Renewable Energy for RMEs

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Statutory Framework

RA 9513 – Renewable Energy Law of 2008

mandates that all electricity generators and consumers are required to source at least 10% of electricity requirement from renewable energy sources

Renewable Energy Technologies

- Ocean
- Geothermal
- Wind
- Biomass
- Hydro
- Solar

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Ocean Power

Tidal

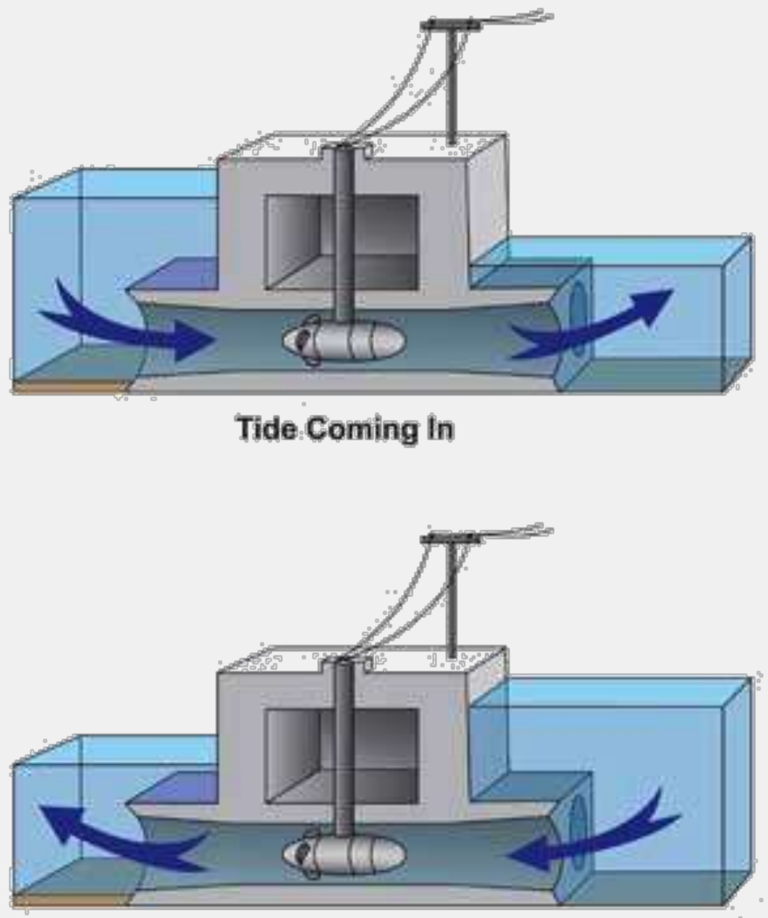
- Potential energy with respect to the change of tide levels
- Result of the moon's gravity

Ocean Current

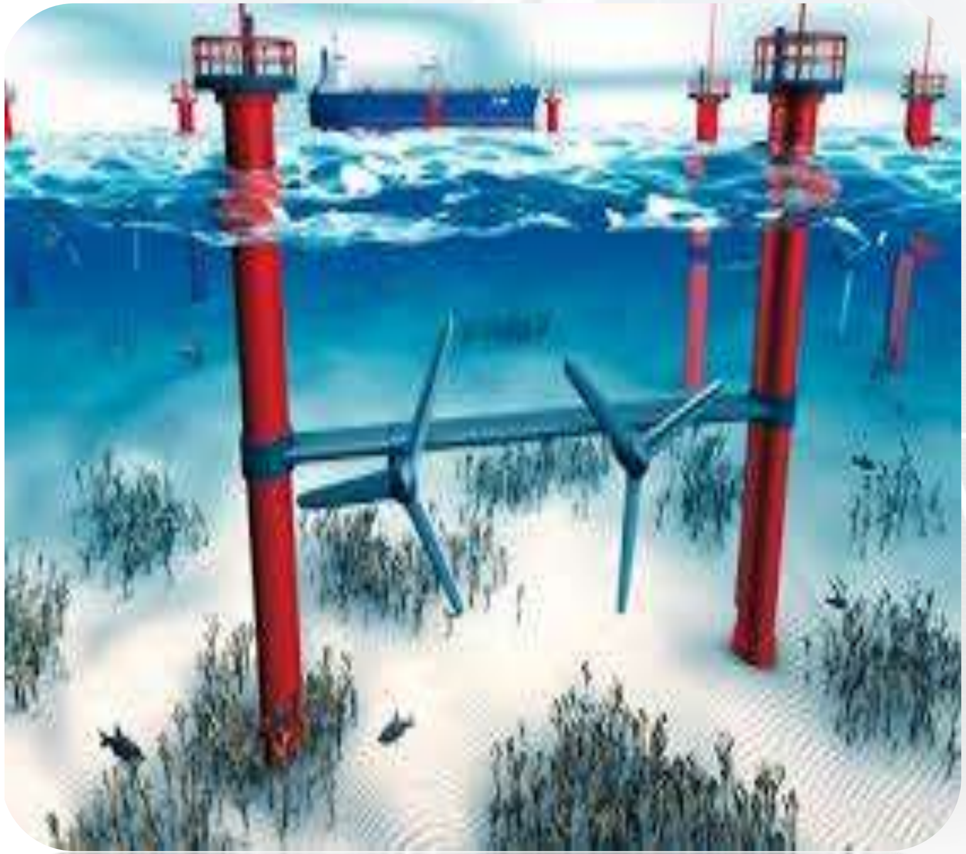
- Kinetic energy conversion, movement or flow of water
- Takes advantage of "venturi effect" of certain sites

Tidal Power

- The differences in tidal elevations on either side of a barrage causes current to flow across a turbine
- Similar to a typical large hydro power plant



Ocean-current



- Certain geologic formations channel water, creating faster current velocities
- At such locations, higher water velocity can turn a turbine, which can then be used to generate electricity
- Very similar in operation to wind turbines, can be horizontal axis or vertical axis

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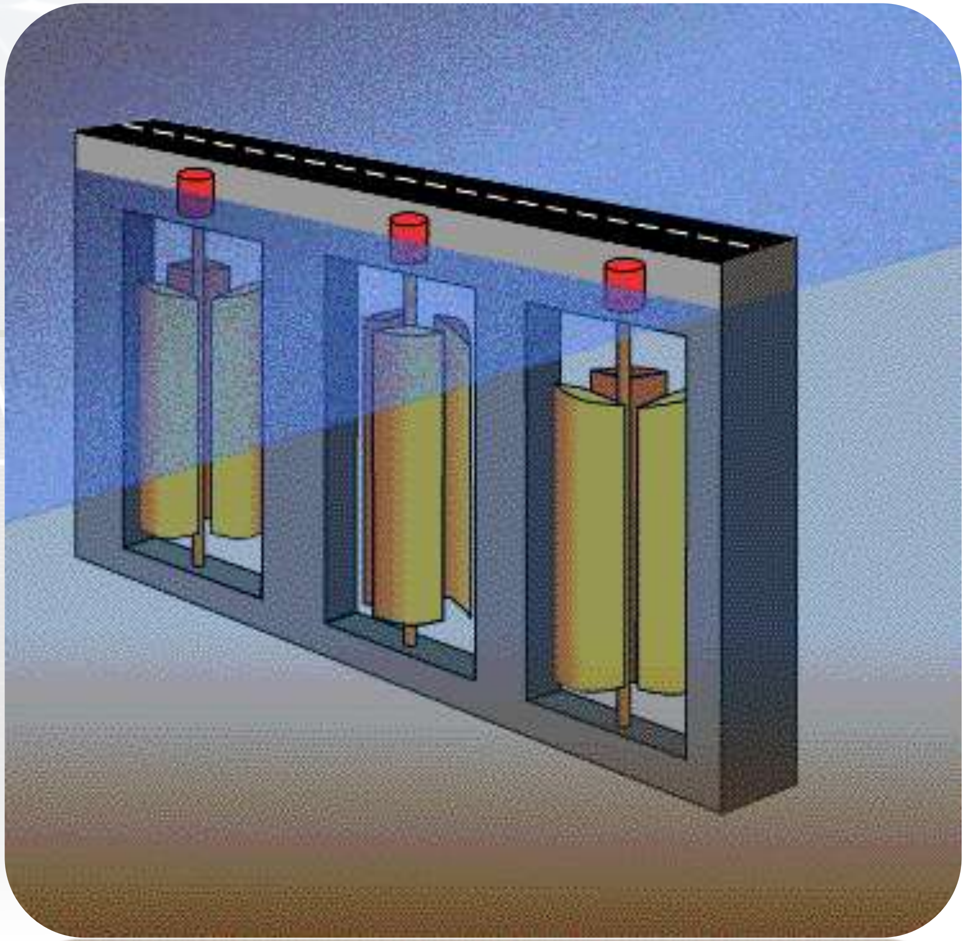
Ocean-current



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Geothermal

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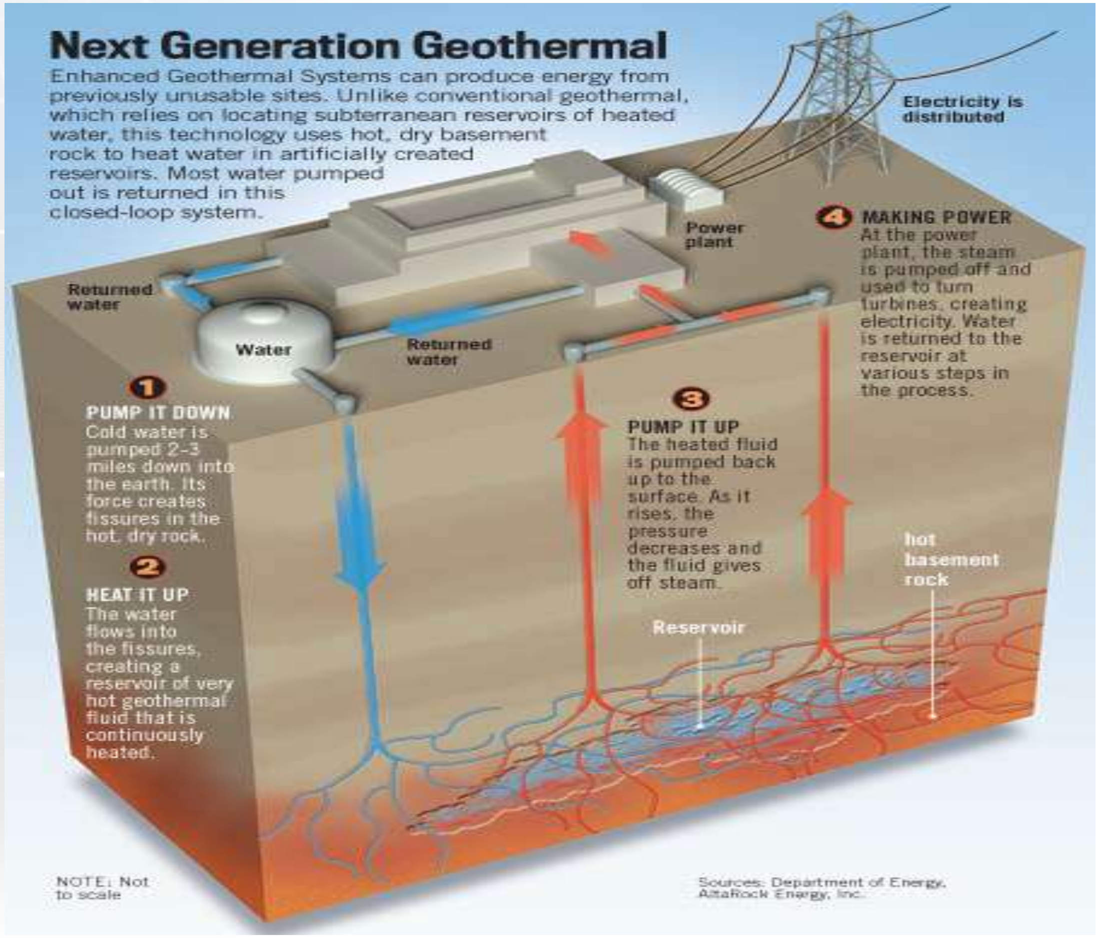
Ocean – Technical Considerations

- Very new technology, with only pilot plants in service
- Difficulty of constructing in open water
- Difficulty of grid interconnection through open water
- Very site specific, needs to have large tide elevations, or high ocean current velocities, which are geology dependent

Geothermal Power

- Water stored in the earth's crust get heated by shallow magma, generating steam
- Steam is harvested via holes drilled deep into the crust, known as "geothermal wells"
- The steam is then used to turn turbines to generate electricity
- **In "Enhanced" Geothermal, water is pumped into hot rock**



Geothermal – Technical Considerations

- Different kinds of steam are drawn, requiring different types of processing.
  - Wet steam is saturated and has high water content. This has to be removed via a pressure vessel known as a cyclone separator.
  - Dry steam is 99% steam and can be delivered to a turbine with minimal processing
  - Geothermal steam is acidic due to high sulfur content, and has to be "sweetened" prior to use
  - Can be base load because of high availability and power density
  - Site specific, reservoir of hot steam, and shallow magma has to be identified
  - Costly development, has to drill 2-3 km long wells into the crust

Wind

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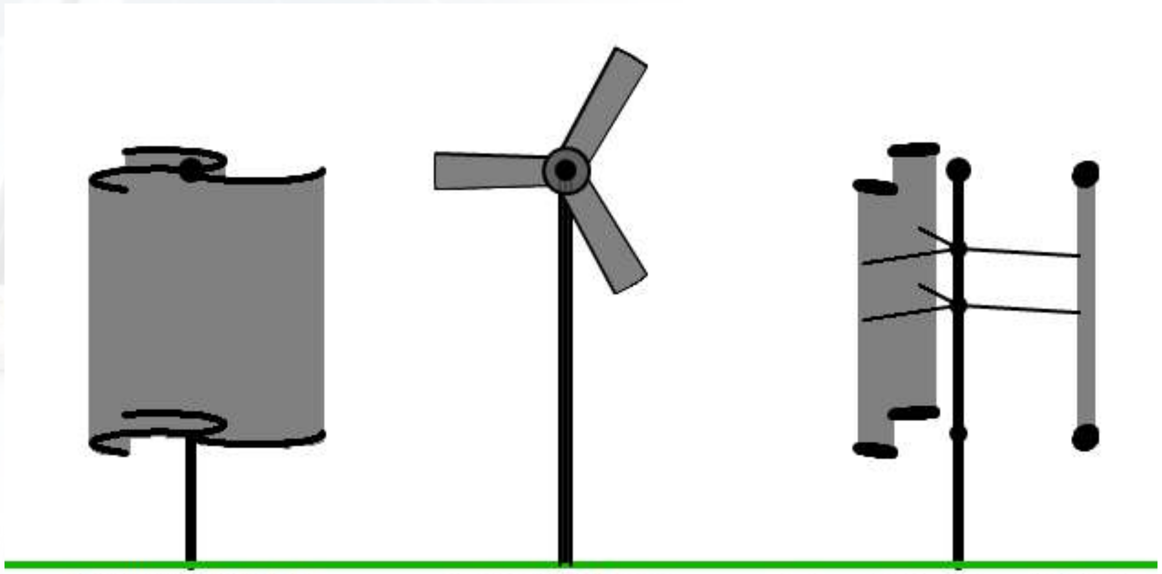
Wind Power



- Conversion of the velocity of wind into rotational energy via a turbine, and use of that rotation to generate electricity
- Several types, in general classified as vertical axis wind turbine (VAWT), or horizontal axis (HAWT)
- Coordination of the blade design, with the electrical generator, is critical

VAWT

- Claims to be
  - Easier to service and maintain, turbine and generator are accessible
  - Can be installed closer to each other, compared to HAWTs
  - Quiter than HAWTs
- Very few successful VAWT operation

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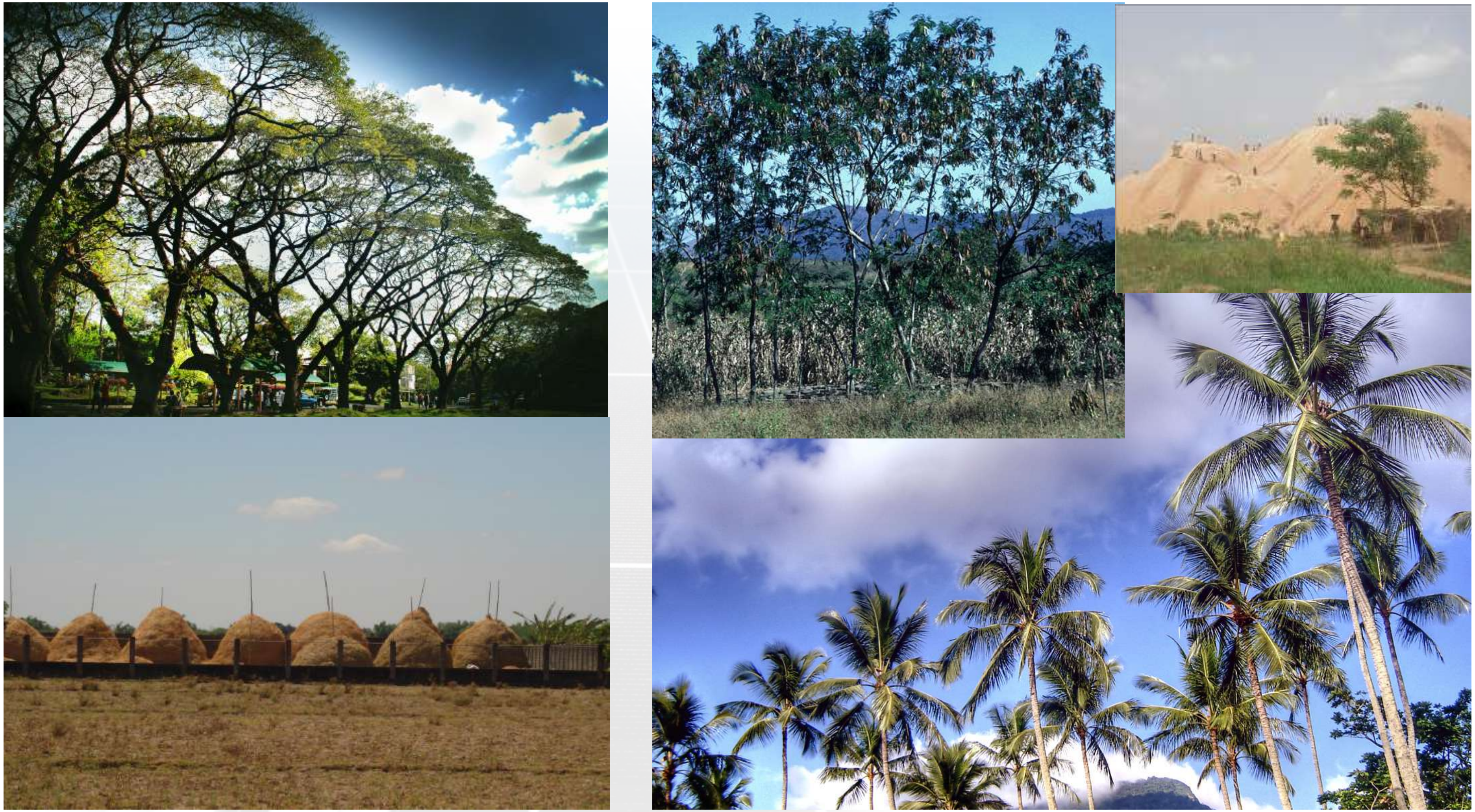
HAWT

- Traditional wind turbine
- Old and tested technology



Biomass

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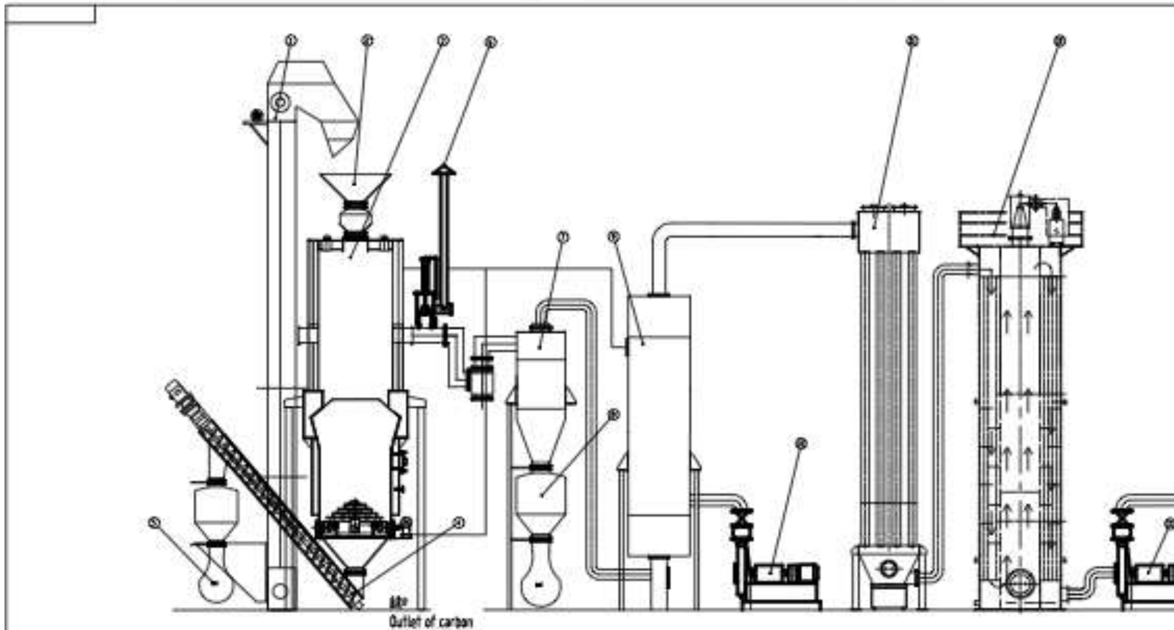
Biomass

- Solid Fuel Technology
  - Pyrolysis or Gasification, with ICE Generation Units
  - Conventional Rankine Cycle (Boiler-Steam Turbine)
  - Indirect Fire Bryton Cycle - Pyrolysis with Combustion Turbines
  - Direct or Indirect Fire Organic Rankine Cycle (ORC) -
- Gas Fuel Technologies
  - Bio-methane using Anaerobic Digesters with ICE Generation sets
  - Land Fill Methane Gas Capture with ICE Generation sets
- Liquid Fuel technologies
  - Biomass to Diesel Fuel Reactors with ICE Generation sets
  - Biomass to Alcohol Fuel
    - Corn / Sugar / Algae and similar sugar rich biomass
  - Coconut Oil to Bio-Diesel (Coco Methyl Ester – CME)

Gasifiers



1	BUCKET ELEVATOR	7	CYCLONE DUST COLLECTOR	13	GAS COMPRESSOR
2	SHELL ASSEMBLY	8	CYCLONE ASH COLLECTION BOX	14	GAS PRYER
3	TWIN-FIRE FIXED BED EASIFIER	9	AIR HEAT EXCHANGER	15	BUFFER TANK
4	SCREW CONVEYOR	10	AIR BLOWER	16	GAS FLARE
5	DRY ASH COLLECTION BOX	11	AIR COOLER	17	GAS GENSET
6	GAS FLARE	12	INTEGRAL ESP AND INDIRECT COOLER		

Anaerobic Digester

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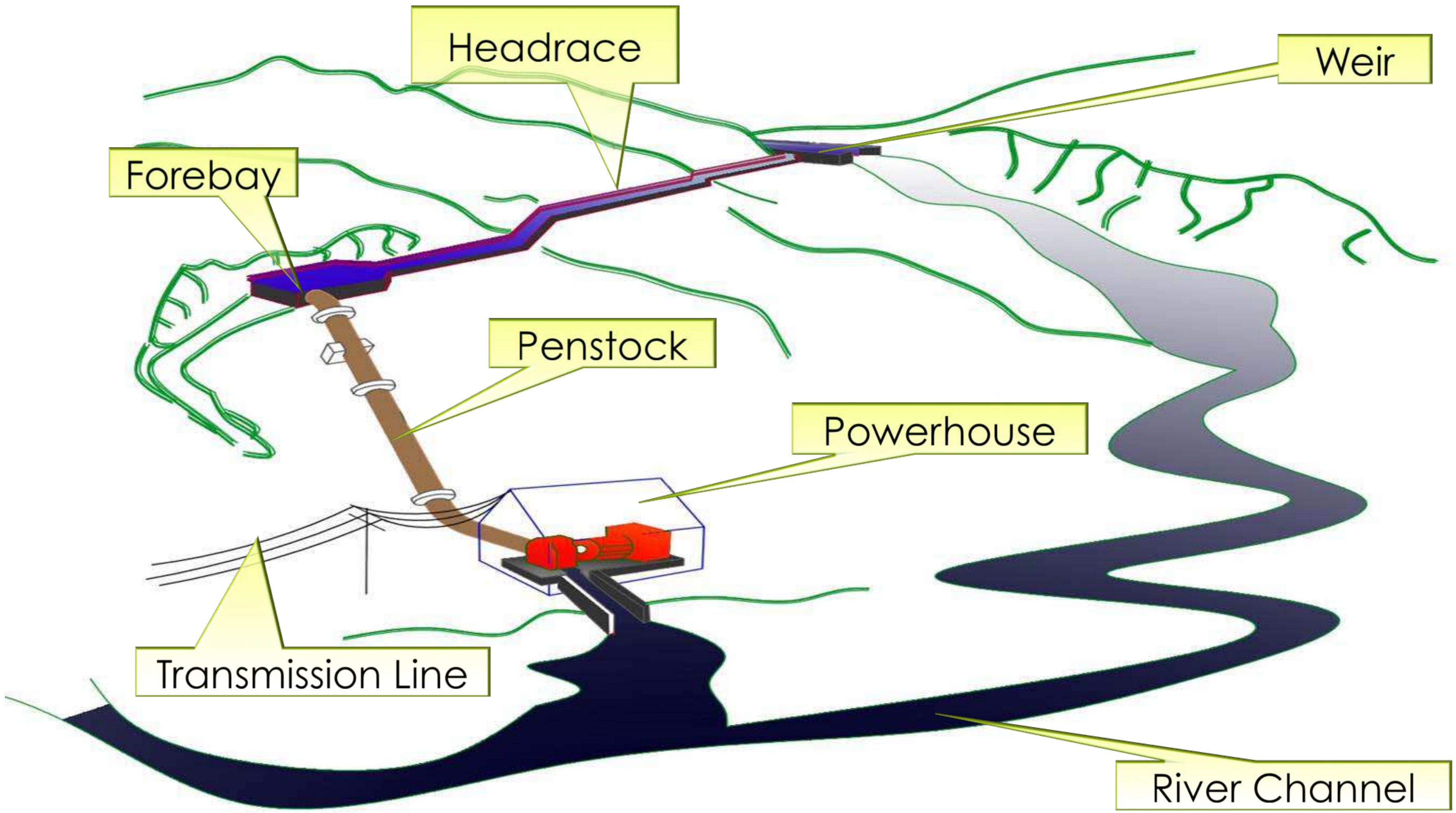
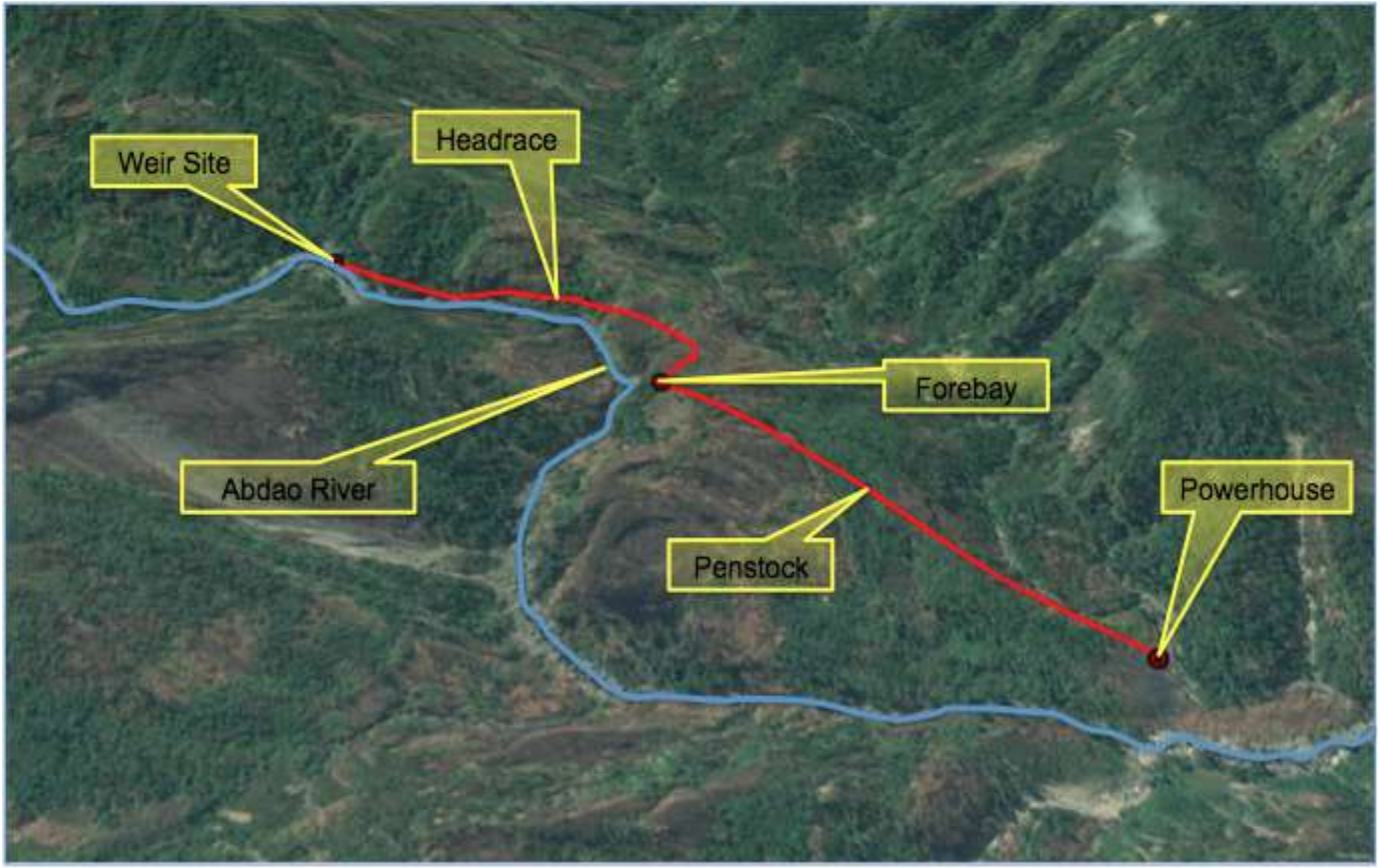

Headrace
Weir
Forebay
Penstock
Powerhouse
Transmission Line
River Channel

Hydro


Weir Site
Headrace
Forebay
Abdao River
Penstock
Powerhouse

Hydro Electric Power Basics

Basic Hydro Electric Power Equation

$$\textbf{Power (kW)} = 9.81 \times WT_{eff} \times G_{eff} \times H \times Q$$

Where:

WT_{teff} - Water Turbine Efficiency

G_{eff} – Generator Efficiency

H – Hydraulic Head, in meters

Q – Water Flow, m^3 per sec

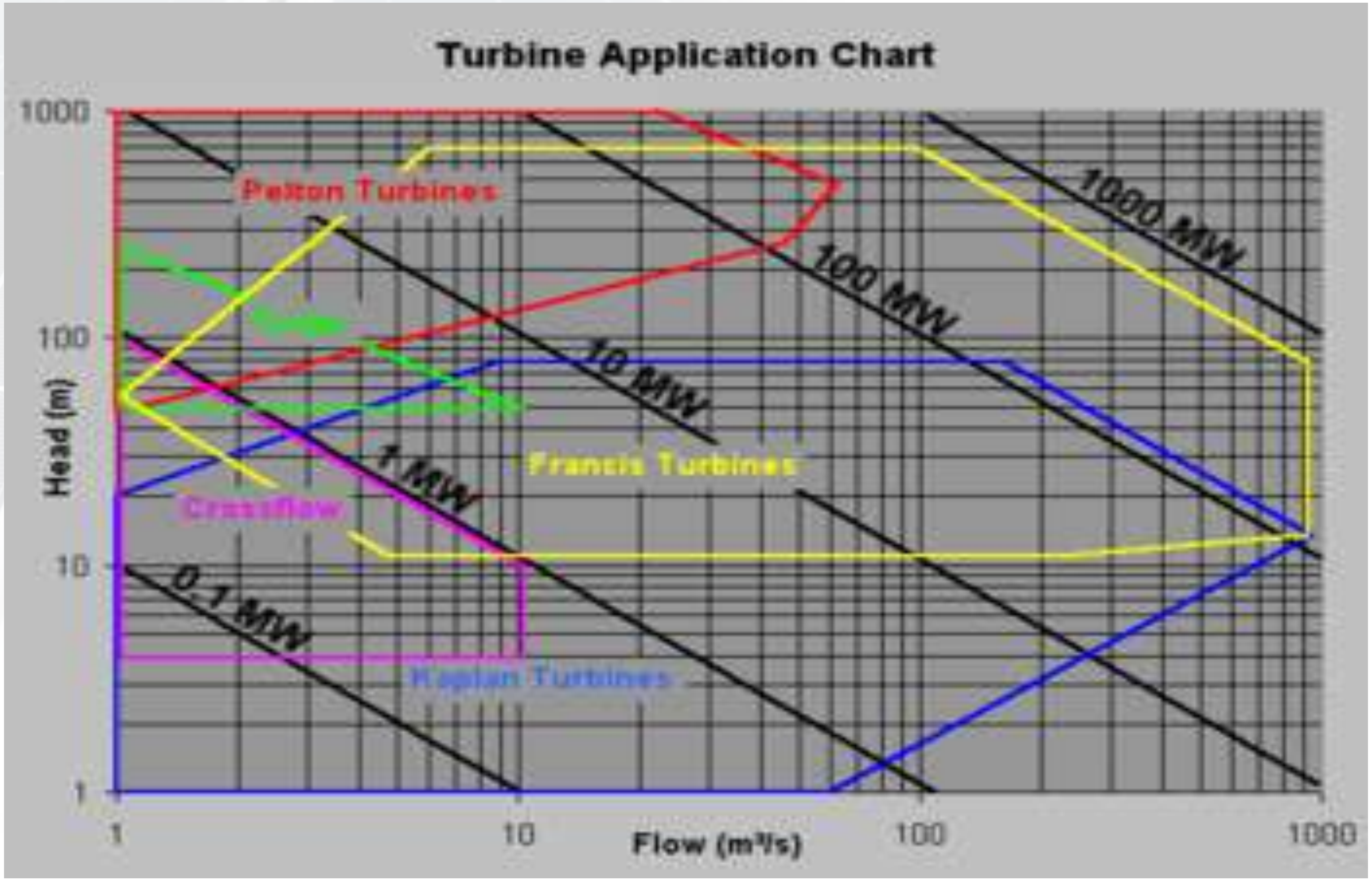
Hydro Electric Power Basics

<u>Basic Hydro Electric Power Plant Types</u>

- **Run of River Type**
  - Pico — <1kw, run or river or stream
  - Micro — >1kW ≤ 100 kW, run of river
  - Mini — > 100 ≤ 50 MW, run of river
- **Impounding Type**
  - High Dam — >50 MW, 50 meter dam
  - Low Dam — >5 MW, ≥15 meter, ≤ 50 meter

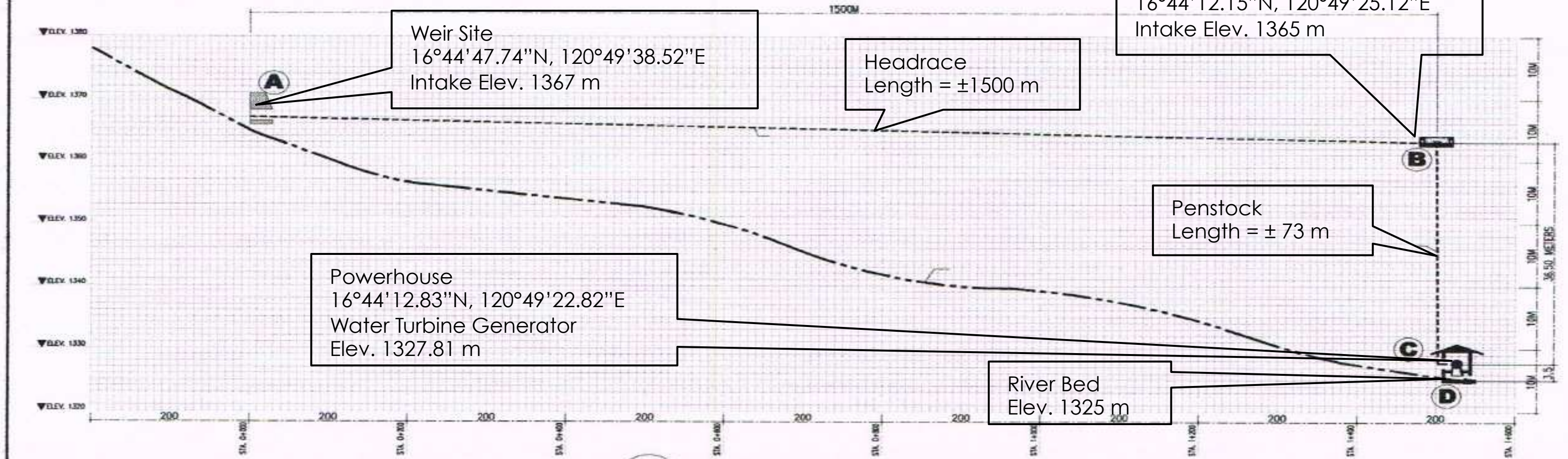
Hydro Electric Power Basics

Water Turbine Selection and Types



Hydro Electric Power Basics

Hydraulic Gradient



HYDRAULIC GRADIENT DIAGRAM

LEGEND: WEIR, FOREBAY, POWER HOUSE

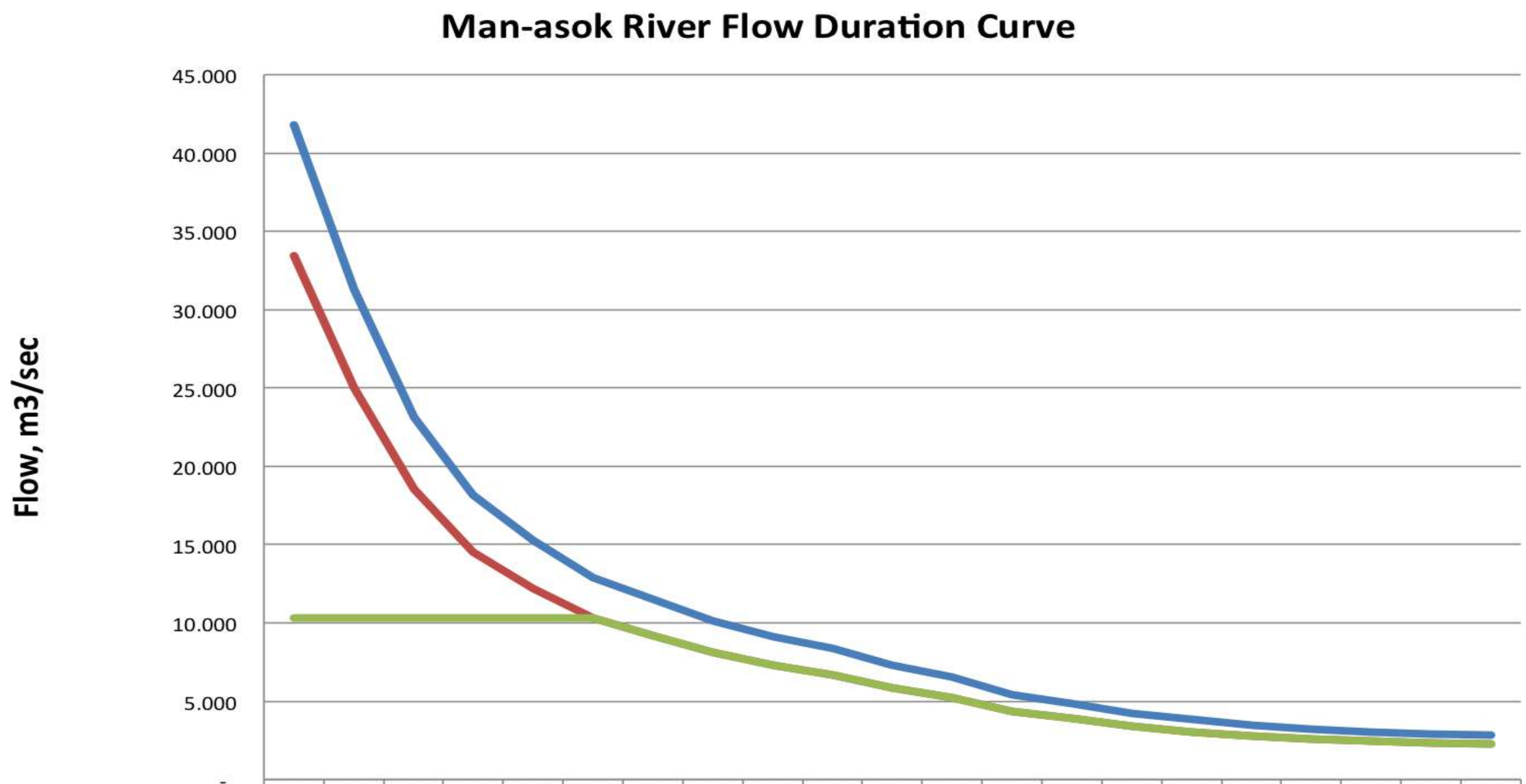
STATION	LENGHT	ELEVATION
A-B	1,500 MTS	1.5 MTS.
B-C	73 MTS	36.5 MTS.
C-D	15.5 MTS	3.5 MTS.

Description		Coordinates Plant 1 Northing	Easting
	Weir	16°44'47.74"	120°49'38.52"
	Forebay	16°44'12.15"	120°49'25.12"
	PowerHouse	16°44'12.83"	120°49'22.82"
Weir Length		18 MTS.	
Elevation			
	Weir	1,366 MTS.	
	Forebay	1,365 MTS.	
	PowerHouse	1,327.81 MTS.	
	Min.Tailwater	1,328.00 MTS.	
Headrace Length		1,500 MTS.	
Penstock Length		73 MTS.	
Head Gross		36.50 MTS.	
Drainage Area		96.74 Km²	
Q (Flow Rate)		11.00 cms.	
Kw		3x1000 kW	

MHP DATA
SCALE: NTS

PROJECT: 3 MW MAN-ASOK RIVER HYDROELECTRICPOWER PLANT
LOCATION: BARANGAY SEBANG, BUGIAS, ATOK BENGUET
OWNER: BENGUET ELECTRIC COOPERATIVE, INC.
SHEET CONTENTS: HYDRAULIC GRADIENT DIAGRAM
CONSULTANT: AVGarcia Power Systems Corp.
DESIGN: ARNOLD V. GARCIA ENGINEER

Hydro Electric Power Basics

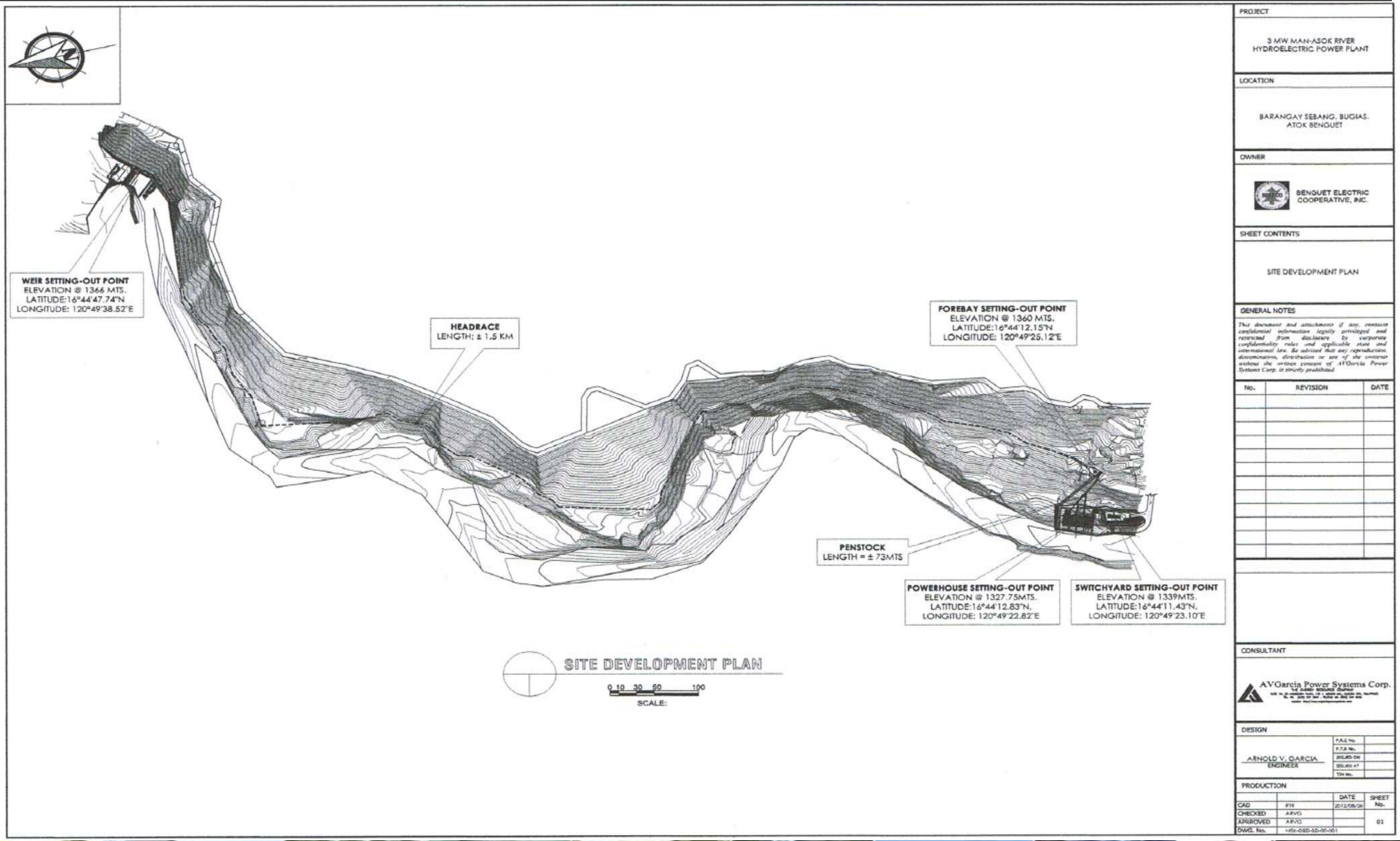


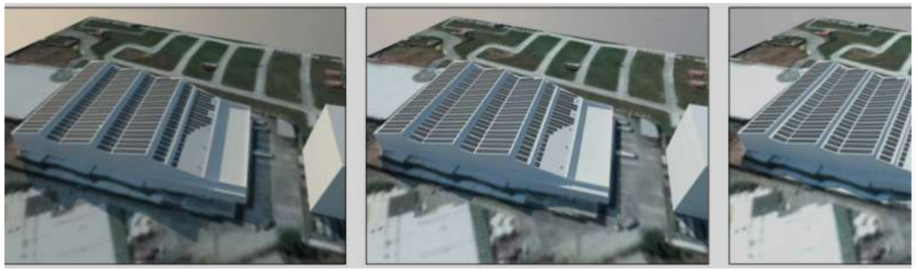
	1%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Dependable Flow	41.82	31.30	23.14	18.17	15.26	12.90	11.48	10.13	9.096	8.336	7.286	6.554	5.442	4.840	4.241	3.816	3.466	3.238	3.050	2.911	2.808
Net Flow for Power	33.45	25.04	18.51	14.53	12.21	10.32	9.186	8.109	7.277	6.669	5.829	5.244	4.353	3.872	3.393	3.052	2.773	2.591	2.440	2.329	2.246
Power Generation	10.32	10.32	10.32	10.32	10.32	10.32	9.186	8.109	7.277	6.669	5.829	5.244	4.353	3.872	3.393	3.052	2.773	2.591	2.440	2.329	2.246

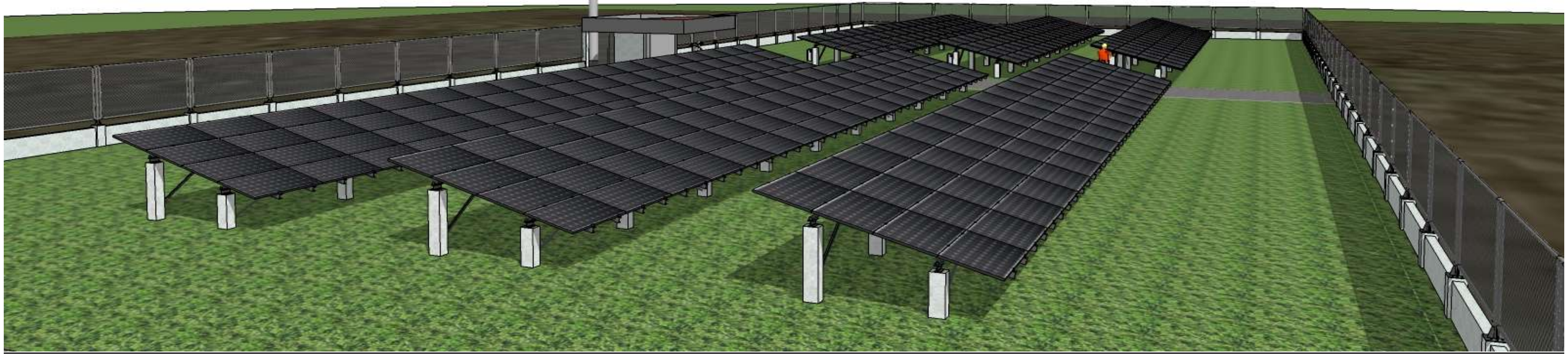
Hydro Electric Power Basics

River Hydrology			Generation Analysis - Reference Base @ 30% Exeedance							
% Exeedance	Q, cms	Net Q, cms	Design Q cms	kWe	Days Operational	Days Generation	Generation kWH	Qty	kWe	% Loading
1%	41.823	33.458	10.324	3,000	4	4	262,800	3	3,000	100%
5%	31.308	25.046	10.324	3,000	18	15	1,051,200	3	3,000	100%
10%	23.149	18.519	10.324	3,000	37	18	1,314,000	3	3,000	100%
15%	18.173	14.538	10.324	3,000	55	18	1,314,000	3	3,000	100%
20%	15.264	12.211	10.324	3,000	73	18	1,314,000	3	3,000	100%
25%	12.905	10.324	10.324	3,000	91	18	1,314,000	3	3,000	100%
30%	11.483	9.186	9.186	2,609	110	18	1,142,702	3	3,000	87%
35%	10.136	8.109	8.109	2,303	128	18	1,008,664	3	3,000	77%
40%	9.096	7.277	7.277	2,067	146	18	905,182	3	3,000	69%
45%	8.336	6.669	6.669	1,894	164	18	829,573	3	3,000	63%
50%	7.286	5.829	5.829	1,655	183	18	725,098	3	3,000	55%
55%	6.554	5.244	5.244	1,489	201	18	652,257	3	3,000	50%
60%	5.442	4.353	4.353	1,236	219	18	541,506	2	2,000	62%
65%	4.840	3.872	3.872	1,100	237	18	481,598	2	2,000	55%
70%	4.241	3.393	3.393	964	256	18	422,070	2	2,000	48%
75%	3.816	3.052	3.052	867	274	18	379,701	2	2,000	43%
80%	3.466	2.773	2.773	787	292	18	344,897	2	2,000	39%
85%	3.238	2.591	2.591	736	310	18	322,244	1	1,000	74%
90%	3.050	2.440	2.440	693	329	18	303,563	1	1,000	69%
95%	2.911	2.329	2.329	661	347	18	289,659	1	1,000	66%
100%	2.808	2.246	2.246	638	365	18	279,431	1	1,000	64%
Gross Annual Generation Capability			kWH				15,198,143			
Equivalent Annual Capacity			kW				1,735			
Annual Theoretical Generation			kWH				26,280,000			
Plant Capcity Factor							58%			
Plant Configuration				3	1,000		3,000			
Net Annual Generation Capability			kWH		2.25%		14,856,185			

Hydro Electric Power Basics







Solar Photovoltaic

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Solar Resource

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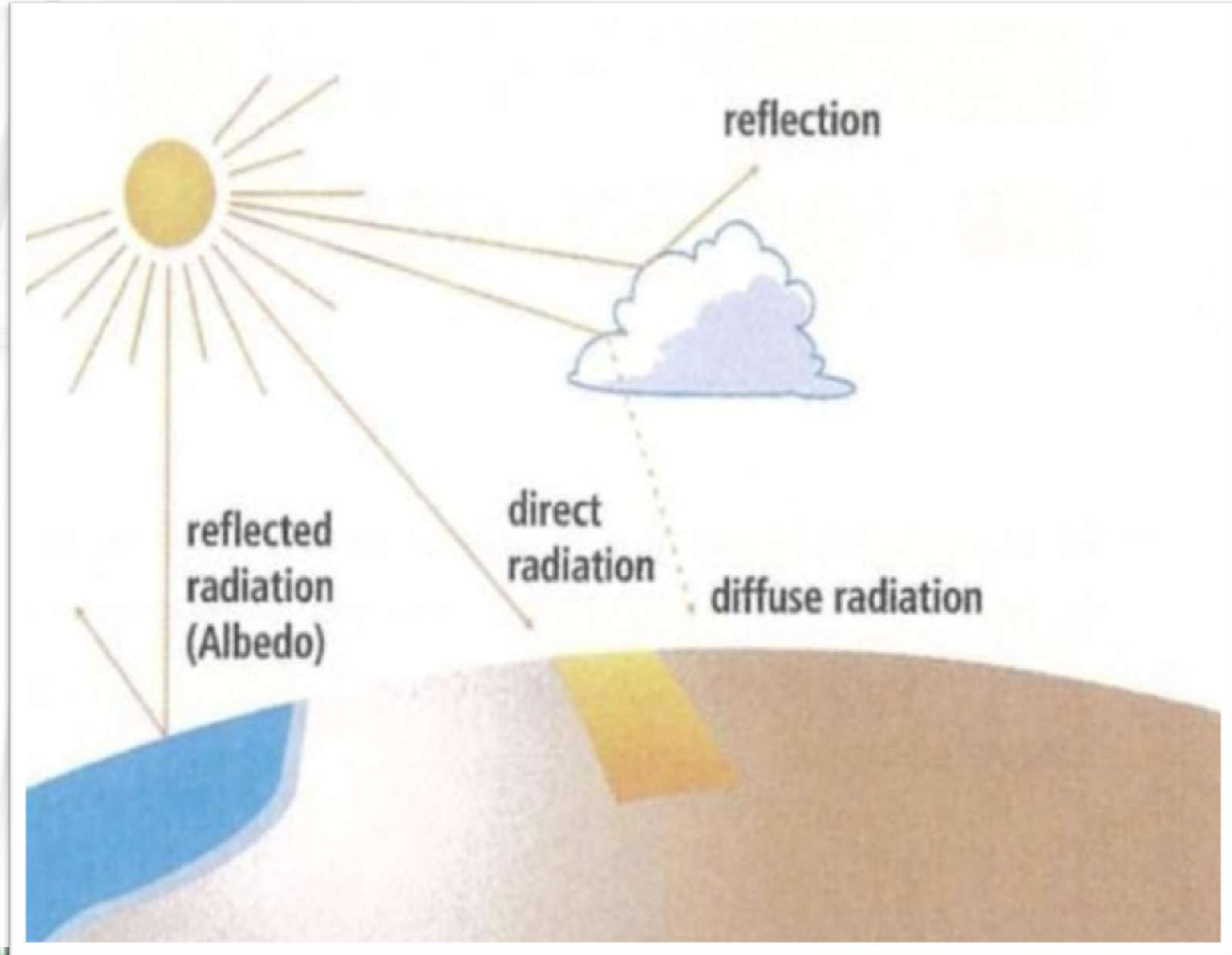
Components of Sunlight

- **Solar Constant**
  $G_o = 1360\ W/m^2$
- **Attenuation** of atmosphere reduces energy on Earth
  - **Direct** beam
  - **Diffuse** beam



Hay Davies Klucher Randl Model

Direct Beam Radiation

Ratio of Beam to Direct Radiation

Diffuse Beam Radiation

Slope of surface

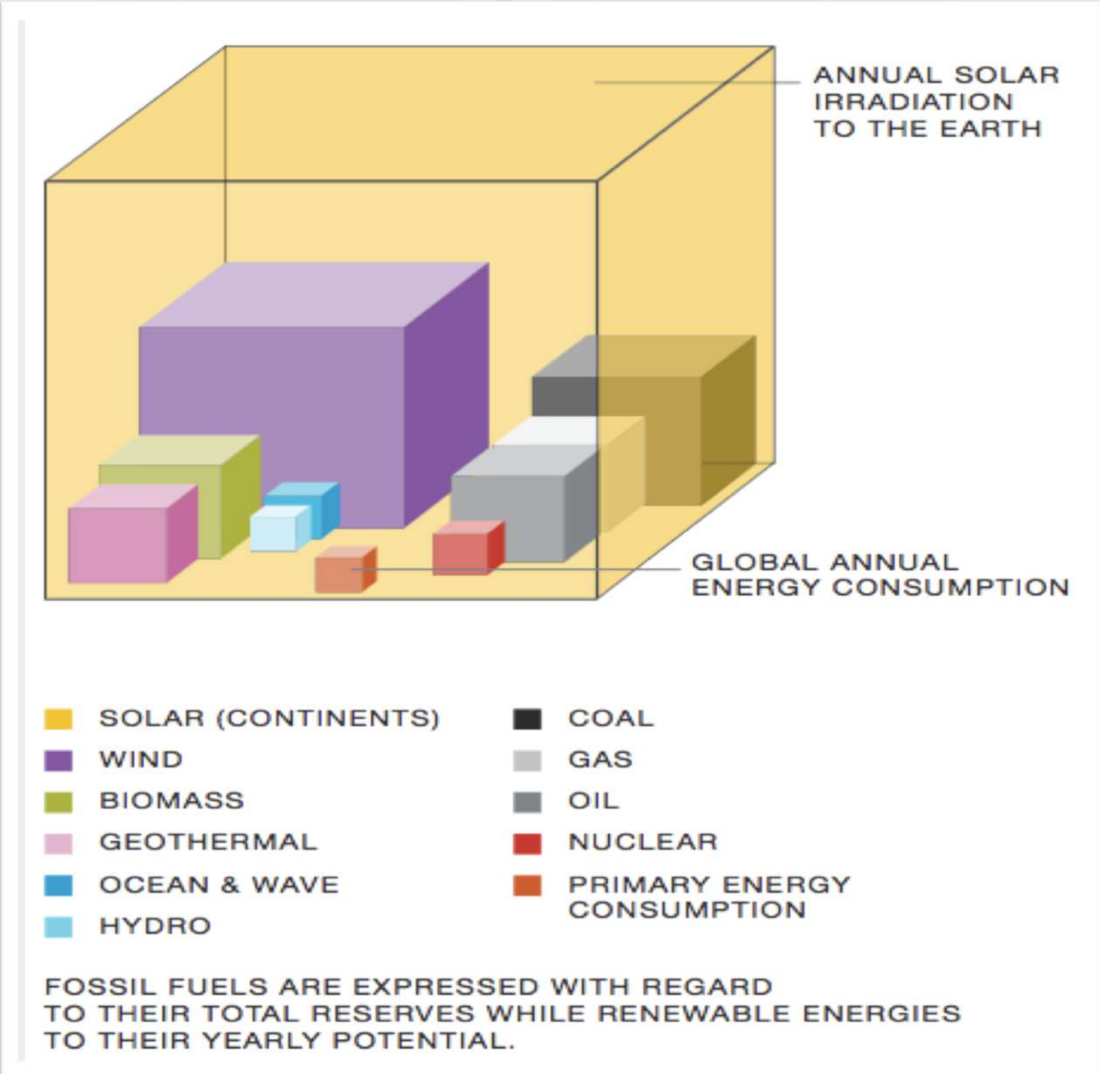
$$I_T = (I_b + I_d A_i)R_b + I_d(1 - A_i)\left(\frac{1 + \cos\beta}{2}\right)\left[1 + f\sin^3\left(\frac{\beta}{2}\right)\right] + I\rho_g\left(\frac{1 - \cos\beta}{2}\right)$$

Anisotropy Index

Form Factor

Reflectivity factor

Solar Resource



Solar Energy has the **largest energy reserve**, can supply world's energy requirements

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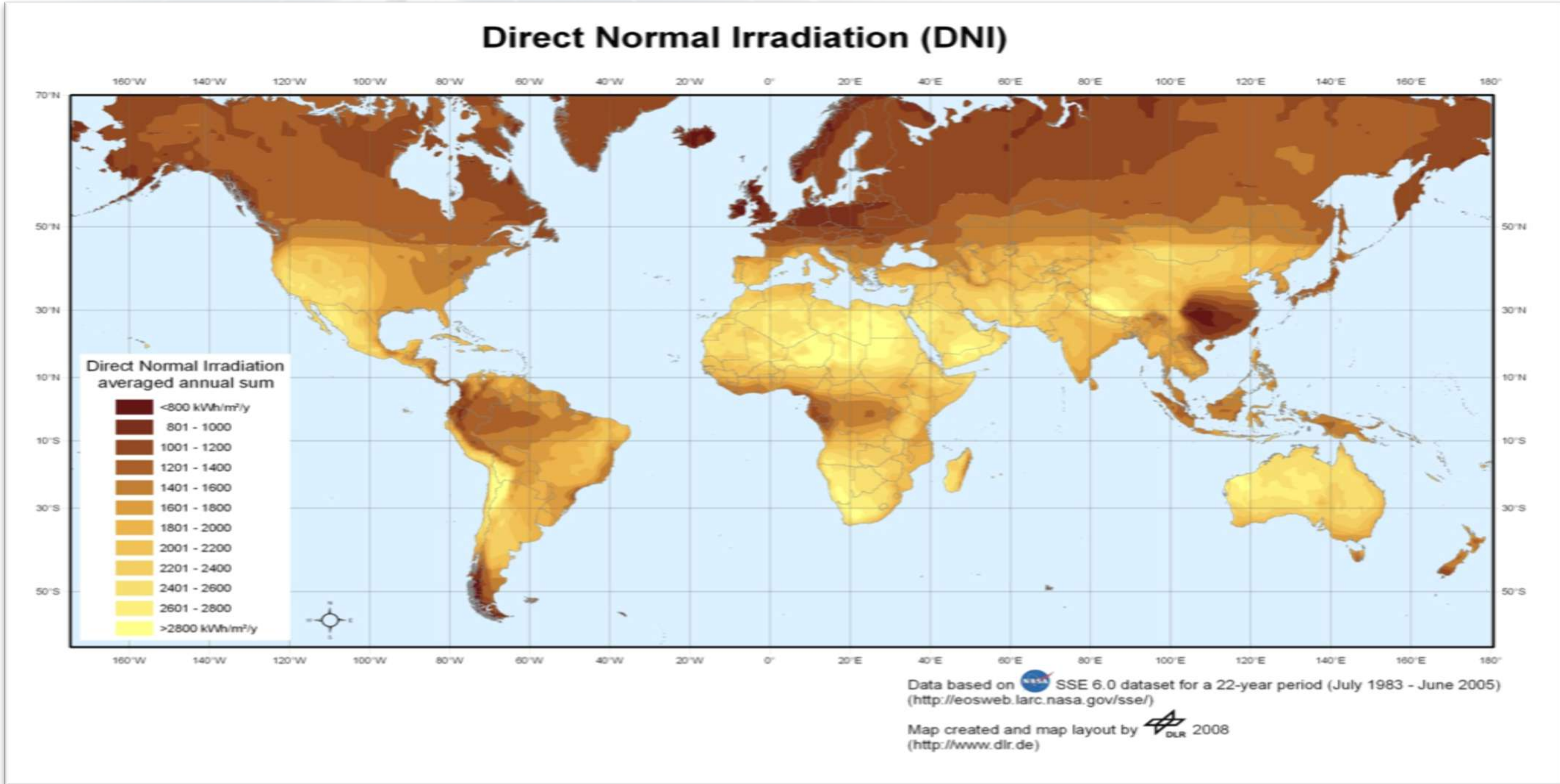
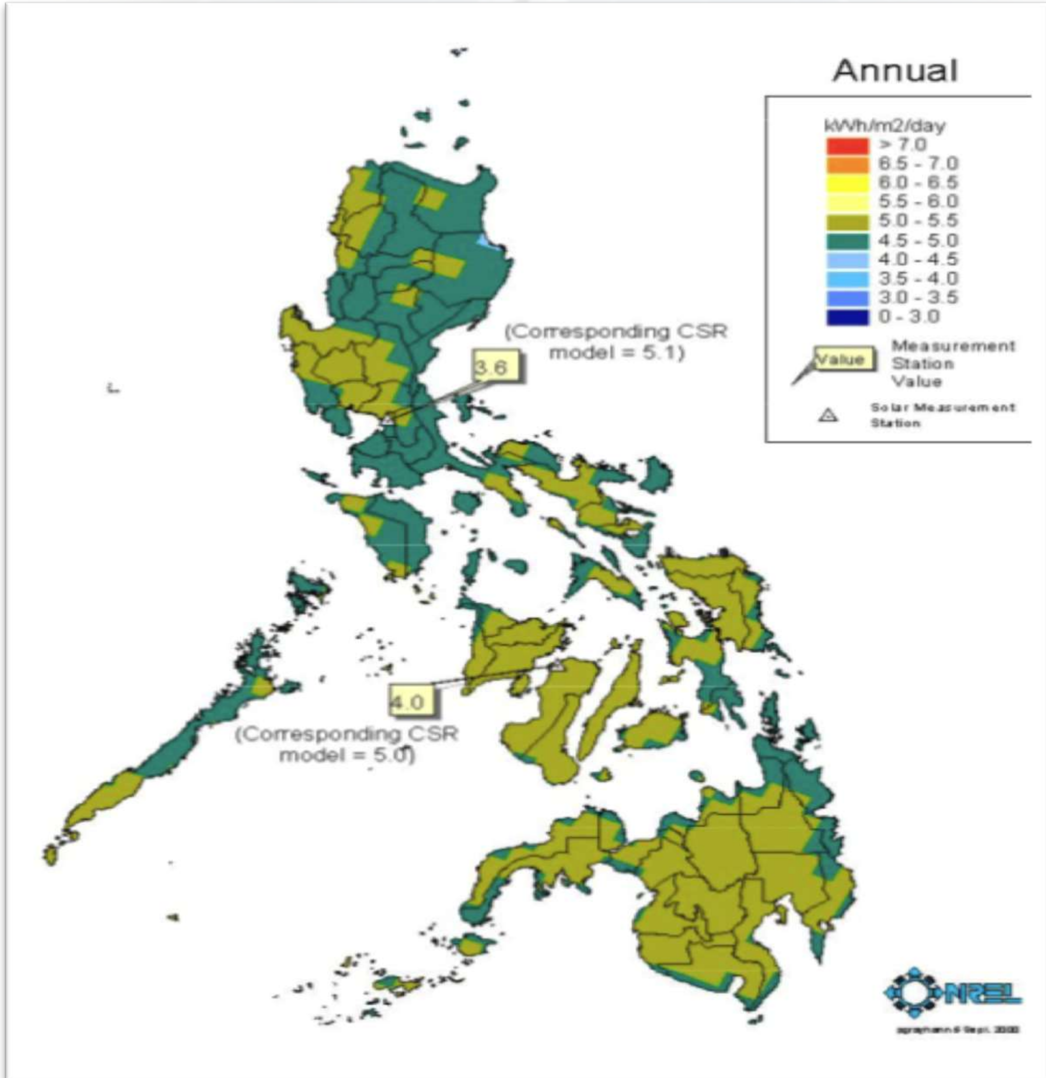
Global Solar Resource

Geography and location has a large impact on the availability of sunlight



Philippines Solar Resource



- **NREL** Solar Resource Map
  - **4.5 to 5.5** kWh/m²-day
  - **1600 to 2000** kWh/m²-year
- Germany: **800 -1000** KWh/m²-year

Germany installed solar - 22GW as of 2012
Philippines current total demand is 15GW

Solar PV System

- On Grid System
  - Operating in parallel with a power grid or reference grid
  - Does not require battery supply or back-up
  - When reference power grid is down, it can not operate as an island power source
  - Reference grid can either a utility system or an independent generator system

- Off Grid System
  - Operating without a reference grid
  - Requires battery supply or back-up
  - It operates as an island power source

Solar PV System

- Hybrid System
  - Operating with a reference grid
  - Reference grid can be any other power supply, but ideally a diesel generating set that can be de-loaded quick enough as the solar resource varies.
  - Ideally can be combined with wind and/or hydro technology to reduce further dependence on diesel technology as reference grid
  - In combination with a reference grid, can work as an island power grid

Solar Design Considerations

- **Capacity Determination**
  - Different Parameters between On-Grid and Off-Grid Systems
  - On Grid systems are demand (load profile) dictated
    - How much solar power penetration is allowed?
  - Off Grid systems are demand and autonomy time dictated
  - Hybrid Systems are dictated by demand and reference grid stability

- **PV Module String**
  - Limited by the capacity, type and model of the inverter
    - String voltage vs inverter input voltage limit
    - Number of string inputs per inverter

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Solar Design Considerations

- **Inverter Selection**
  - String or Central Type
  - With or without transformers?
  - DC Input voltage limitation
  - Single phase or Three phase
  - AC Output voltage
  - Performance Factor
  - Efficiency

- **Grid Interface**
  - Central or Distributed Type
  - AC Integration Voltage
  - Grid Interface Voltage

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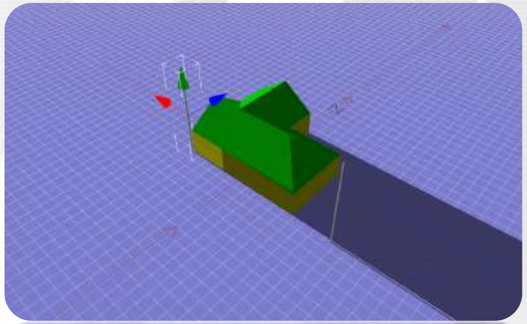
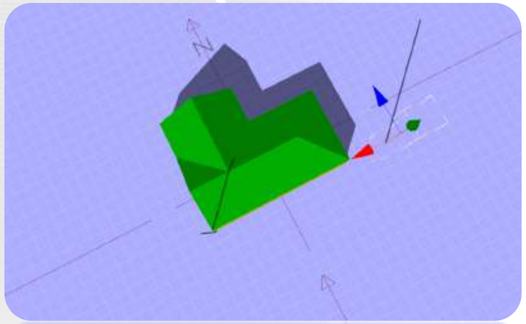
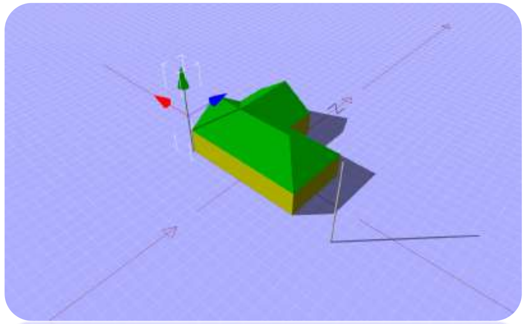
Solar Design Considerations

- **Orientation**
  - Will impact **yield and economics** of PV system
  - Ideally south facing

Solar Design Considerations

- **Shadowing**
  - Results in heating of part of the solar array, depending on the degree of shadowing

Solar Design Considerations

- Resource data is **site specific**
  - Data available is typically for the **global horizontal**
  - Varies with **latitude**, and local **geographic** and **climatic conditions**
- Solar resource **varies with orientation** of the receiving surface
  - **Optimal slope** needs to be determined
- Ability to **understand site specific** resource, and resource with respect to **orientation** is **critical** in success

Other System Considerations

- **Module**
  - Temperature **Deration**
  - **Line** Losses
- **Inverter**
  - System **grounding**
  - Physical **earth**
  - **Input** parameters
- **Surge** Protection
- **Tracking**
  - **Moving** parts
- **Maintenance**
  - Module **dusting**
  - Inverter **cooling**

Design Considerations

- Good engineering design
  - Impact of resource
  - Impact of temperature
  - Module selection
  - Inverter selection
  - Grid interconnection
  - Overall performance
- Performance Ratio - 75% to 80%

Solar Photovoltaic Technology

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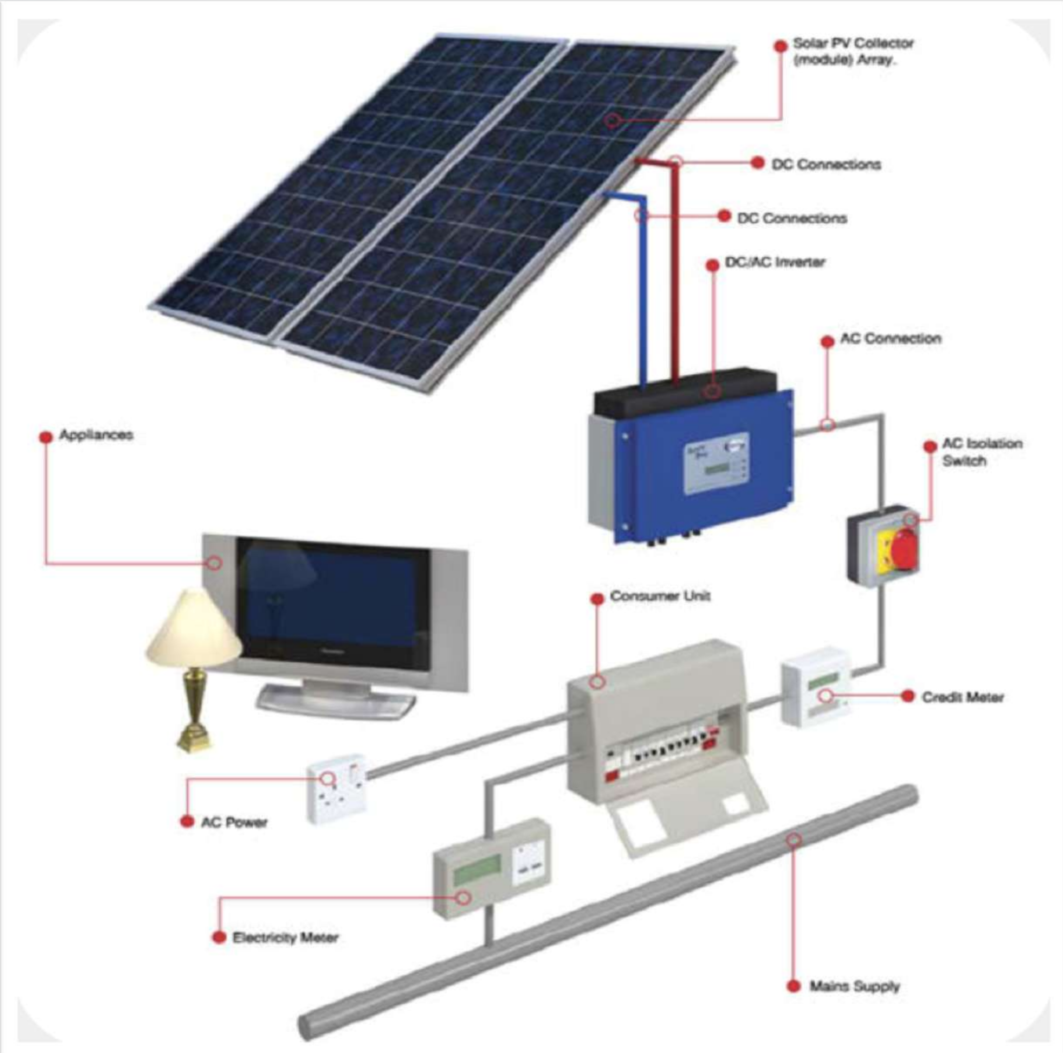
Solar PV Technology

- Solar Photovoltaic **Modules**
- **Inverters**
- **Mounting**
- Grid **Interconnection**



Solar Photovoltaic Technologies

Crystalline Silicon

- Made out of cutting crystal silicon into wafers
- Delivered as modules (with or without frame)
- High efficiency
  - Monocrystalline – up to 25%
  - Polycrystalline – up to 18%
- Reliable technology
- Rigid

Thin Film Technologies

- Printing technology (chemical deposition)
- Delivered as modules
- Lower efficiency
  - Amorphous Silicon - 7%
  - CdTe – 8%
  - CIS – 10%
- Newer Technology with limited field experience
- Flexible

Solar Photovoltaic Technologies

Photovoltaic Technology	Description
Monocrystalline Silicon	Uses crystalline silicon cells manufactured using Czochralski process. Expensive but efficient.
Polycrystalline Silicon	Uses crystalline silicon cells manufactured using the ingot process. Moderately expensive, but less efficient.
Amorphous Silicon Thin Film	Uses sputtering techniques for silicon deposition. Cheap, but highly inefficient.
CIGS Thin Film	Uses chalcopyrite to create PV junction. Cheap, but inefficient.
CdTe Thin Film	Uses II-VI semiconductors. Cheap but inefficient.

Thin Film PV

- Deposition of extremely thin layers of photosensitive materials on a low cost backing (glass, stainless steel or plastic)
- Advantages
  - Low consumption of raw materials
  - Suitable for building integration
  - High automation of production
- Disadvantages
  - Lower efficiencies
  - Less experience on module lifetime performance
  - Production is still small

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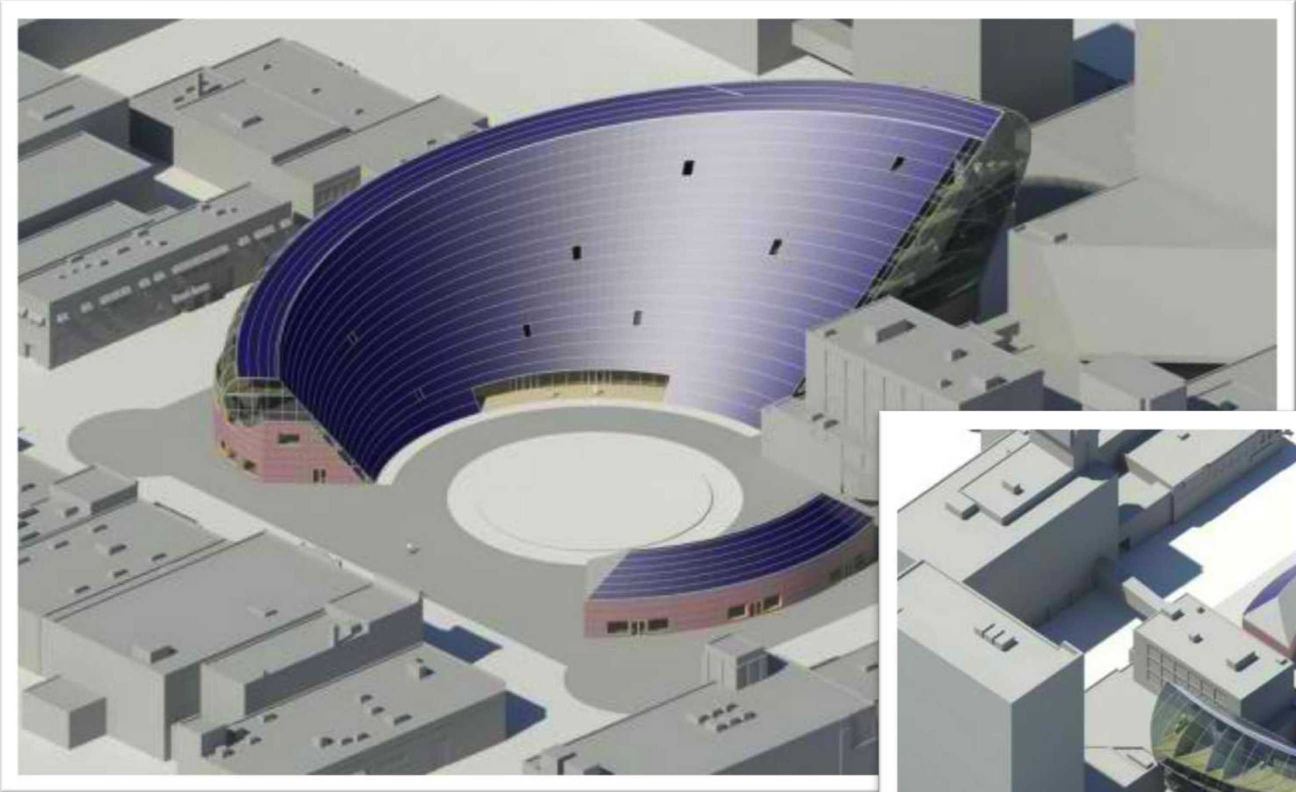
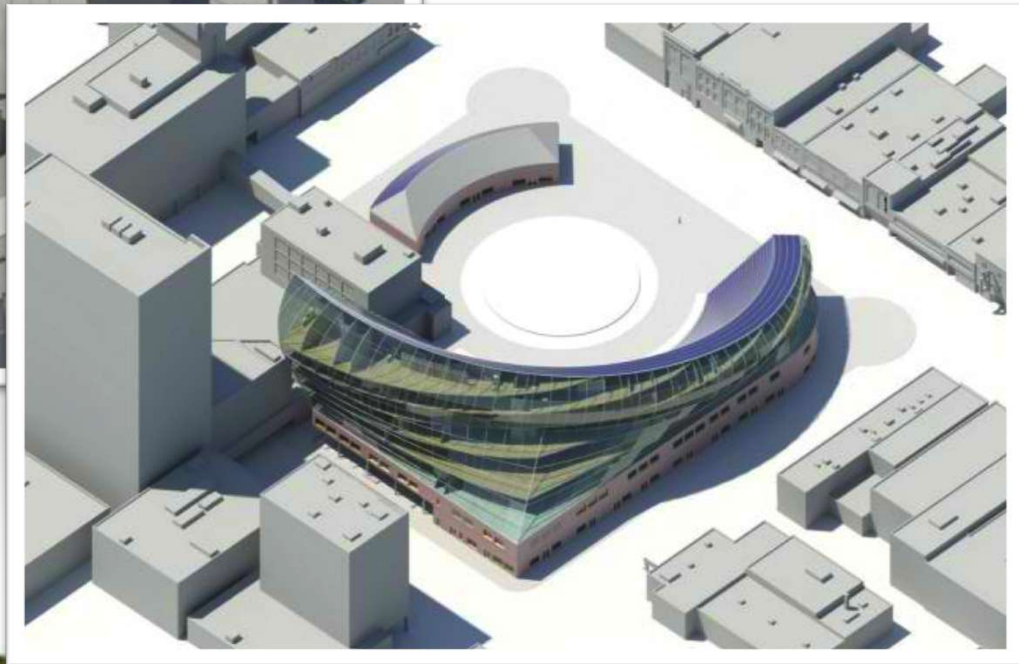
Thin Film

Solar Carport

- Approximately 40 to 120 Watts per square meter for Thin Film

Solar Building Skins





Inverter Technologies

Inverter Class	Typical Capacity	Inverter Efficiency
Central	> 25 KW	97%
String	Between 1 KW and 25 KW	95%
Module	< 1 KW	93%

Inverter Installation – 40 kW Rooftop

Transformer vs. Transformerless

Transformer-based Topographies

- Less efficient
- Heavier
- Bulkier
- Provides galvanic isolation

Transformerless Topographies

- More efficient
- Lighter
- Smaller
- Does not provide galvanic isolation

Grid-interconnection important!

Module-type important!

Mounting Technologies

- Orientation of the surface affects the availability of resource (sunflower concept)
- Classes
  - Fixed Tilt
  - Fixed Tilt with Seasonal Adjustment
  - Single Axis Tracking (North-South Axis)
  - Single Axis Tracking (East-West Axis)
  - Two Axis Tracking

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Mounting Systems

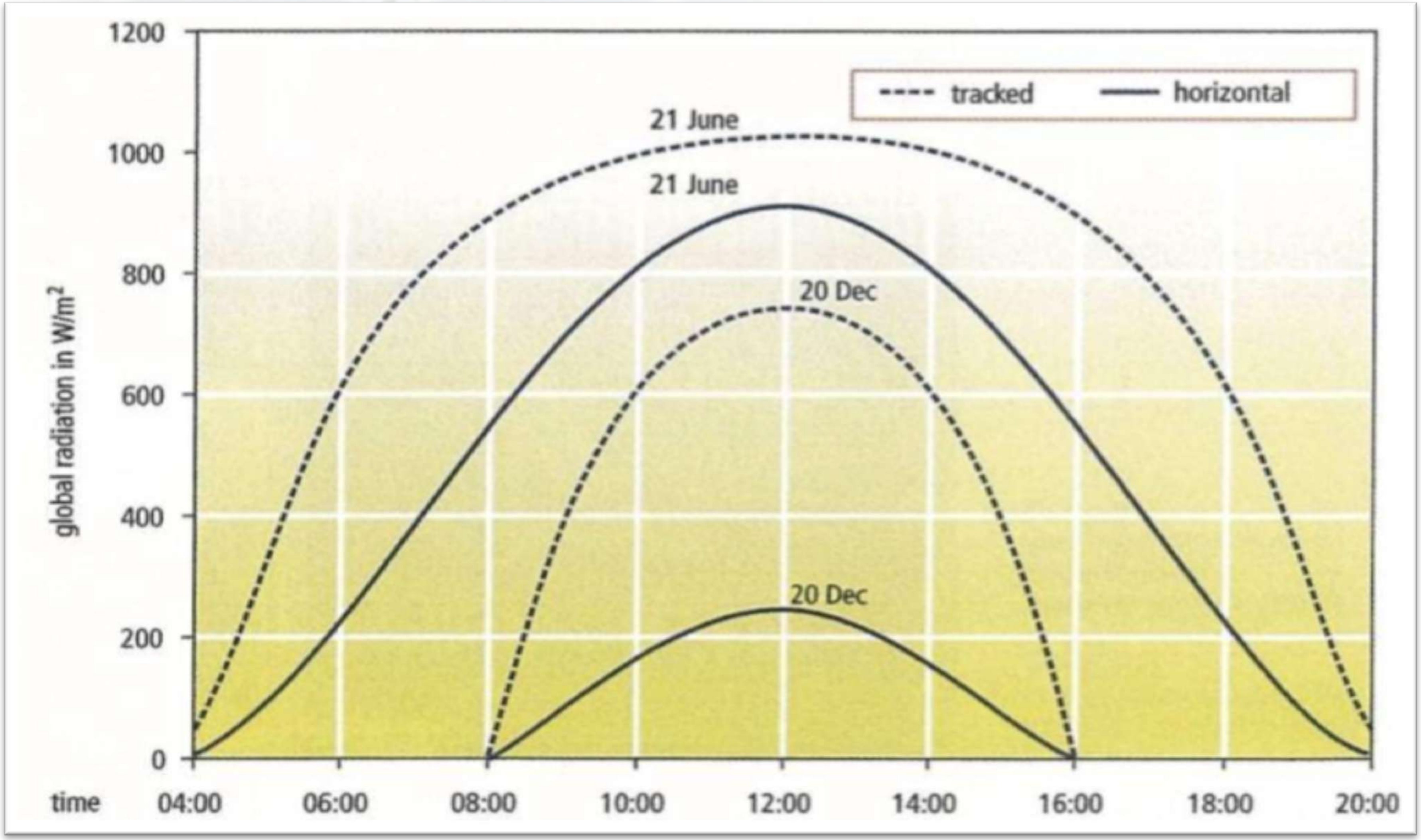
Mounting System	Description
Fixed Tilt	Fixed tilt system with module orientation at zero azimuth and slope equals latitude
Fixed Tilt with Seasonal Adjustment Mounting	Fixed tilt system at zero azimuth and quarterly adjustments to the slope for seasonal optimization
North-South Single Axis Track	Single axis tracking system mount that tracks the seasonal variation of the sun's position
East-West Single Axis Track	Single axis tracking system mount that tracks the daily variation of the sun's position
Two Axis Track	Two-axis tracking system that that fully optimizes resource availability

Mounting Technologies

Single Axis Trackers

Two-Axis Trackers

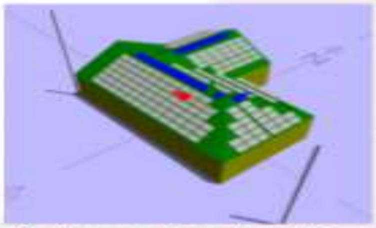
Resource of Tracked versus Fixed



Solar PV Project Development and Economics

Site evaluation – Solar Pathfinder

Site evaluation – Pyranometer and Datalogger



Shadow model and analysis

Installation work

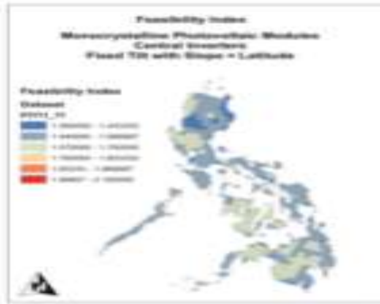
Project Conceptualization
Pre-feasibility Study
Financing Options

Resource Analysis
Site Assessment
Shadowing Analysis

Detailed Engineering
Feasibility Study
Roof Structural Verification
Detailed Engineering

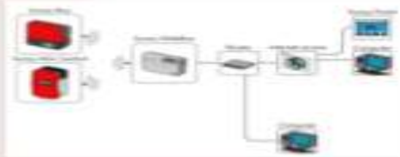
Execution
Procurement and Importation
Construction
Project Management

Operations and Maintenance
Warranty Reporting
Operation and Maintenance Contracts



Feasibility Index Maps

Detailed Engineering

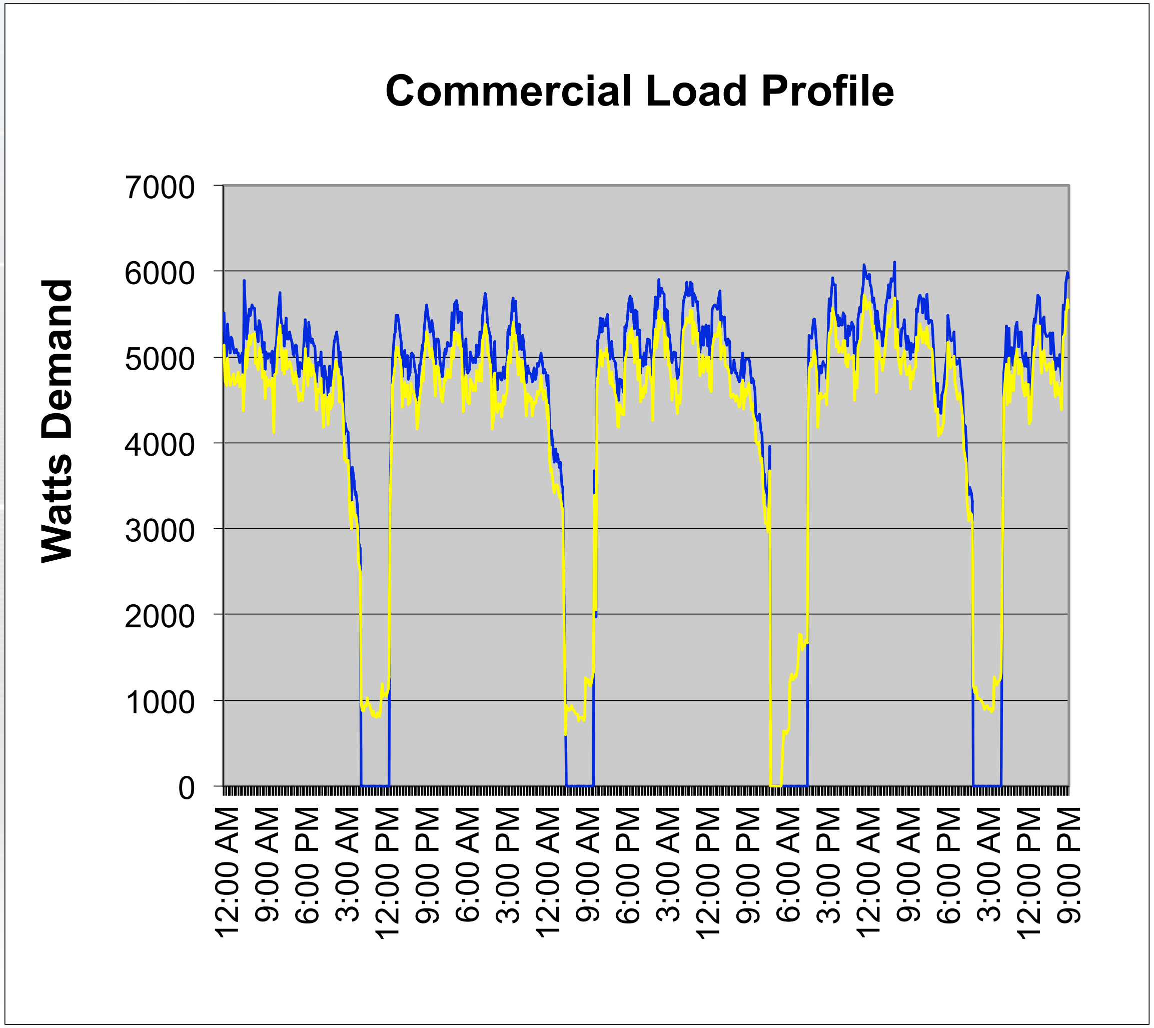


Communications

Commissioning

Capacity Definition

- Review of Load Profile
- Without net-metering with utility, solar PV electricity has to be 100% consumed
- With net-metering, excess solar PV electricity can be sold to distribution utility



Power Generation

Power Generation	
100	KWp
4.75	Sun-hours Per Day
365	Days Per Year
80%	Performance Ratio
138700	KWh per year

Economics

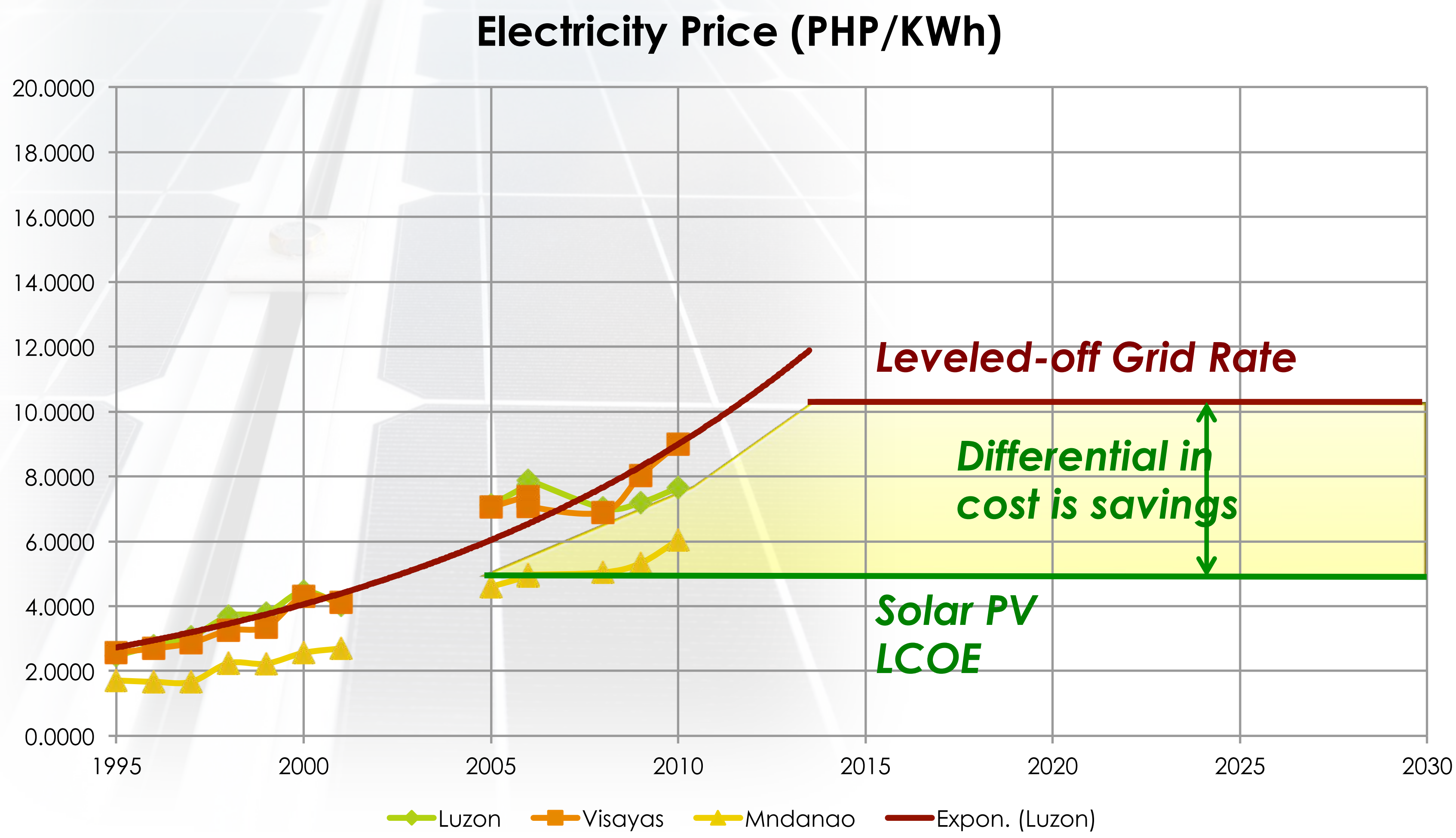
	USD	PHP
Total Capital and Operating Cost	400 Thousand	17 Million
Total Energy Generation (KWh)	3.2 Million	3.2 Million
LCOE (Currency/KWh)	**0.129**	**5.31**

- Consider degradation rate (0.5%)
- Most operational issues come from inverters.
- Maintenance cost assumption replaces inverter every 10 years

Economics

	100 kWp	500 kWp	
Cost Recovery	**8 to 10**	**8 to 10**	**Years**
25-YEAR SAVINGS	**30 Million**	**160 Million**	**PHP**
INVESTMENT COST	17 Million	65 Million	PHP
LEVELIZED COST OF SOLAR	**4-6**	**4-6**	**PHP/ KWH**

Electricity Cost Savings



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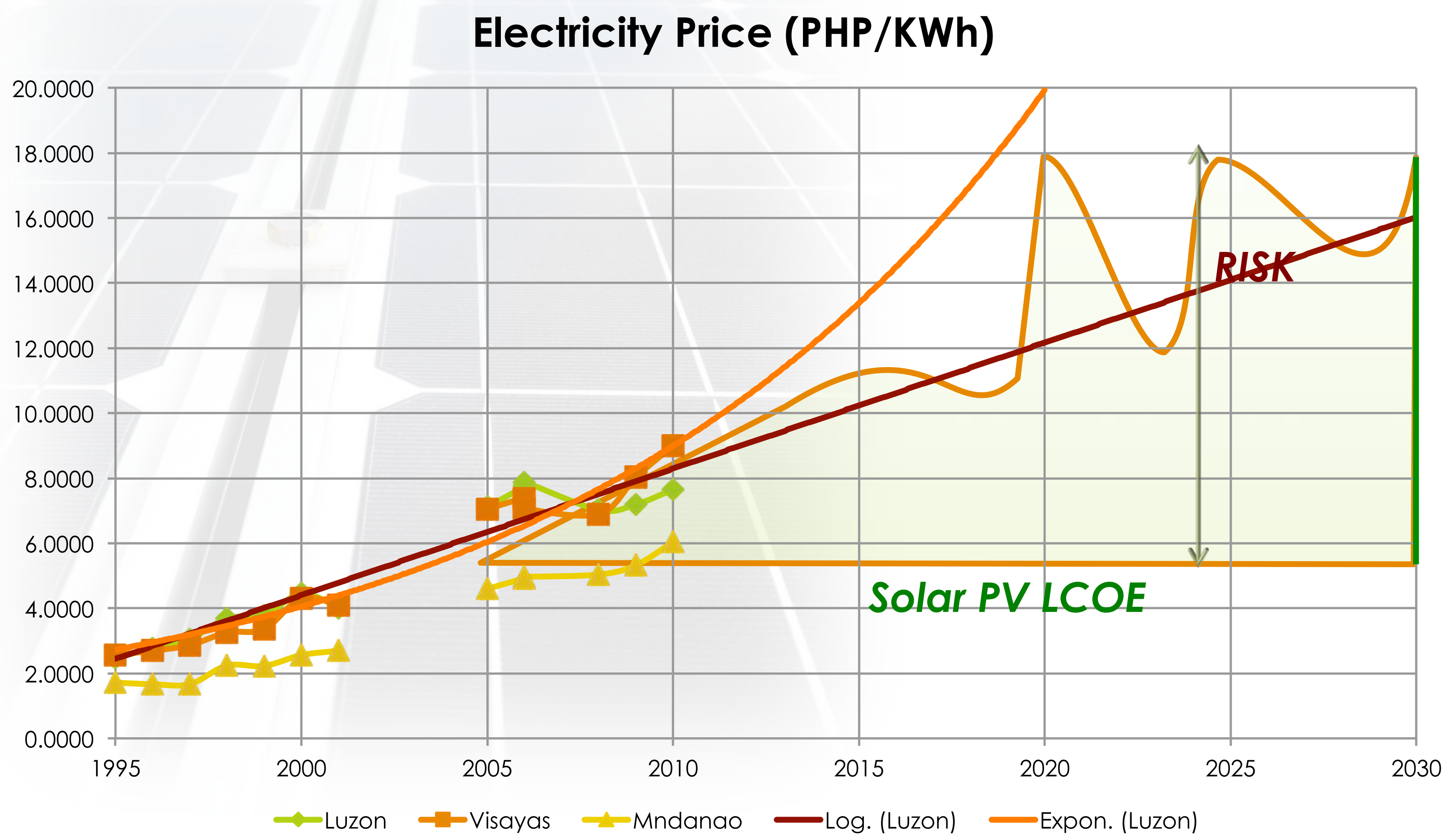
Electricity Cost Savings



Environmentally-friendly Energy

- **Avoidance** of greenhouse gas emissions

- **Contribute** to the global climate change mitigation efforts

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Solar Car Parks and Waiting Sheds

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Solar Rooftops

- Approximately 120 to 180 Watts per square meter for Crystalline

Solar Building Skins

40 kW Rooftop Installation - Dagupan

Solar Building Skins

Solar Building Skins (Retrofit)

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AVGarcia Power Systems Corp.
The Energy Resource Company
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Renewable Energy

Power Generation Systems

Adel Garcia, Jr. – PEE

Mobile: +63 917 522 2225

Email - adelgarcia@gmail.com

Short Resume

Adelino V. Garcia, Jr.

Professional Electrical Engineer – 1584

Chairman and President
AVGarcia Power Systems, Corp.
Quezon City, Philippines

Director
Caraga Renewable Energy Corp

35 Years of Energy Systems Engineering and Integration
Project Management, Execution and Implementation
Business Development and Management

Short Resume

Expertise and Qualifications:

- Energy Engineering and Systems Integration of various technologies such as: Coal Thermal; Combustion Gas Turbine; Heavy/Light Fuel Oil; Biomass and Biogas; Hydroelectric, Solar PV, Wind and Fuel Cell Energy Generation Facilities

- Business and Project Development of Conventional and Renewable Energy Generation Technologies

Short Resume

Expertise and Qualifications:

- Project Development, Design and Engineering, Project Execution and Management, Operation and Maintenance of various Power Generation Facilities (PGF):
  - > 3,000MW of Coal Thermal PGF
  - > 1,500MW of HFO/LFO Diesel PGF
  - > 1200MW Combustion Turbine PGF
  - > 100MW of Biomass/Biogas PGF
  - >100MW of Run-of-River Hydroelectric PGF
  - >100MW of Solar PV PGF
  - >50MW of Fuel Cell /Hydrogen Technology

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Short Resume

Expertise and Qualifications:

- Engineering and Execution of Grid Connection Facilities for PGFs:
  - > 2000MW of 500kV Switchyards
  - > 1,500MW of 230kV Switchyards
  - > 1,000MW of 115/138kV Switchyards
  - ➢ 1,000MW of 72kV Switchyards & Substations
  - ➢ 100MW of 36kV Switchyards & Substations
  - ➢ 100MW of 15kV Switchyards & Substations

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