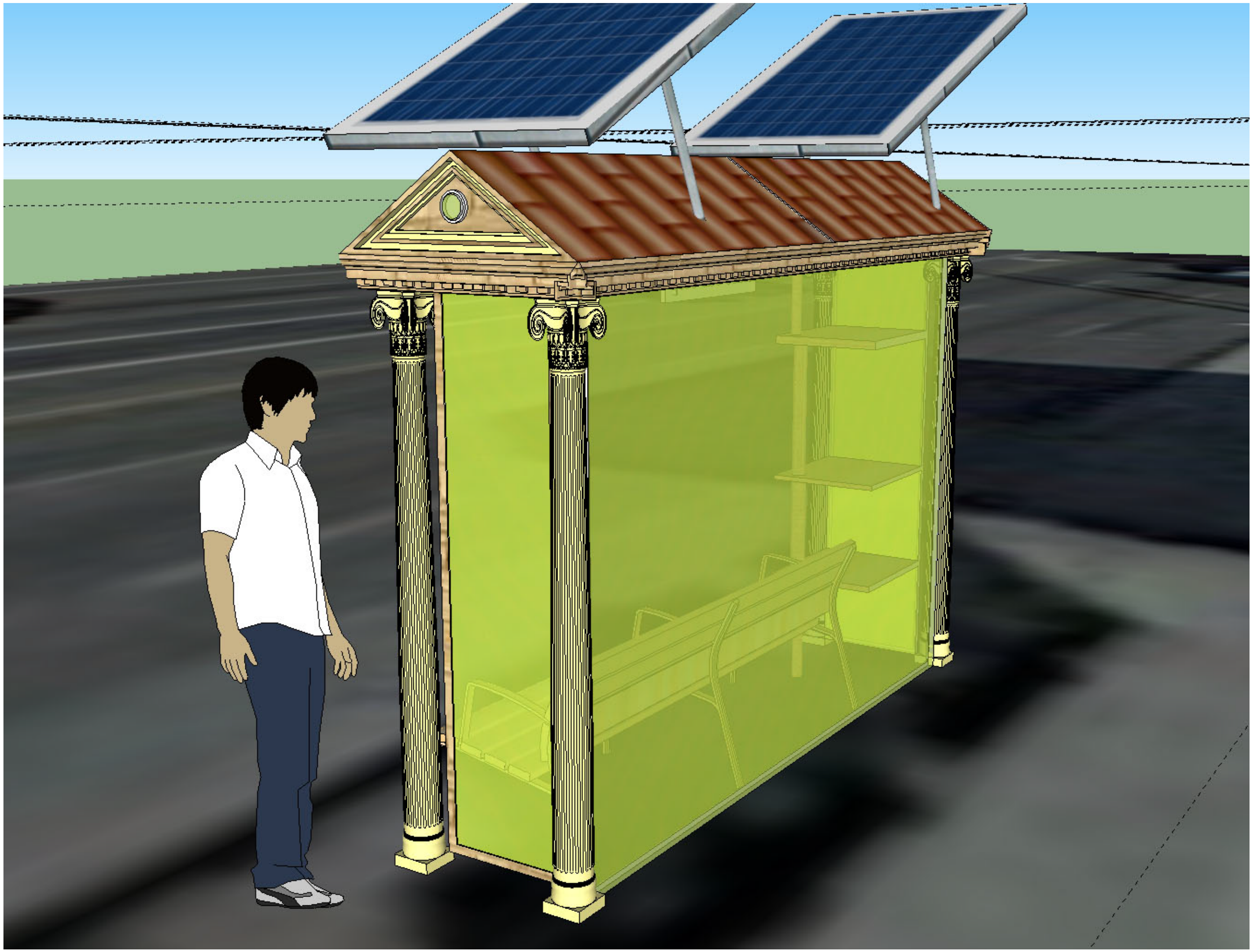


Urban Planning Project
(Solar Powered Bus Stop, Team A)



Urban Planning Project (Solar Powered Bus Stop, Team A)

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Urban Planning Project (Solar Powered Bus Stop, Team B)

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Urban Planning Project
(Solar Powered Bus Stop, Team B)

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Urban Planning Project
(Solar Powered Bus Stop)

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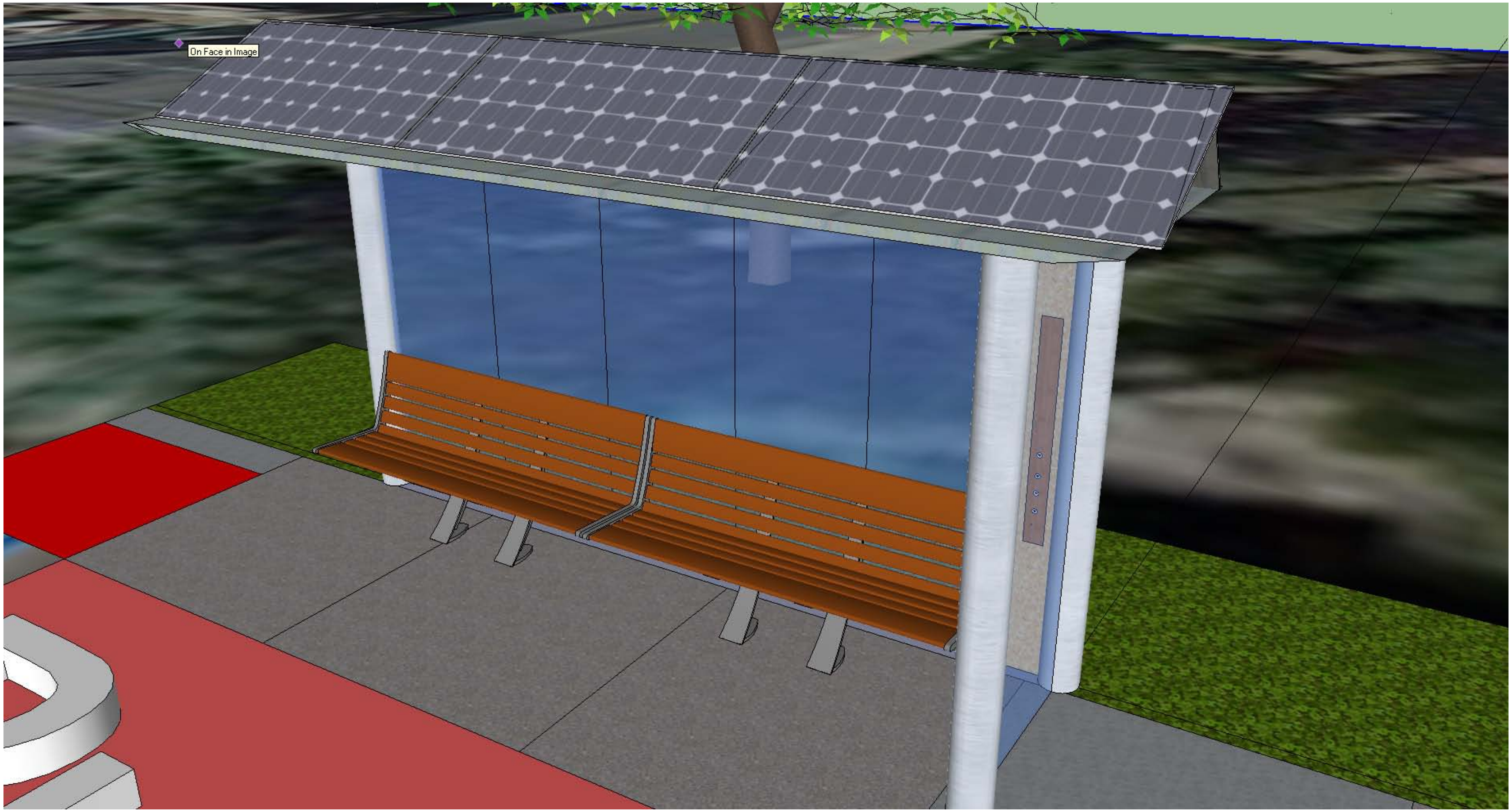

Acknowledgements

- Special thanks to professors Ragan Maas and Zeynep Tocker

Q&A

15 Minutes