Solar Micro-grid Technology and Cost

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Outline of Presentation

- Basics of Solar Energy
- Solar Photovoltaic Technologies
- Solar Thermal Technologies
- Site Selection
- Cost Estimation

Basics of Solar Energy

Basics of Solar Energy

- Electromagnetic radiation emitted by the sun, Diff. wavelengths, Heat, Light & UV
- 1367.7 W/m² outer space, 1000 W/m^2 on earth surface
- Direct radiation
- Diffuse radiation
- Two together referred as global radiation

Solar Radiation Measurements 1/3

- Global horizontal irradiance (GHI): Pyranometer
- Total: Direct + Diffuse
- Useful for PV

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Solar Radiation Measurements 2/3

- Direct Normal Irradiance (DNI): Pyrheliometer
- Direct on perpendicular surface
- Useful for Reflectors, CSP

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Solar Radiation Measurements 3/3

- Solar insolation - total amount of solar energy received at a particular location during a specified time period
- Unit - $kWh/m^2/day$
- Power project :
  - » CSP min. 1800 $kWh/m^2/yr$ (Reported)
  - » SPV min. 1500 $kWh/m^2/yr$ (Suggested)
- Micro-grid: No standard
- Actual ground data: Not always available
- Derived data: NASA, METONORM, GeoModel

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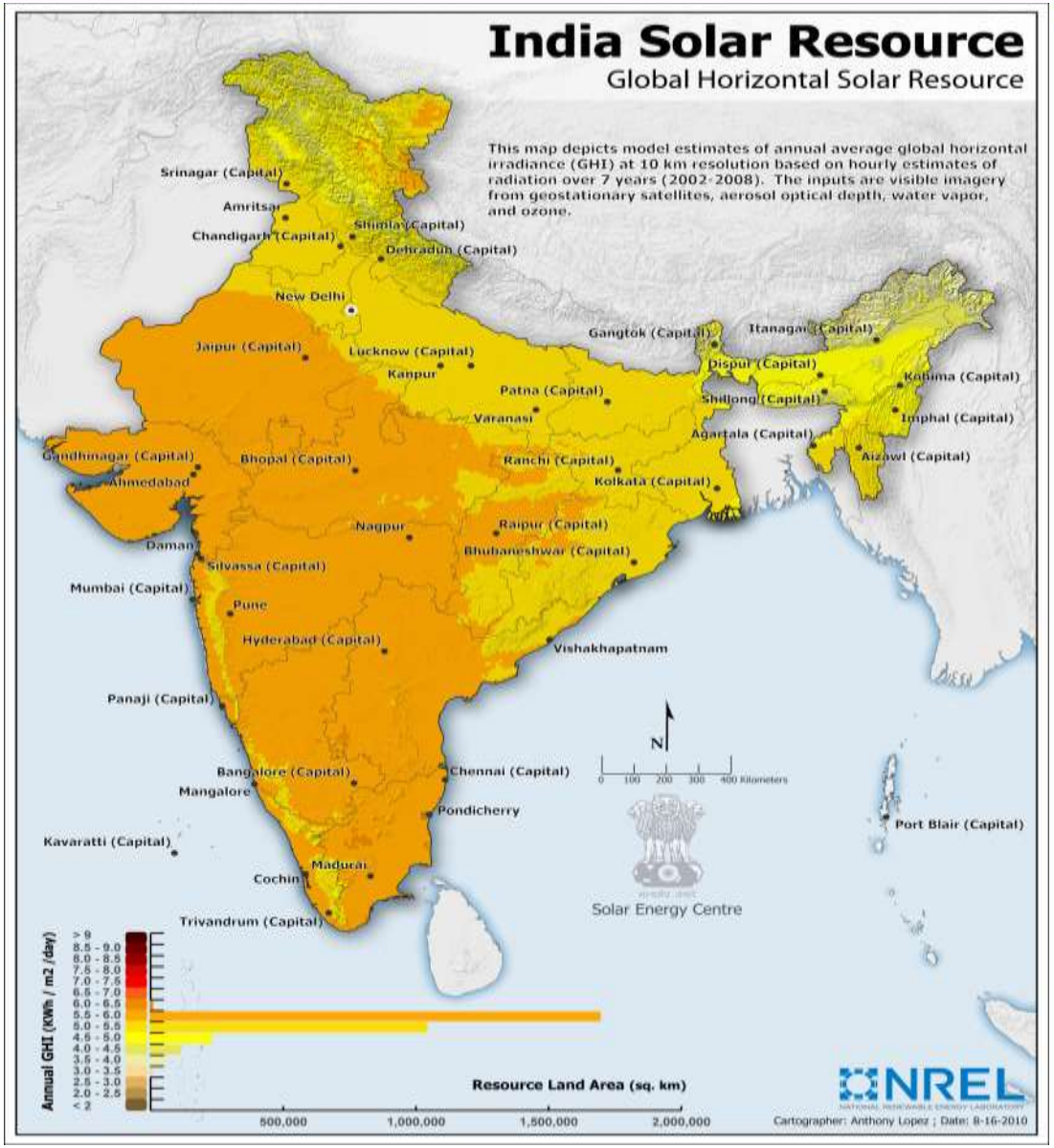
Solar Radiation Map 1/2



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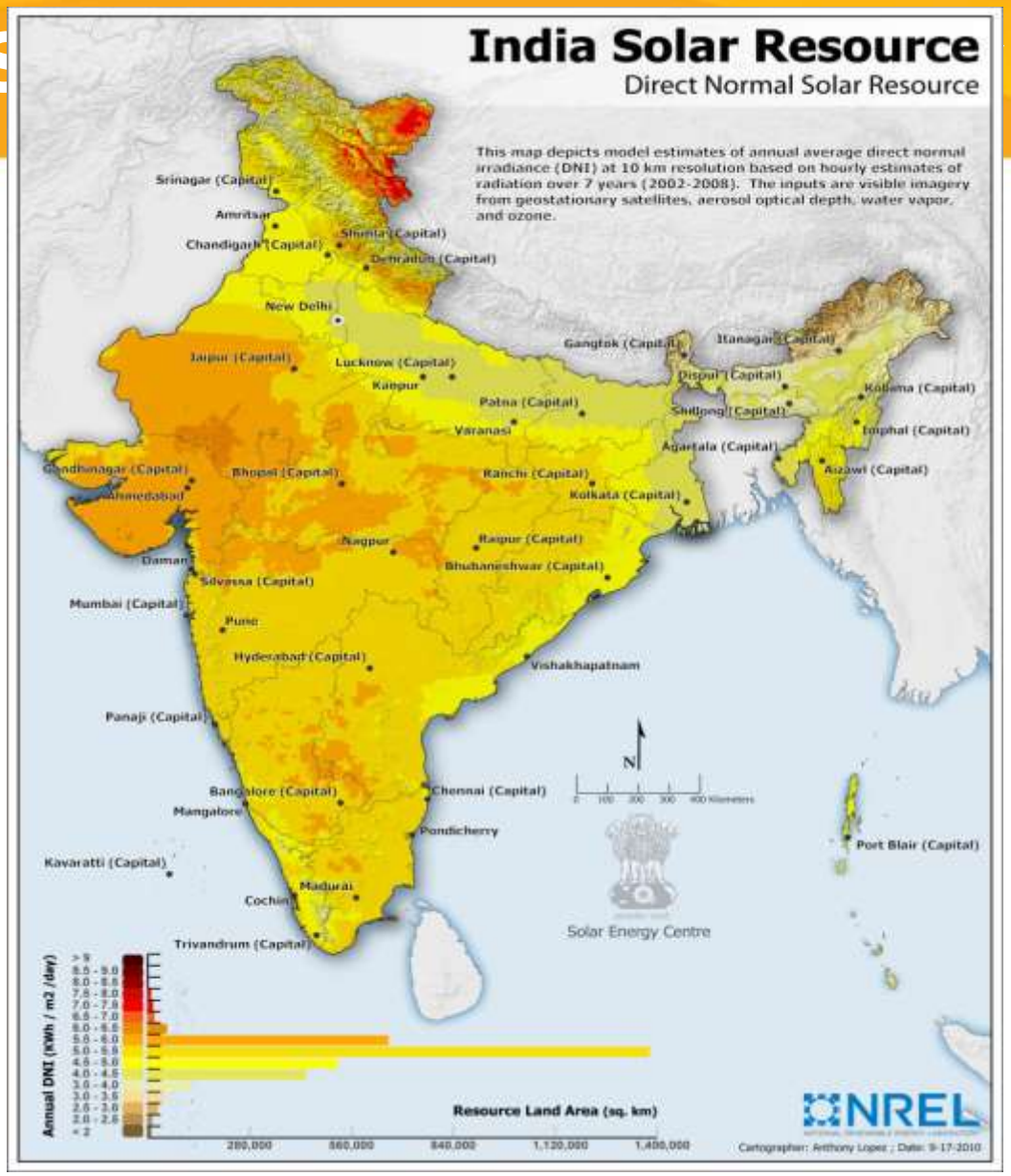
India Solar Resource
Direct Normal Solar Resource
This map depicts model estimates of annual average direct normal irradiance (DNI) at 10 km resolution based on hourly estimates of radiation over 7 years (2002-2008). The inputs are visible imagery from geostationary satellites, aerosol optical depth, water vapor, and ozone.
Srinagar (Capital)
Amritsar
Chandigarh (Capital)
Shimla (Capital)
Dehradun (Capital)
New Delhi
Jaipur (Capital)
Lucknow (Capital)
Kanpur
Patna (Capital)
Varanasi
Gangtok (Capital)
Itanagar (Capital)
Dispur (Capital)
Kohima (Capital)
Shillong (Capital)
Imphal (Capital)
Agartala (Capital)
Aizawl (Capital)
Gandhinagar (Capital)
Bhopal (Capital)
Ahmedabad
Ranchi (Capital)
Kolkata (Capital)
Nagpur
Raipur (Capital)
Daman
Bhubaneshwar (Capital)
Silvassa (Capital)
Mumbai (Capital)
Pune
Hyderabad (Capital)
Vishakhapatnam
Panaji (Capital)
Bangalore (Capital)
Chennai (Capital)
Mangalore
Pondicherry
Port Blair (Capital)
Kavaratti (Capital)
Madurai
Cochin
Trivandrum (Capital)
Solar Energy Centre
Annual DNI (kWh / m2 /day)
Resource Land Area (sq. km)
280,000
560,000
840,000
1,120,000
1,400,000
NREL

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Solar Technology Options

- Solar Photovoltaic Electricity Generation
  - » Convert sunlight falling on PV cell into D.C. electricity
- Solar Thermal Electricity Generation
  - » Solar energy is focused through mirrors to heat working fluid
  - » Heated working fluid produce steam
  - » drive a turbine-generator to produce electricity

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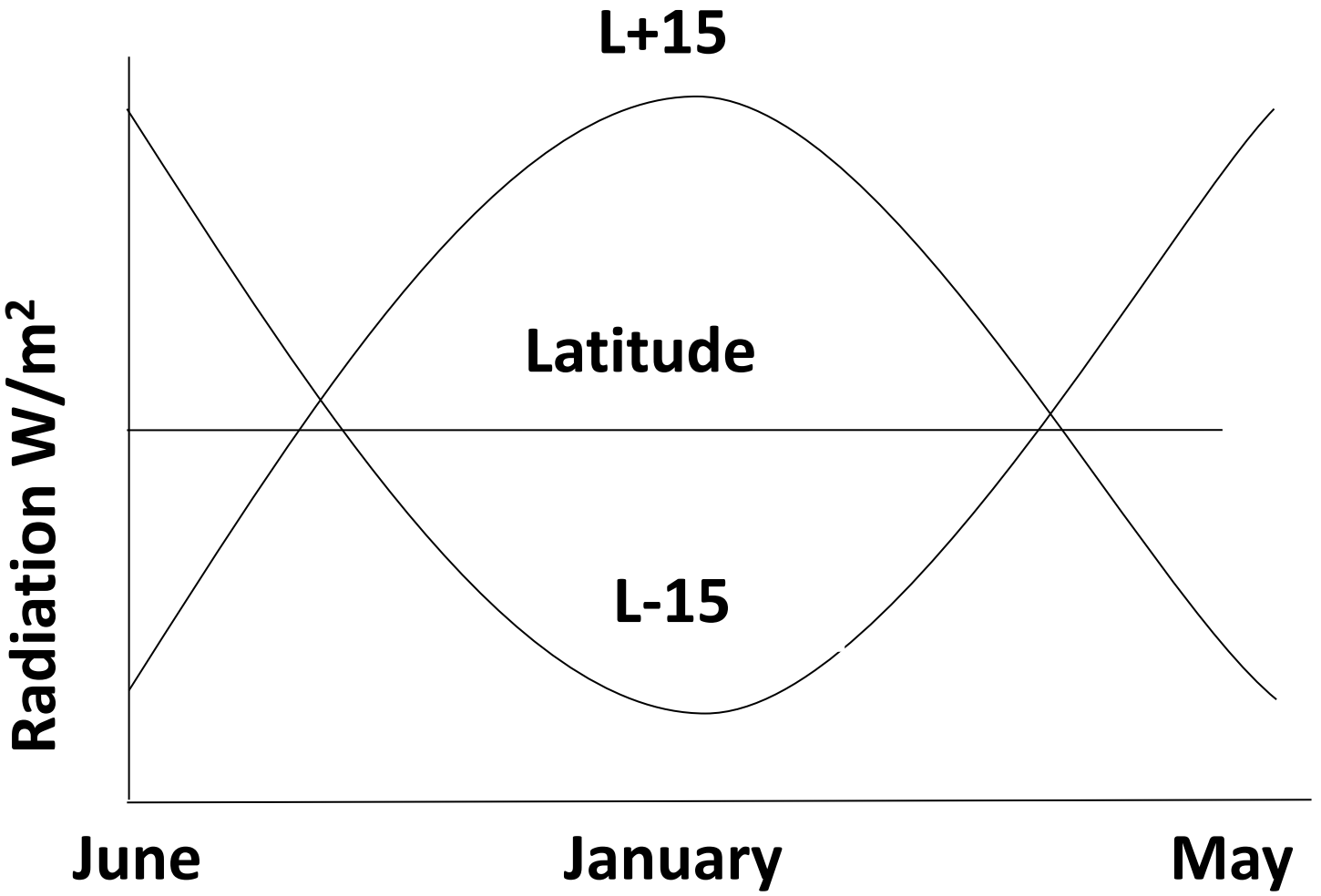
Winter or Summer Optimization



Solar Photovoltaic Technologies

Types of PV Cells

- Crystalline
  - » Mono-crystalline silicon solar cells
  - » Polycrystalline silicon solar cells
- Thin film
  - » Amorphous silicon
  - » Cadmium telluride
  - » Copper indium di-selenide
- Emerging technologies
  - » Gallium arsenide
  - » Organic semiconductors
  - » Dye-sensitized cells
  - » Nanotechnology solar cells
  - » Comparison Study: http://www.wisein.org/pdf/PV_Due_Diligence_Report.zip

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Types of PV Cells

Mono

Poly

Thin Film

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Mono-crystalline Silicon Solar Cells

- Majority solar cells manufacturers
- Input material SiO_2
- Principle of Czocharalski process
- Practical efficiencies - 14 to 17%

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Polycrystalline Silicon Solar Cells

- Second most common natural substance
- Manufacturing process - simpler and cheaper
- Casting process
- Practical efficiencies - 13 to 15%

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Amorphous Silicon Solar Cell

- Requires low process temperature
- Technological capability for large-area deposition exists
- Has low material requirements
- Has larger band gap
- Low energy consumption during manufacture, and
- Possibility of automation of the manufacturing process: Commercialized
- Low efficiency 6-9%, faster degradation, light soaking reduction

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Cadmium Telluride Solar Cell

- Highest theoretical conversion efficiency
- Energy gap of 1.44 e.v.
- Efficiency - 6 to 10%
- Technically best among thin films
- Degradation more than crystalline
- Possibility of production hazards
- Environmental pollution
- Commercialized

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Copper Indium Diselenide Solar Cell

- Ideal material photovoltaic application
- Band gap of 1.53 ev
- Efficiency 11.4%
- Number of alloy components makes the multiple processes extremely complex
- Expensive and rare metals - cost of manufacturing increase
- Not commercialized

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Gallium Arsenide

- Used in space application
- High cost
- Most efficient solar cell
- Cell efficiencies -about 30 to 34%
- Too expensive for terrestrial applications

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Organic Semiconductors

- Manufacture using processes reel-to-reel deposition
- Possibilities for ultra thin, flexible devices
- Solar power conversion efficiencies of over 3%
- Classified into insoluble, soluble and liquid crystalline
- Organic solar cells have a stability problem

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Dye-sensitized Cells

- Photosensitization of wide-band-gap semiconductors
- Does not require high-purity semiconductors
- Efficiencies of 7% on 30 cm x 30 cm areas reached
- Considered as a potential and low-cost PV technology
- Under research

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Nanotechnology solar cells

- To increase the efficiency of solar cells
- To reduce manufacturing cost
- Not made from silicon
- Not require expensive equipment
- Utilize tiny nano-rods
- Spectrum modification
- Rare earth metals: Lanthenides
  - Praseodymium- Pr^{3+}
  - Yttrium fluorides- YF_3
  - Gadolinium- Gd^{3+}

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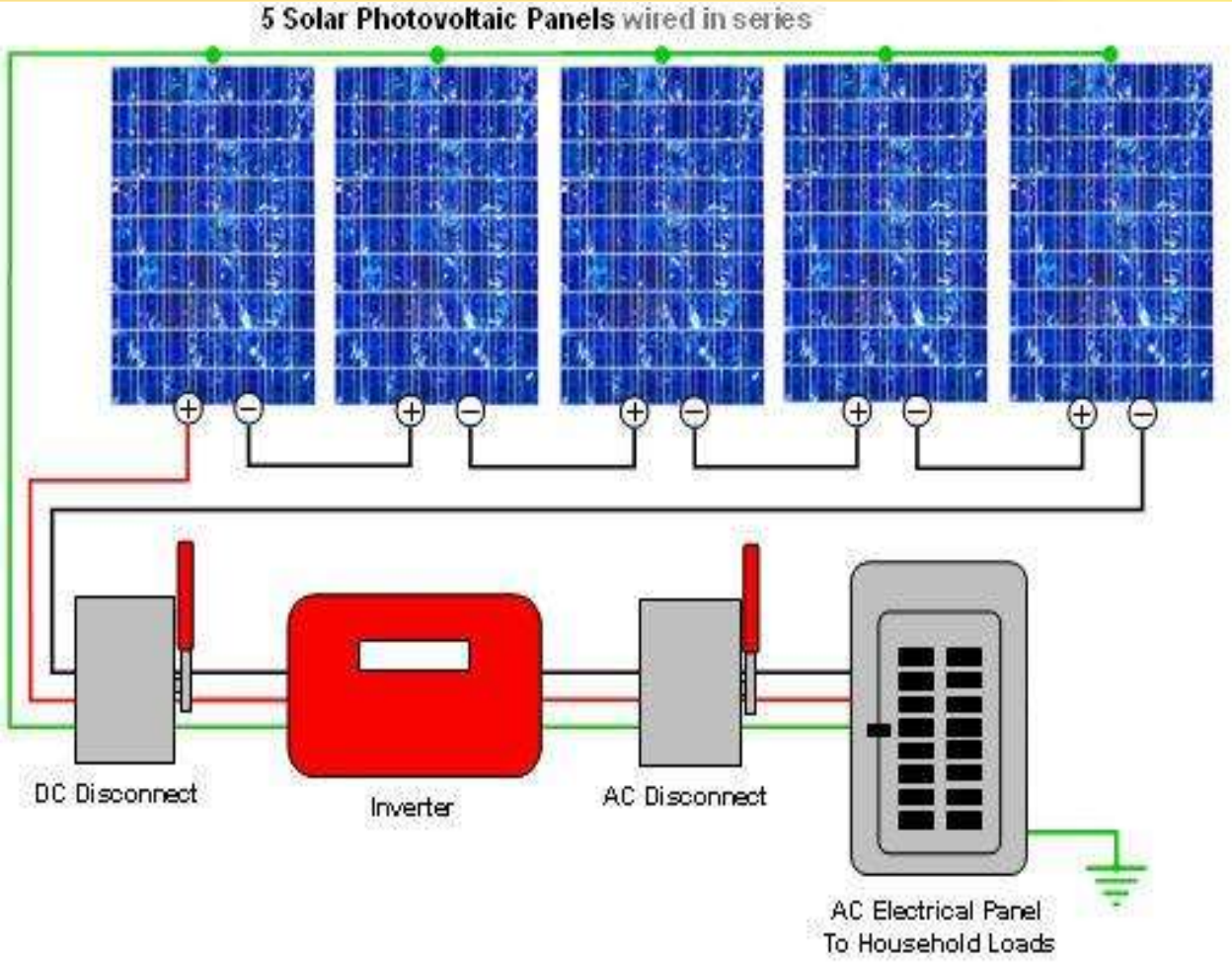
Suitability for Micro-grid Applications

- Use the poly-crystalline modules solely because
  - » Slight cost advantage,
  - » Relatively easier availability with vendors
  - » Good efficiency
  - » Least degradation
  - » Local availability and
  - » Better life



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Photovoltaic Micro-grid

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Solar Thermal Technologies

Types of Solar Thermal Technologies

- Parabolic trough solar thermal system
- Compact linear fresnel reflector (CLFR) solar thermal system
- Parabolic dish solar thermal system
- Power tower solar thermal system

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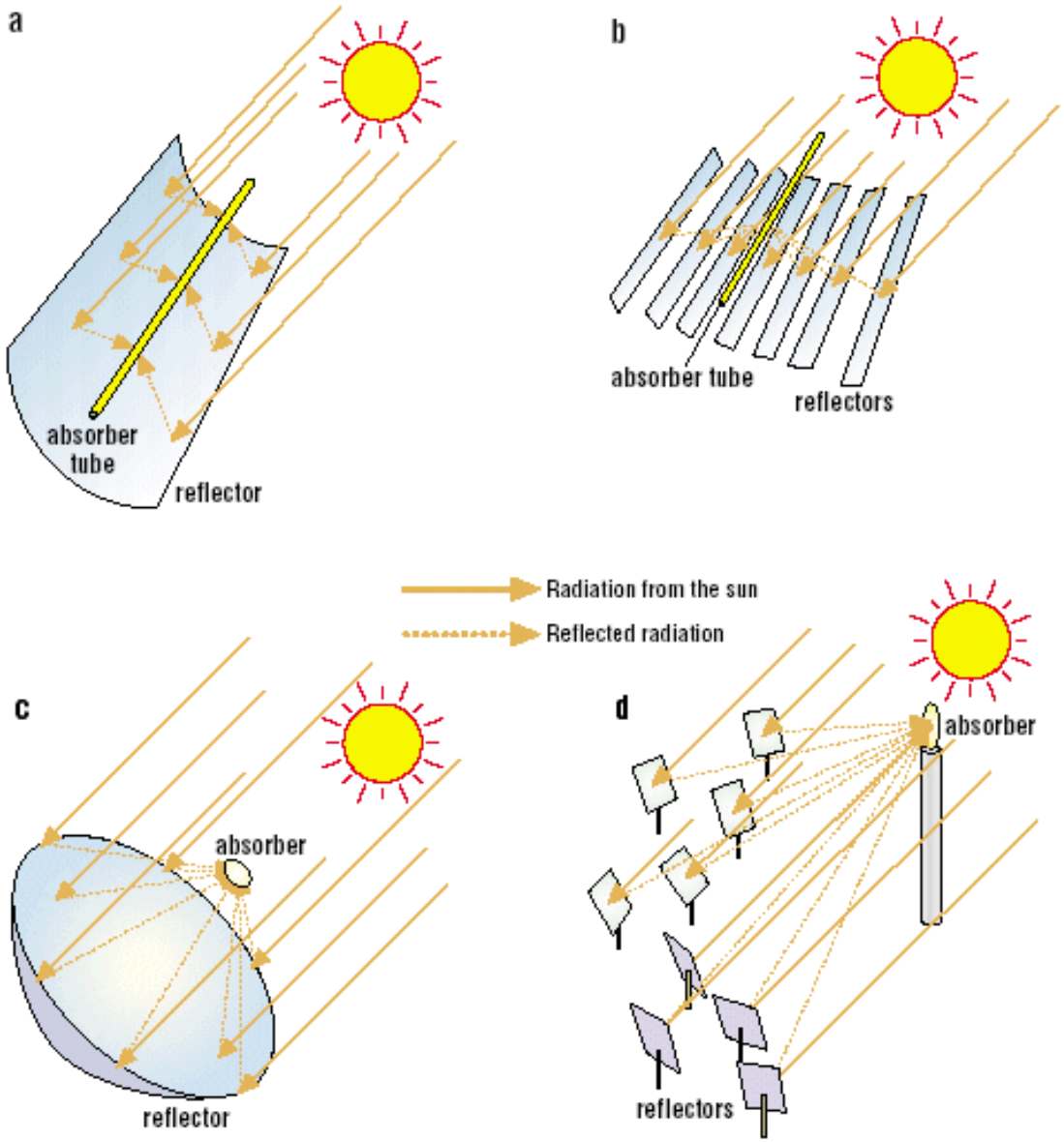
Types of Solar Thermal Technologies



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Parabolic Trough Systems

- Parabolically curved, trough–shaped reflectors
- Run in a north–south direction and track the sun from east to west
- Absorber pipes consist of a metal pipe which contains HTF surrounded by a glass pipe
- Hot HTF is used to generate steam
- Steam used to power a steam turbine to turn an electric generator to produce electricity

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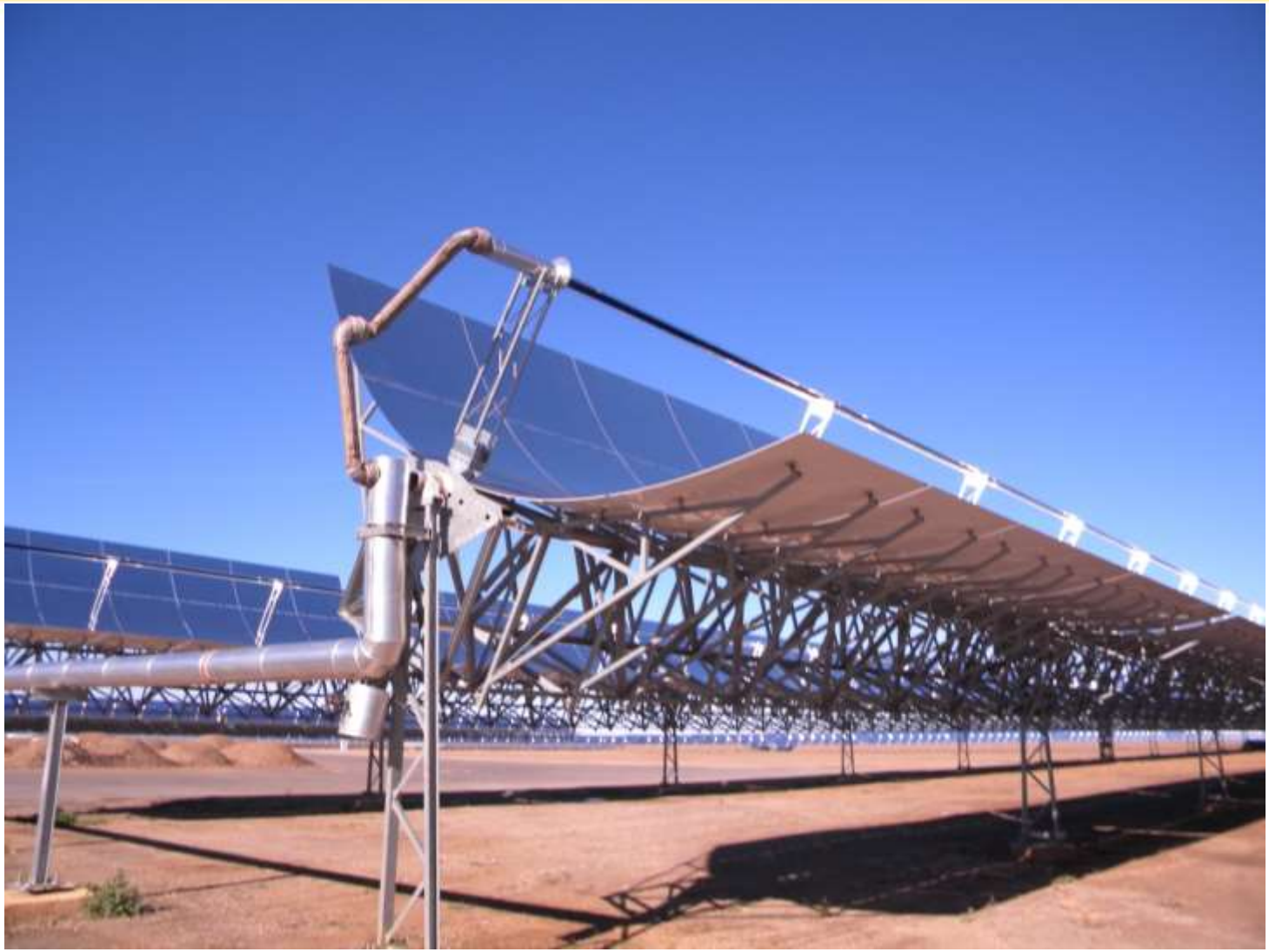
Parabolic Trough Systems –Andasol, Spain



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Parabolic Trough Systems –Andasol, Spain

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Compact Linear Fresnel Reflector (CLFR)

- Line focusing system
- Array of nearly flat reflectors
- Flat segments of rectangular shaped mirrors are arranged horizontally in a north–south direction
- Track the sun from east to west

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CLFR- Kogan Creek, Australia

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Parabolic Dish

- A parabolic–shaped point focus concentrator
- Reflects solar radiation onto a receiver mounted at the focal point
- Concentrators are mounted on a structure with a two axis tracking system
- Collected heat utilized directly by a heat engine (sterling engine)

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Parabolic Dish

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Power Tower

- Called central receivers
- Utilizes a two axis sun-tracking mirrors called heliostats
- HTF heated in the receiver
- Used to generate steam in the steam generator
- Steam is used to power steam power cycle to turn steam turbine to generate electricity

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Power Tower- Abengoa, Spain

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Power Tower- Abengoa, Spain

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Power Tower- Abengoa, Spain

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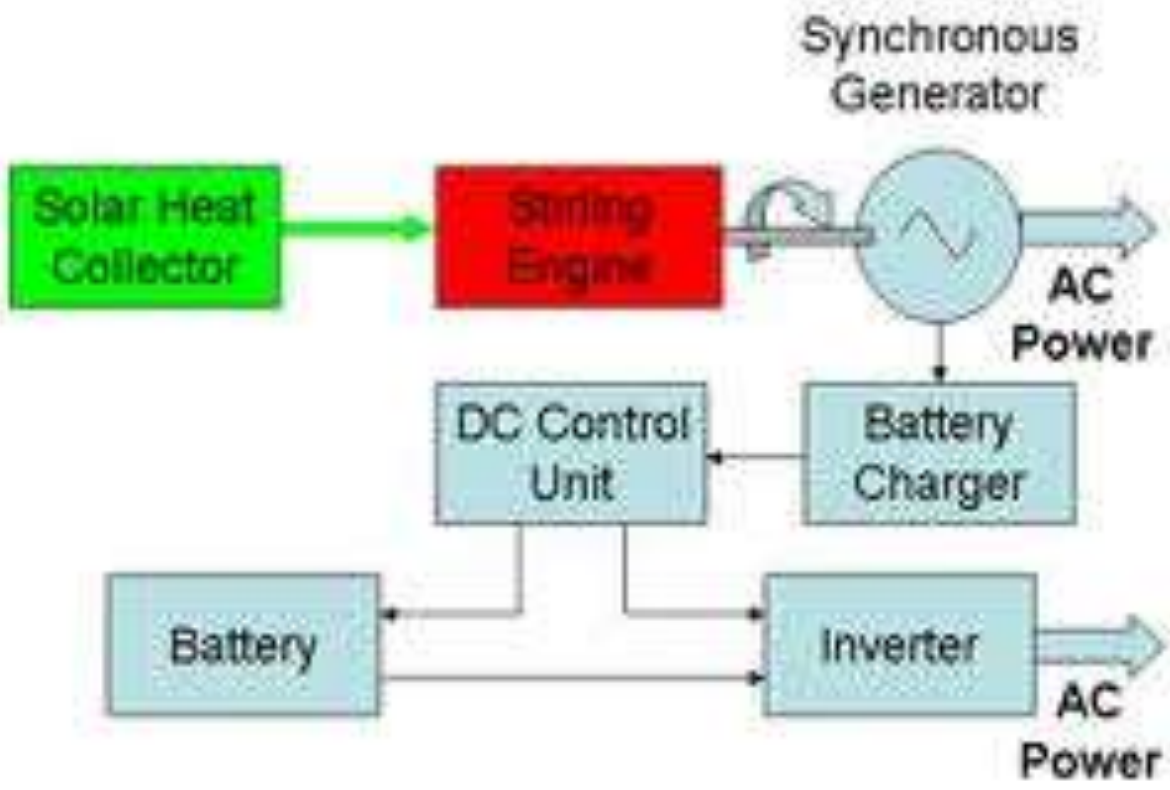
Suitability for Micro-grid Applications

- Parabolic trough systems, CLFR systems & solar tower systems **not suitable**
- Parabolic dish systems **only suitable**



Small Scale Electric Power from Solar Thermal Energy

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Site Selection

Site Selection Criteria 1/2

- **Solar radiation**
  - Depends greatly upon the reliable annual average solar radiation data
  - Directly affecting the output, project feasibility, techno-economic viability and performance of the project
  - Determine the amount, quality and duration of solar energy available at a specific site
- **Topography and soil testing**
  - Provides information about topography, geology and soil type
  - Concerned with local detail : elevation, contours, vegetation and human-made features
  - Involves the recording of terrain, the quality of the surface, and identification of specific land forms
  - Could stand the weight and vibrations of the power plant

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Site Selection Criteria 2/2

- **Meteorological assessment**
  - Average annual temperature, relative humidity, wind speed, precipitation
- **Flood risks and drainage arrangement**
  - Site should be free from flood risks and proper drainage infrastructure should be provided
- **Seismic zone**
  - Site must be free from any seismic hazards
  - Or care must be taken while designing and construction to minimize loss
- **Approach road and other infrastructure**
  - Site must be easily assessable

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Cost Estimation

Cost Estimation

Sample 100 kW polycrystalline PV system without battery

S N	Item	Approx. cost/ 100 kW (INR Lakh)
1	Polycrystalline modules	41
2	Inverter	10
3	Transformer	5
4	Support structure	15
5	Electric cables	8
6	Junction boxes	8
7	Civil and misc. electrical work	10
	Sub-total	97
8	Contingency/ miscellaneous (5% of Sub-total)	4.85
	Grand Total	**101.85**

Cost Estimation

Costs of dish sterling CSP system

S N	Dish details	Approx. cost/dish	Approx. cost/ 100 kW (INR Lakh)
1	25 kW SES dish	Unknown	Unknown
2	3 kW Infinia	USD 20000	421
3	10 kW Euro dish	Unknown	Unknown

CSP is a technology of scale and not suitable for small capacity projects

THANK YOU

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