ICLEI Local Governments for Sustainability

100% RENEWABLES CITIES & REGIONS ROADMAP

Supported by:
Federal Ministry for Economic Affairs and Climate Action
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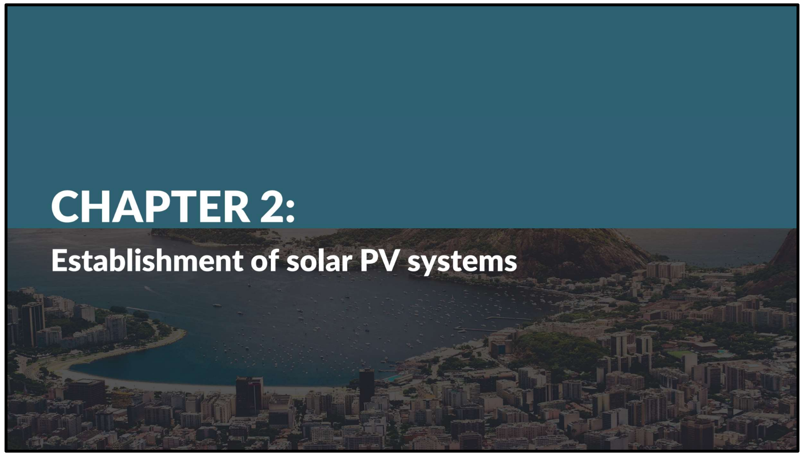
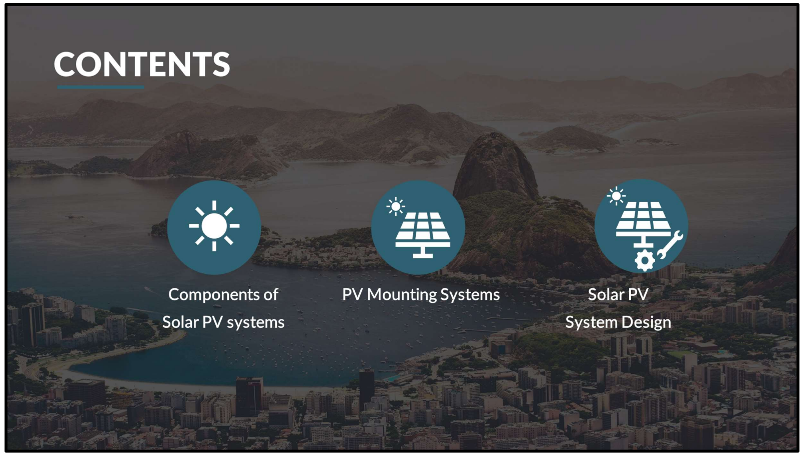
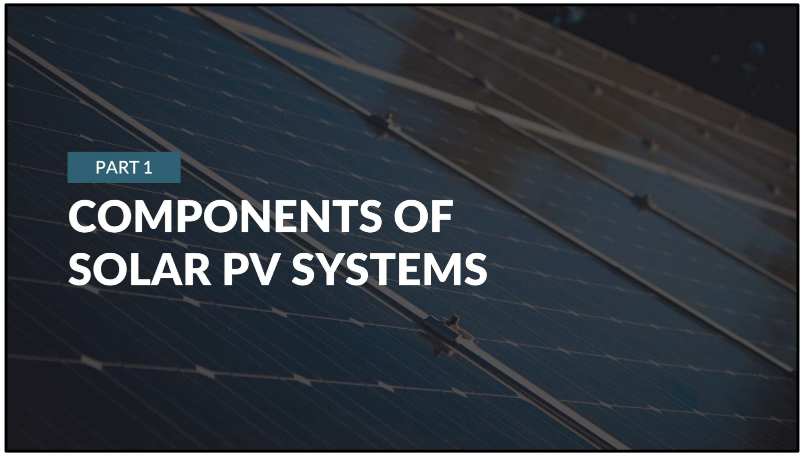
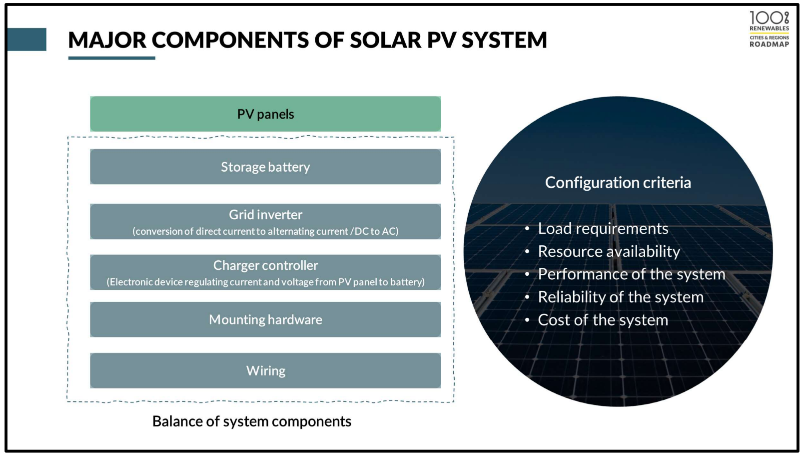
IKI INTERNATIONAL CLIMATE INITIATIVE

Capacity Building Module: Solar Energy Basics & Solar Photovoltaic Systems


CHAPTER 2:
Establishment of solar PV systems


CONTENTS
Components of Solar PV systems
PV Mounting Systems
Solar PV System Design


PART 1
COMPONENTS OF
SOLAR PV SYSTEMS



A PV (photovoltaic) system consists of several key components that work together to generate electricity from sunlight. The main elements are PV panels and balance of system (BOS) components. PV panels are the primary energy generators, converting sunlight into electrical energy. The BOS components complement the PV panels and ensure that the system operates efficiently.

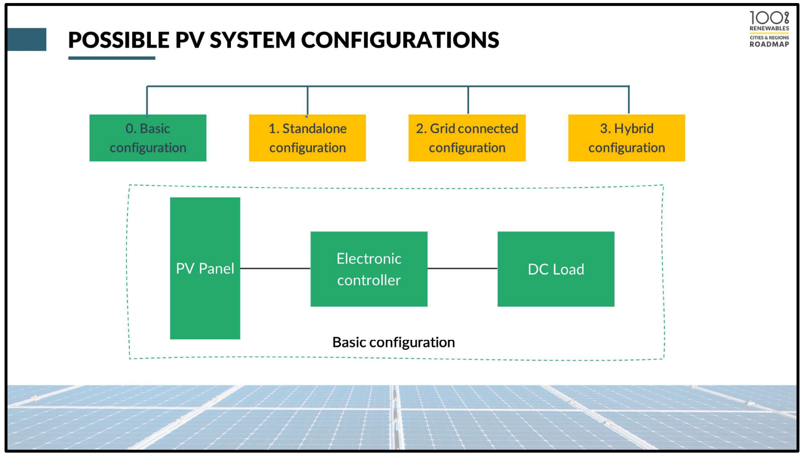
BOS components include essential elements such as storage batteries, grid inverters, charge controllers, mounting hardware and cabling.

Storage batteries store excess energy generated during the day for use at night or during periods of high demand.

Grid inverters convert the direct current (DC) electricity produced by the PV panels into alternating current (AC) electricity suitable for household or grid use.

Charge controllers manage the battery charging process, preventing overcharging or deep discharging that can damage batteries. Mounting hardware includes the structural elements that hold the PV panels in place, such as racks or frames, and ensure they are properly positioned for optimal exposure to sunlight.

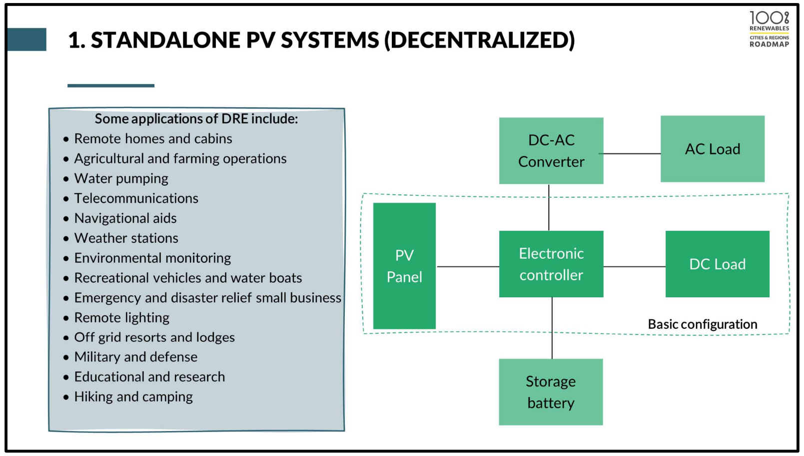
Wiring connects all the components and facilitates the flow of electricity within the system.



PV systems are designed to meet the load requirement in the best possible manner. In doing so, a system designer determines the configuration of PV system, which components (PV panels, load, battery, controllers, diesel generator etc.) to connect in a system and how? Depending upon the type of the load (AC or DC, light or heavy etc.), depending upon the load requirement (critical/non-critical, reliability, cost, etc.) and depending on its geographical location (wind resources, solar resources, proximity with grid, etc.), the configuration and design of the system will change.

A solar PV system configuration can be very simple, incorporating only two components (load and the PV panel), or it can be very complex, containing several power sources, sophisticated controllers and multiple energy storage units to meet stringent load requirements. Thus , the choice of the system configuration mainly depends on the following parameters:

- Load requirements
- Resource availability
- Performance of the system
- Reliability of the system, and
- Cost of the system



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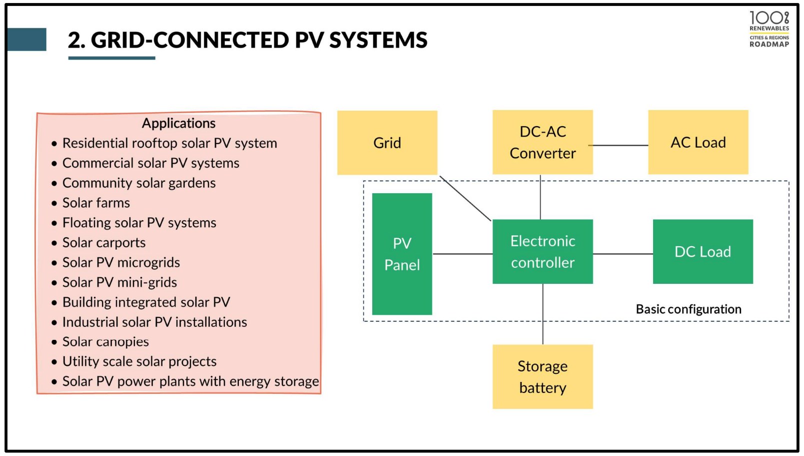

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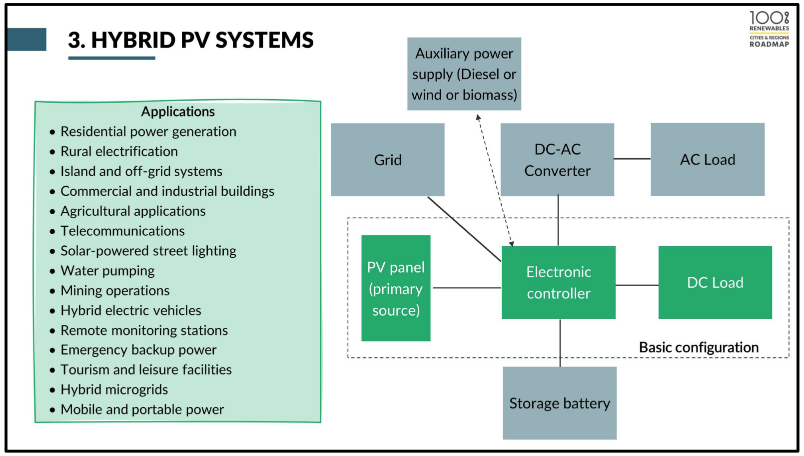

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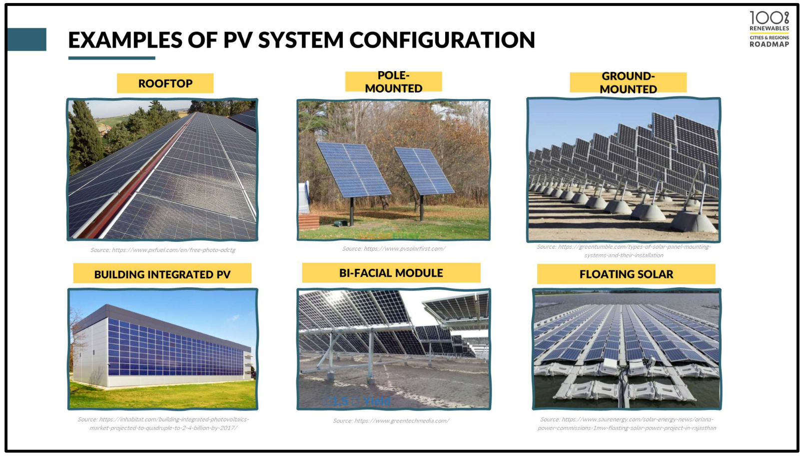
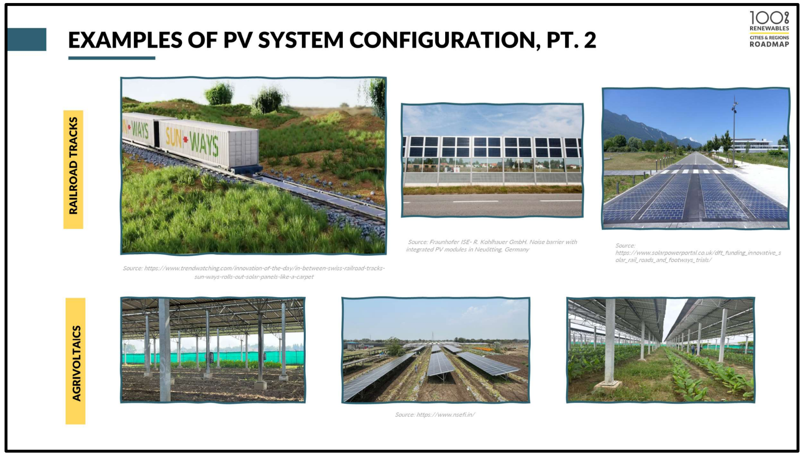
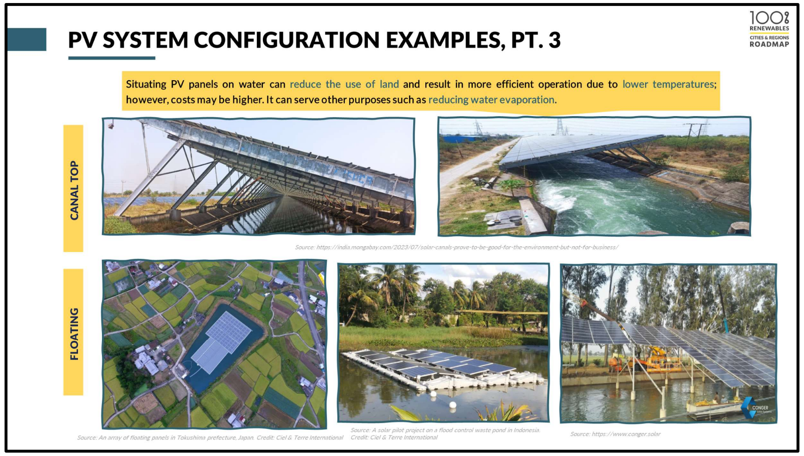


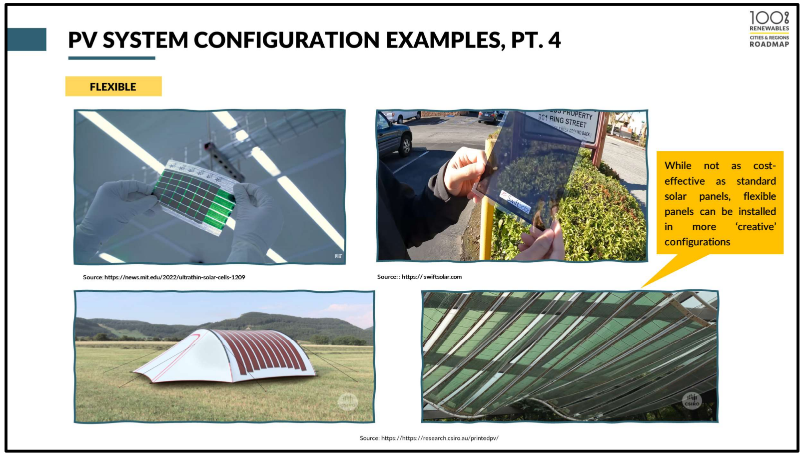
Imagine a world where solar panels are seamlessly integrated into our environment, harnessing the sun's energy in ingenious ways. They adorn rooftops, converting sunlight into electricity for homes and businesses, all while reducing our carbon footprint. But the innovation doesn't stop there. Journey further, and you'll find pole-mounted solar arrays, elegantly reaching towards the sun, efficiently generating power in open spaces. Explore ground-mounted installations, spanning vast areas, a testament to our commitment to clean energy, collecting solar power on a larger scale and contributing to our renewable energy goals. Urban architecture takes sustainability to the next level with building-integrated PV systems, turning sun-kissed glass facades into energy generators, reducing our reliance on traditional sources. Now, meet bifacial solar panels, capturing sunlight from above and reflected light from the ground, maximizing energy output in an artful manner. As your exploration continues, prepare to be amazed by floating solar PV, panels atop water surfaces, turning reservoirs, lakes, and the open sea into power-generating platforms, a promise of sustainable energy from unexpected spaces. This diverse range of solar technologies, from rooftops to ground-mounted, building-integrated to bifacial, even floating solar PV, illustrates our commitment to cleaner, greener energy. Each innovation leads us towards a brighter, more sustainable future, where the sun's boundless energy becomes our greatest ally in tackling climate change and powering our world.



PV Systems covering various land, road surfaces



PV Systems covering various water surfaces


PV SYSTEM CONFIGURATION EXAMPLES, PT. 4
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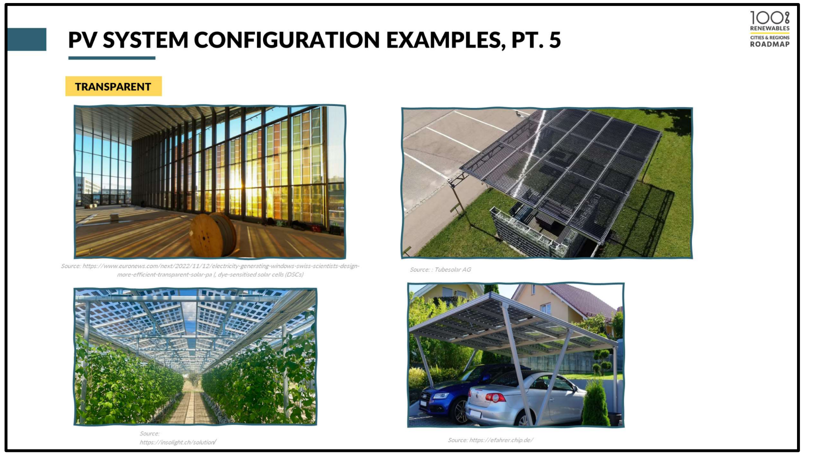
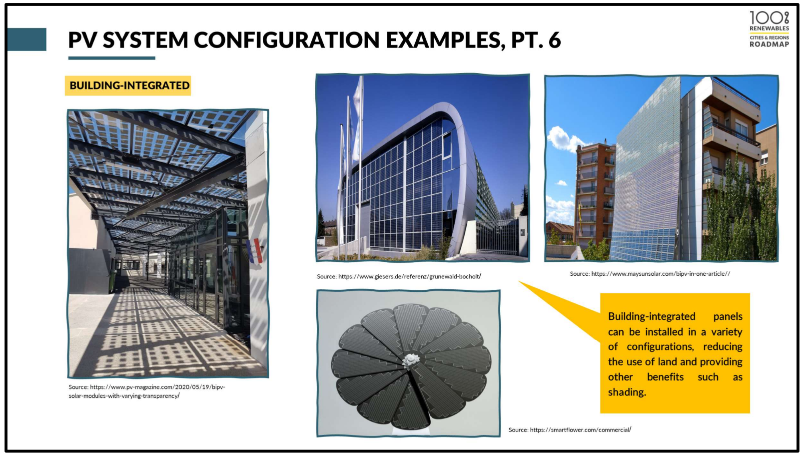
FLEXIBLE
Source: https://news.mit.edu/2022/ultrathin-solar-cells-1209
Source: : https:// swiftsolar.com
While not as cost-effective as standard solar panels, flexible panels can be installed in more 'creative' configurations
Source: https://https://research.csiro.au/printedpv/

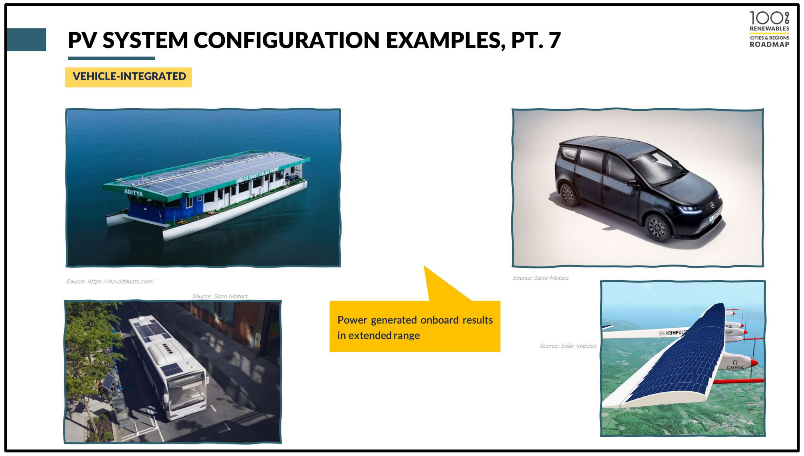
Flexible



Integrated structures

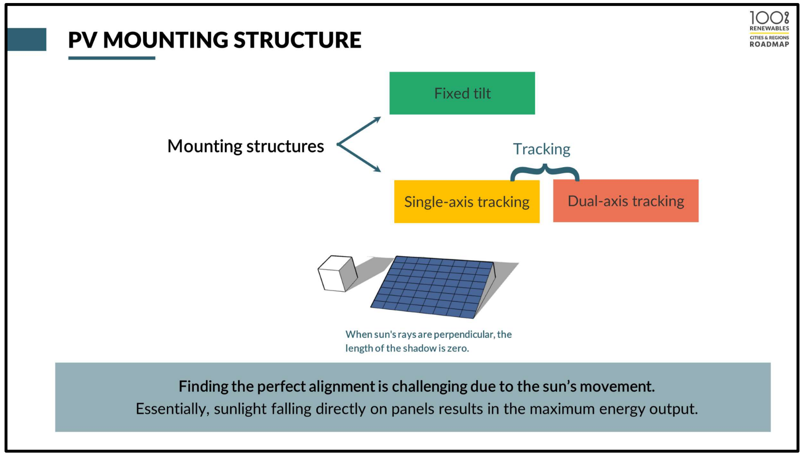


Building integrated and architecture



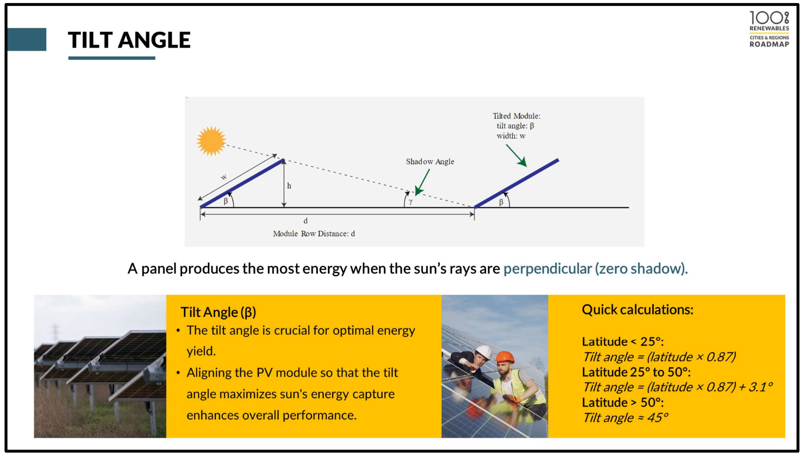
Vehicle integrated .. And many more


PART 2
PV MOUNTING SYSTEMS



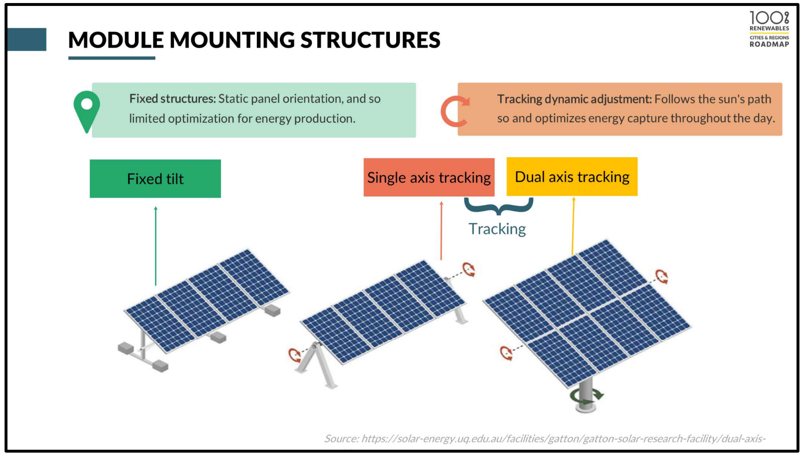
When sunlight falls vertically on an object, it casts no shadow, and the same principle applies to solar panels. Aligning a photovoltaic (PV) panel precisely with the sun's rays ensures that it receives the maximum amount of solar radiation, which translates into higher energy production. In the real world, however, achieving and maintaining perfect panel alignment is a challenge, given the sun's changing position throughout the day.

This is where tracking systems come in. Tracking systems are mechanisms designed to adjust the orientation of PV panels to ensure that they continuously face the sun. In doing so, they maximize the panel's exposure to sunlight, resulting in improved energy production.



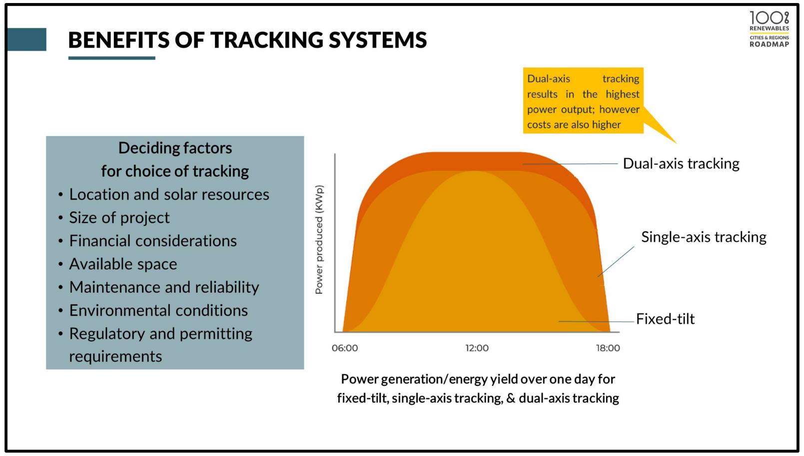
Based on the selection of site, PV modules can be installed (rooftop, ground mounted, any other structure)

The tilt angle of a solar module is determined based on the geographic location's latitude.
It's optimized to capture the most sunlight throughout the year, with a typical tilt angle being equal to the latitude.
Adjusting the tilt angle can enhance energy production in certain seasons.
For example, in higher latitudes, steeper angles are used to capture more sunlight during the winter months.
In lower latitudes, shallower angles are employed to maximize energy during the summer.
Proper tilt angle ensures optimal energy generation, contributing to the efficiency and effectiveness of the solar system.



There are two main types of module mounting structures: fixed and tracking. Fixed mounting structures maintain a static panel orientation, which may not always optimize energy production. On the other hand, tracking mounting structures dynamically adjust the angle and direction of the panel to follow the path of the sun. This adaptability allows the panels to effectively capture sunlight from dawn to dusk.

The tracking structure includes both single and dual axis tracking mechanisms. These mechanisms further enhance a module's productivity by precisely tilting and rotating the panel to align with the sun's position throughout the day.



Fixed Tilt: Fixed tilt solar panels are stationary and are positioned at a fixed angle relative to the ground. This angle is usually set based on the geographical location's average solar angle. While simple and cost-effective to install, fixed tilt panels are less efficient during parts of the day when the sun is at an angle different from the panel's fixed position.

Single-Axis Trackers: Single-axis trackers allow solar panels to follow the sun's path from east to west throughout the day. This movement enhances energy production by keeping the panels perpendicular to the sun's rays as it moves across the sky. This tracking improves efficiency compared to fixed tilt systems, but they are more complex and expensive to install. Fixed tilt panels are stationary and cost-effective,

Dual-Axis Trackers: Dual-axis trackers not only move panels from east to west but also adjust their tilt angle to follow the sun's elevation throughout the day. This dynamic movement optimizes energy capture and increases efficiency even further. Dual-axis trackers yield the highest energy output among the three options but come with a higher upfront cost and greater maintenance requirements.


PART 3
SOLAR PV SYSTEM DESIGN

TYPE OF GRIDS FOR DECENTRALIZED RENEWABLE ENERGY APPLICATIONS

TABLE : TYPES OF GRIDS

Type	PICO	Solar Home Systems	Mini-Grids	National Grids
Capacity	1–11 Wp	10–250 Wp	< 15 Wp	> 15 MW
Scale	Small home appliances and devices such as calculators, toys, cameras, cell phones and tablets	Standalone systems for residences	Decentralized systems for a localized group of customers isolated from the grid, involving one or more small-scale electricity generation units (solar PV, fuel cells, micro hydro, wind, storage devices such as flywheels and batteries)	Interconnected network that provides electricity to multiple customers over large distances
Market	Remote communities	Isolated users/ institutions, remote communities	Isolated users/ institutions, remote Communities, rural towns	Regional and urban areas

Source: https://renewablesroadmap.iclei.org/resourcescategories/fact-she

OVERVIEW OF SOLAR PV SYSTEM DESIGN

Approximate system design

- Determine the connected load in Watts *W) and Watt hours (Wh)
- Determine size and choice of electronic components
- Determine battery size (number, capacity voltage, Ampere hour (Ah) rating, etc.)
- Determine PV module size (number, capacity, rating, etc.)
- Determine size of wires in mm, fuse (A), junction box (Volts & Amps), etc.

QUESTION: ESTIMATING SOLAR PV SYSTEM DESIGN

QUESTION

A house has the following electrical appliance usage. Determine its power consumption demands and design the system using this approximate estimation.

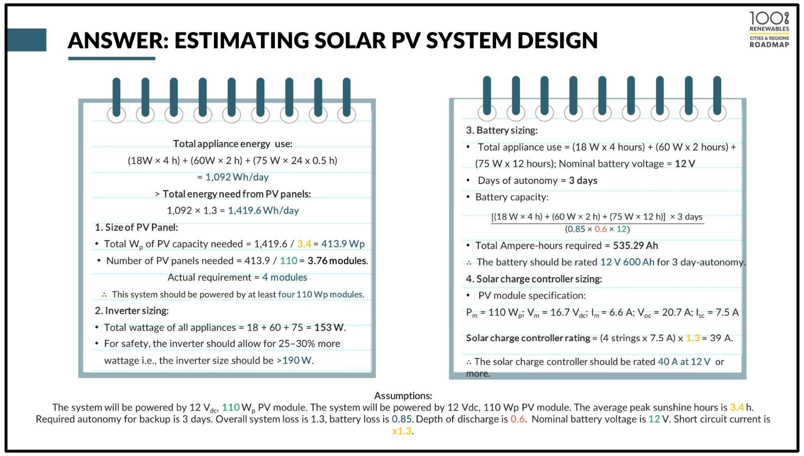
Appliances	Lamp	Fan	Refrigerator
Consumption (in Watts)	18	60	75
Hours of operation (h)	4	2	12

Assumptions:
The system will be powered by 12 V_{dc}, 110 W_p PV module. The system will be powered by 12 Vdc, 110 Wp PV module. The average peak sunshine hours is 3.4 h. Required autonomy for backup is 3 days. Overall system loss is 1.3, battery loss is 0.85. Depth of discharge is 0.6. Nominal battery voltage is 12 V. Short circuit current is x1.3.

Assumptions:

The average peak sunshine hours is 3.4

- Required autonomy for backup is 3 days
- The overall system loss = 1.3
- Battery loss= 0.85
- Depth of discharge = 0.6
- Nominal voltage of battery = 12 V
- Calculating solar charge controller rating, Short circuit current X 1.3



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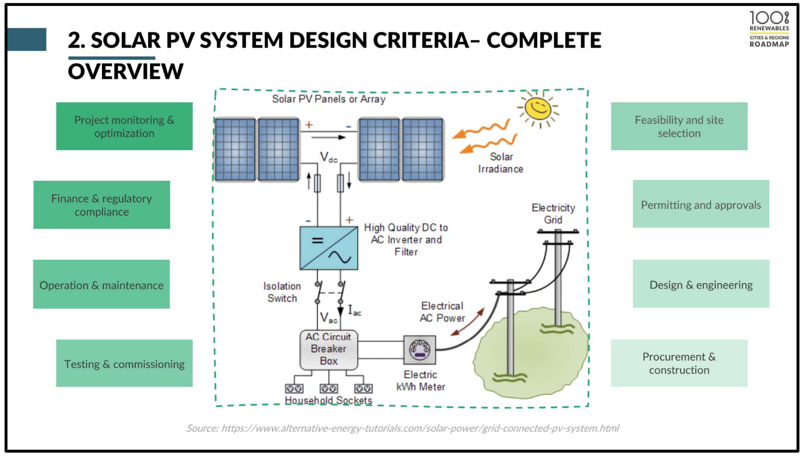
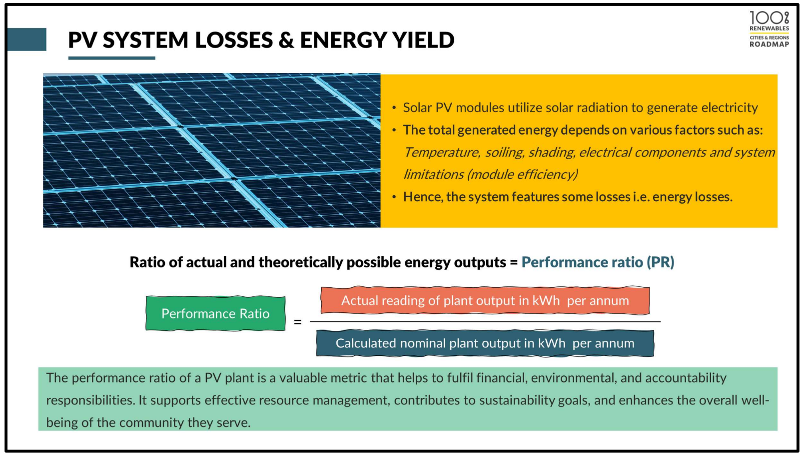
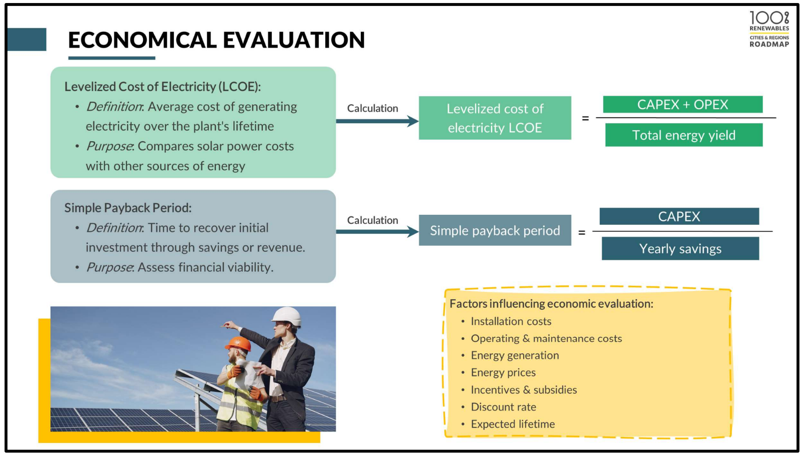


Local governments start by assessing their energy needs and identifying suitable sites for solar installations. They ensure compliance with regulations and secure funding. They choose the right technology, size the system and consider energy storage. Grid connection, contractor selection, and system maintenance are critical steps. Public relations and education foster community support. Sustainability and environmental impact are addressed, with ongoing performance monitoring and reporting. Long-term planning focuses on scaling solar projects, and resilience plans include solar for emergencies. Public-private partnerships help leverage resources and expertise for successful solar initiatives.



Ratio of actual and theoretically possible energy outputs – Performance ratio, PR.
With the PR,
the energy output of PV plant can be compared with that of other PV plant to monitor status.
How energy efficient and reliable PV plant
Area, A; Pre conversion efficiency □pre; System efficiency □sys; Relative module efficiency □rel; Nominal module efficiency □npm; Annual global irradiance h in 1000 W/m2



Levelized Cost of Electricity (LCOE):

LCOE is a metric used to calculate the average cost of generating electricity from a solar PV plant over its lifetime, taking into account all costs and revenue streams.

It represents the per-unit cost of electricity produced by the plant and helps in comparing the cost of solar power with other sources.

LCOE considers both capital costs (installation, equipment, etc.) and operating costs (maintenance, repairs, etc.) over the plant's expected lifetime.

The formula for LCOE involves dividing the total lifetime costs by the total lifetime electricity generation, giving the cost per unit of electricity (e.g., $/kWh).

A lower LCOE indicates a more cost-effective solar PV plant.

Simple Payback Period:

The simple payback period is a straightforward method to assess how long it will take for the initial investment in the solar PV plant to be recovered through energy savings or revenue generation.

It calculates the time it takes for the cumulative savings to equal the initial investment.

The formula for the simple payback period is: Payback Period = Initial Investment / Annual Savings.

A shorter payback period indicates a faster return on investment and a potentially more financially viable project.

A lower LCOE and a shorter payback period indicate a more economically viable solar PV plant.

The LCOE helps in comparing solar power costs to other energy sources, aiding decision-making.

The payback period helps in understanding how quickly the initial investment will be recouped.

Economic evaluations can also consider factors like inflation, future energy price trends, and potential future maintenance and replacement costs.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END OF CHAPTER 2 OF 3
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