Basics of Solar Energy and Rooftop Solar PV Systems

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What is happening in Sri Lanka..?

- Customers are allowed to generate electricity atop their roofs
- A good analogy between water supply and electricity
  - Water connection from NWS&DB
  - Using your own well

The Analogy

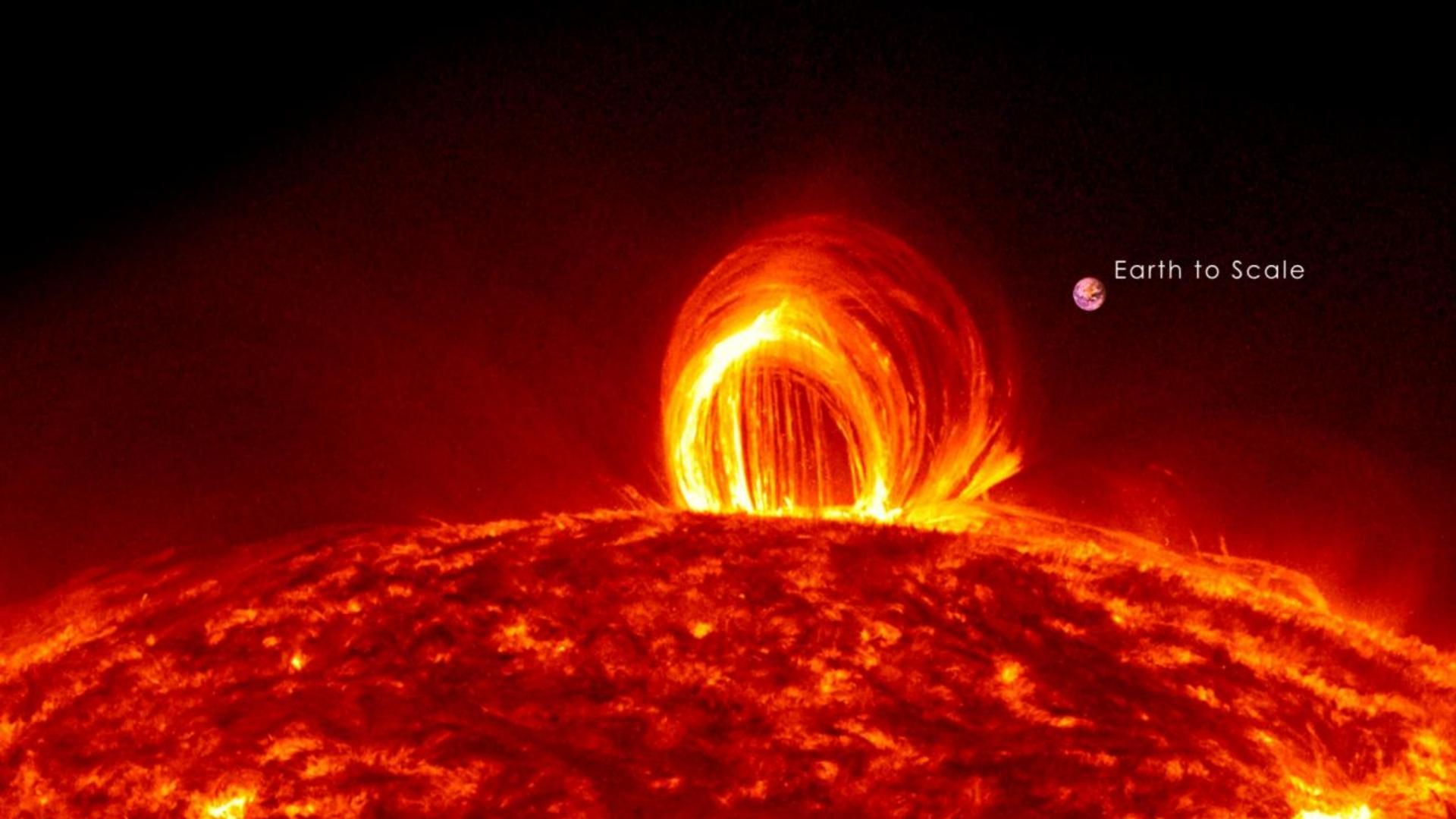
- NWS&DB connection will provide you water for a fee based on volume of water supplied
- Well water, pumped up using an electric motor will ‘charge’ the tank above – free of charge
  - Imagine you pump well water to NWS&DB line and reversing the meter reading..!
- Solar rooftop does this for electricity
  - Pump electricity during sunny hours to grid
  - Draw electricity during night hours from grid

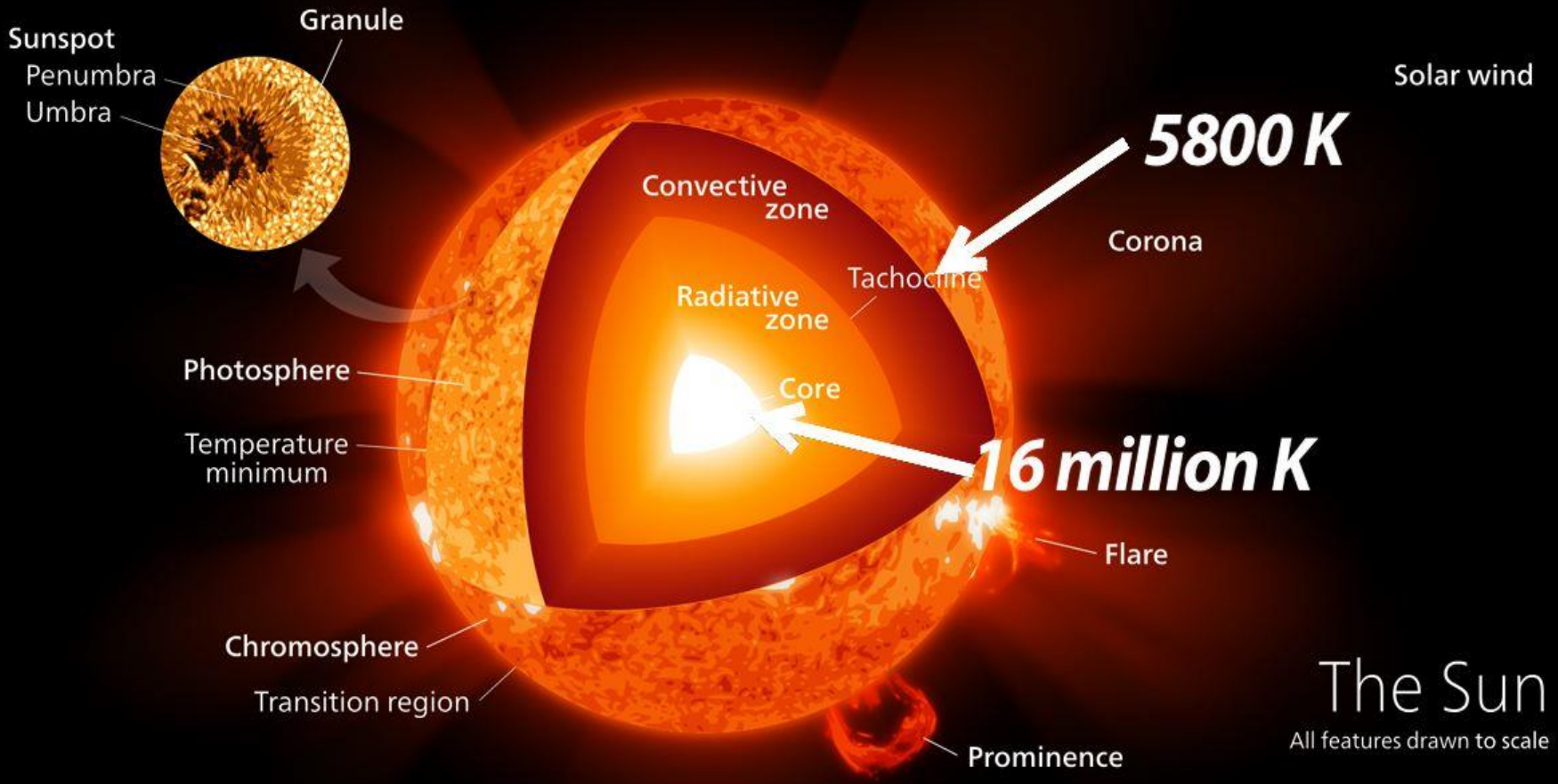
Outline

- Basic components involved
- How solar energy is received on earth
- Basic numbers
- Typical system costs
- Factors affecting generation
- Schemes on offer


Static Single Phase Energy Meter
Orange

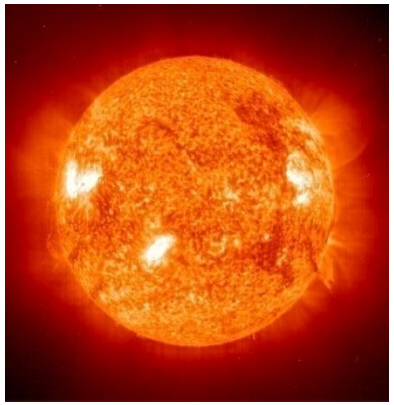

SUNNY CENTRAL

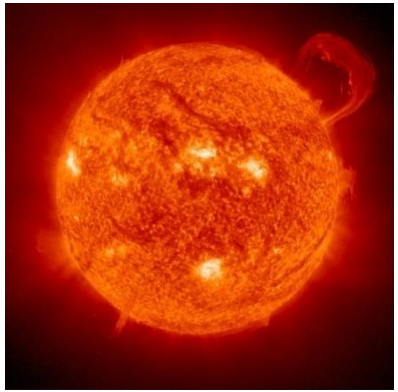

Earth to Scale


Sunspot
Penumbra
Umbra
Granule
Solar wind
5800 K
Convective zone
Corona
Tachocline
Radiative zone
Photosphere
Core
Temperature minimum
16 million K
Flare
Chromosphere
Transition region
Prominence
The Sun
All features drawn to scale

Our Star – the Sun

- At the core of the sun, a nuclear fusion reaction is fusing hydrogen atoms to become helium atoms at a rate of 0.6billion tonnes / sec
- This gives out intense radiation of approximately 390,000,000,000,000,000,000MW of power.
- Sri Lanka maximum electricity demand is 2,500MW
- A conservative estimate implies that earth receives 600,000,000MW of energy, and global demand is only 20,000,000MW by 2050

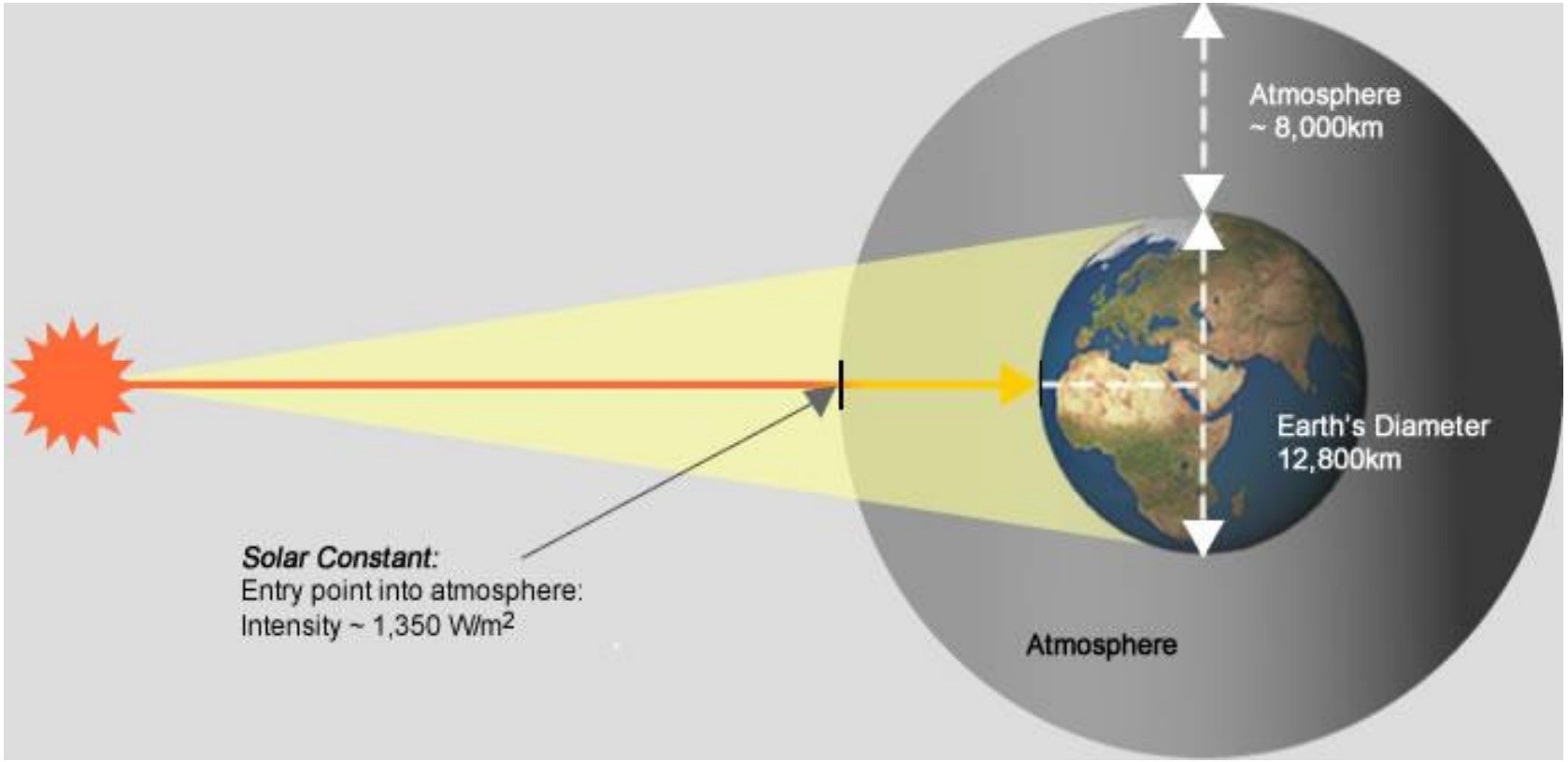




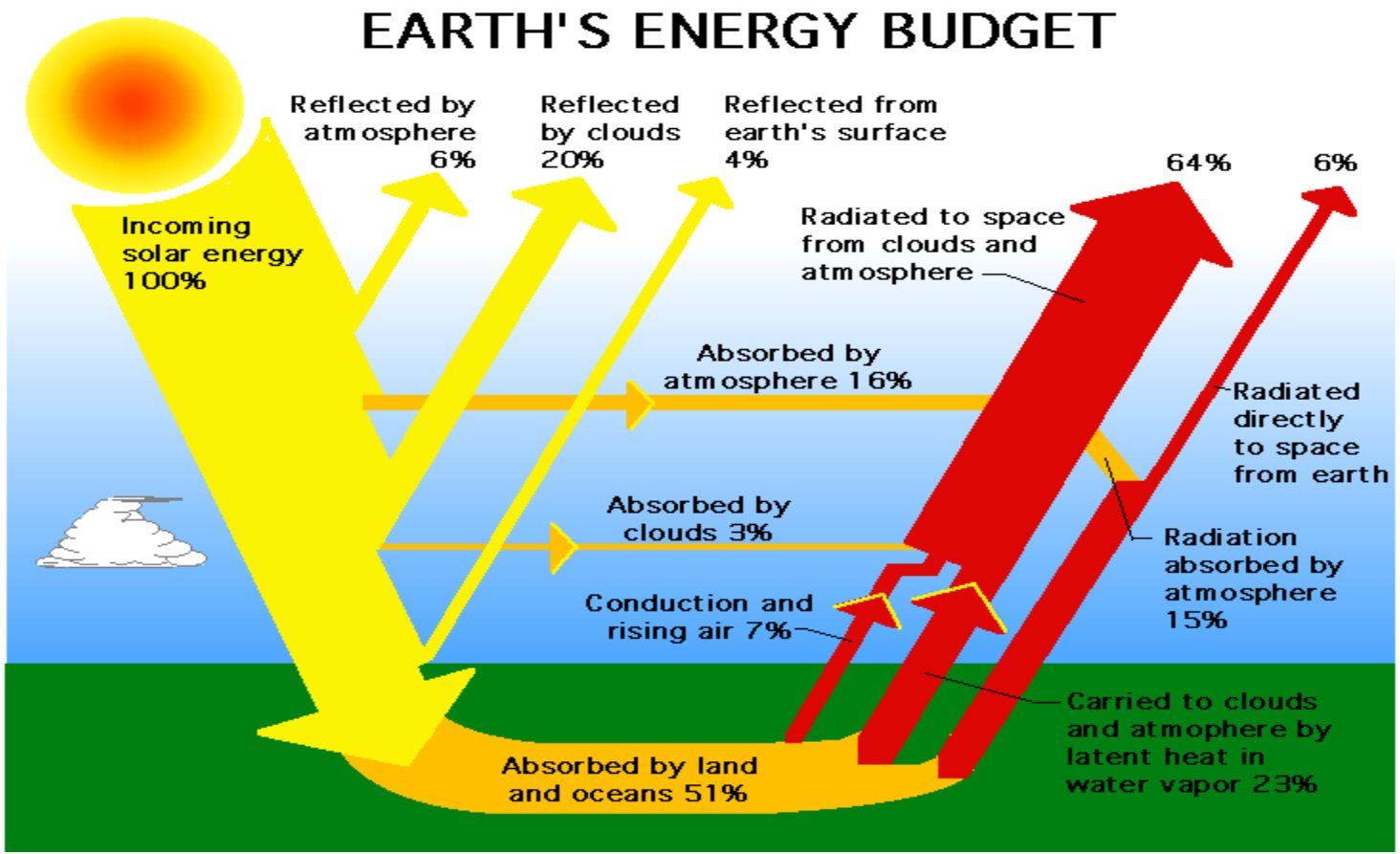
Basic Concepts

- There are various terms associated with solar energy
  - Irradiance, Insolation and Irradiation
- Irradiance – instantaneous power incident on a unit area.
  - Measured in W/m^2 and is around $1,000W/m^2$ in the tropics
- Insolation/Irradiation – an integration of exposure to a particular irradiance over a specific period Wh/m^2 per day or more popularly kWh/m^2 per day or kWh/m^2 per year

Solar Radiation 1,367W/m^2



What happens after atmosphere?



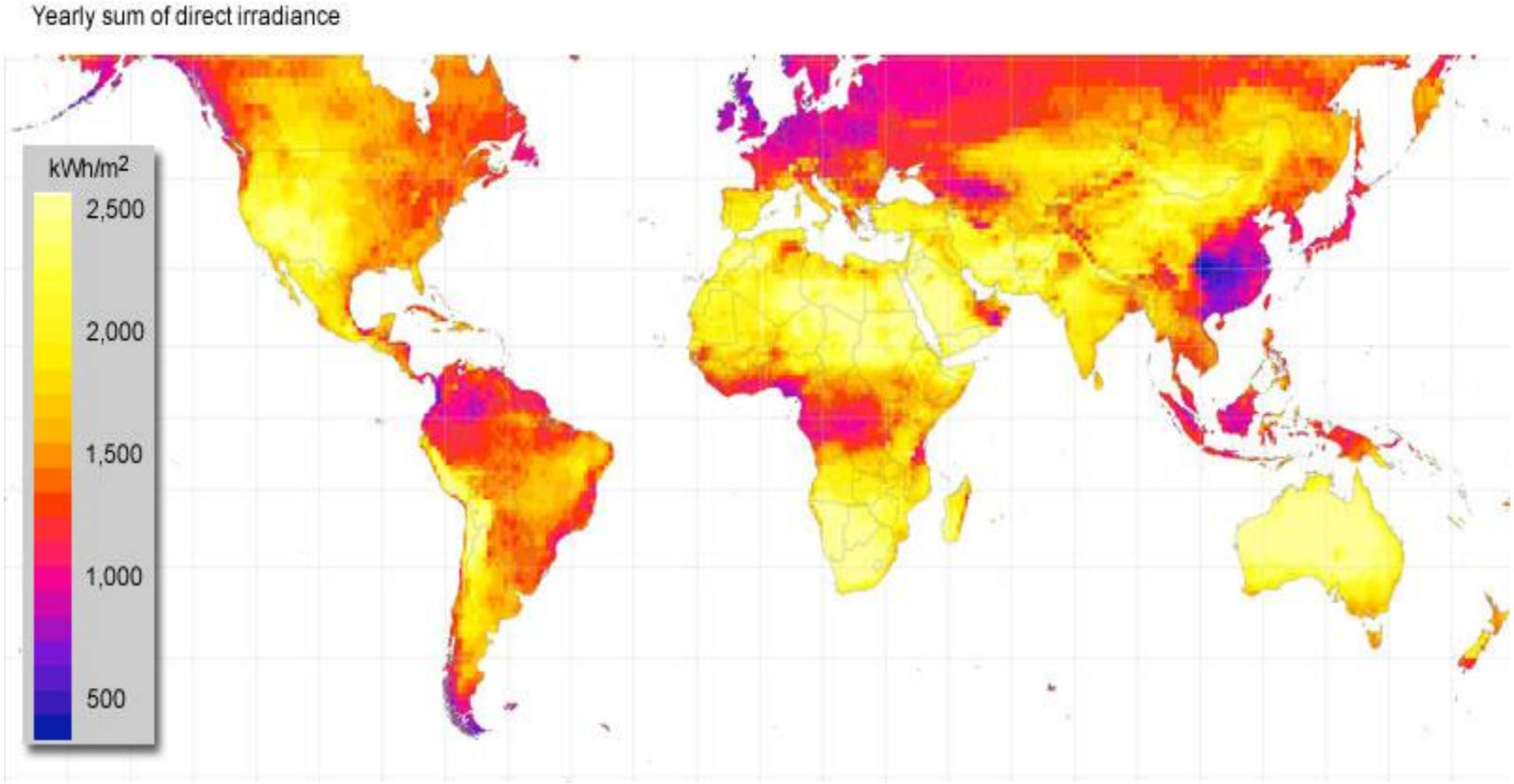
Important Values

- Direct Normal Irradiance (DNI)
  - Taken by looking directly at solar disc (Pyroheliometer) always following the sun
  - Measured in W/m^2 but summed over a period and relates to the shadow casting component of sun light
- Global Horizontal Irradiance (GHI)
  - Taken by summing up all the irradiance from the visible hemisphere (reflected, defused, scattered and DNI) incident on a horizontal plane
  - Measured in kWh/m^2 for a period

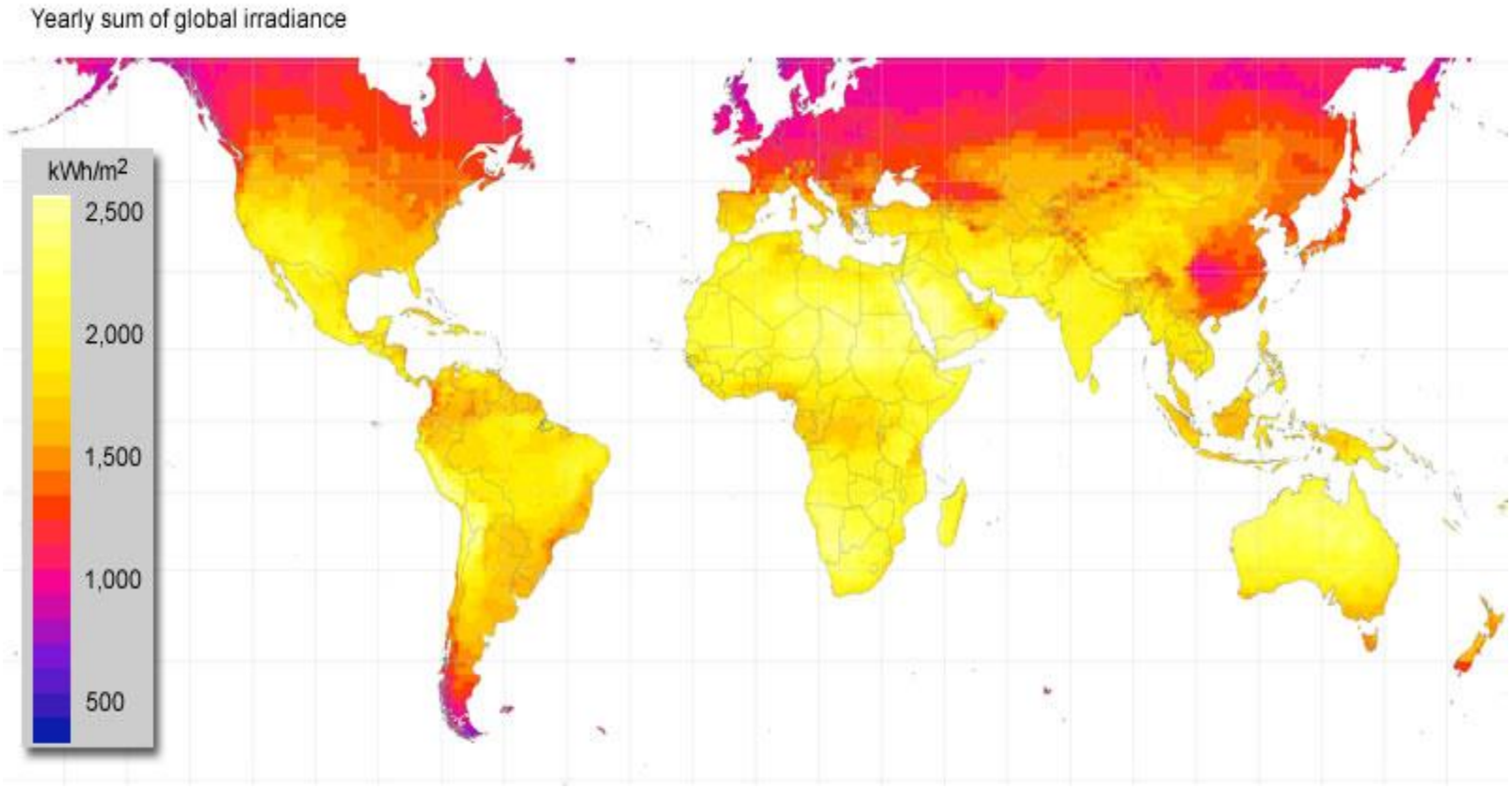
Important Values

- Diffused Horizontal Irradiation (DHI)
  - Taken by summing up all the irradiance from the visible hemisphere (reflected, defused, scattered except DNI) incident on a horizontal plane
  - Measured in kWh/m^2 for a period
  - Used in the low cost measurement of DNI (DNI = GHI-DHI)
- Global Irradiation on Tilted Surfaces (H_T)
  - Similar to GHI, but measured on a tilted surface (at an angle of interest)

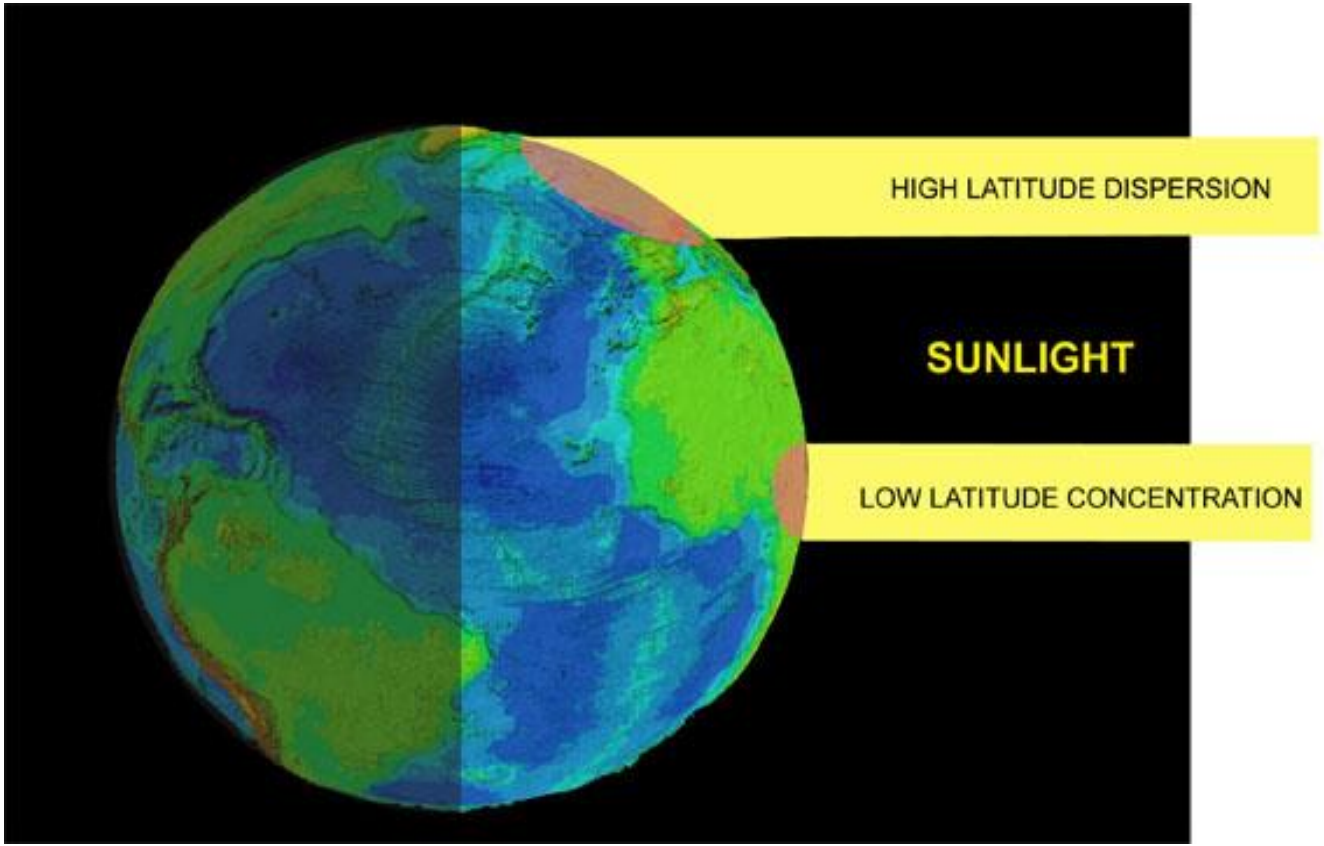
Direct Normal Irradiation



Global Horizontal Irradiation

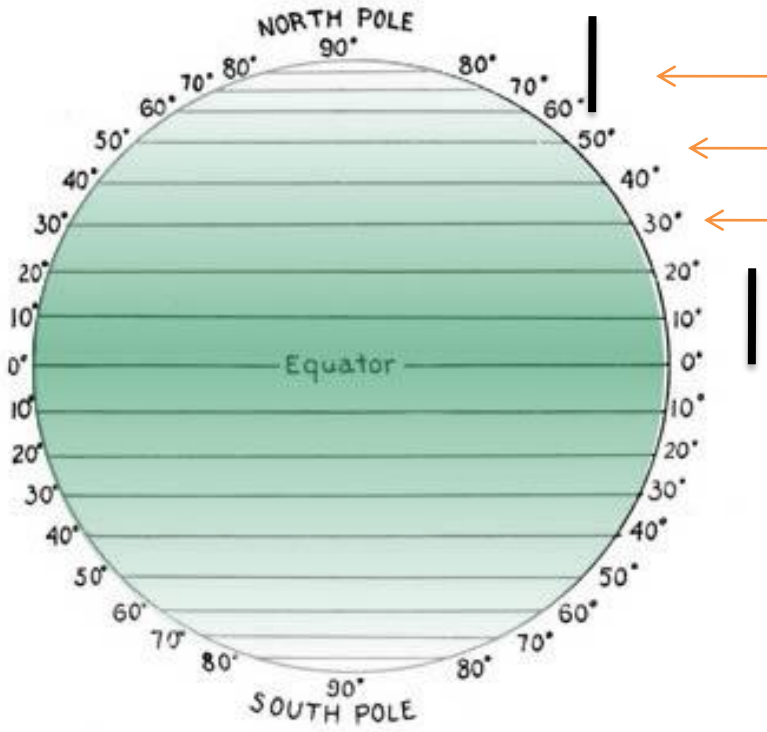


Radiation is felt differently



Nearer to equator, more radiation per square area than in a higher latitude location

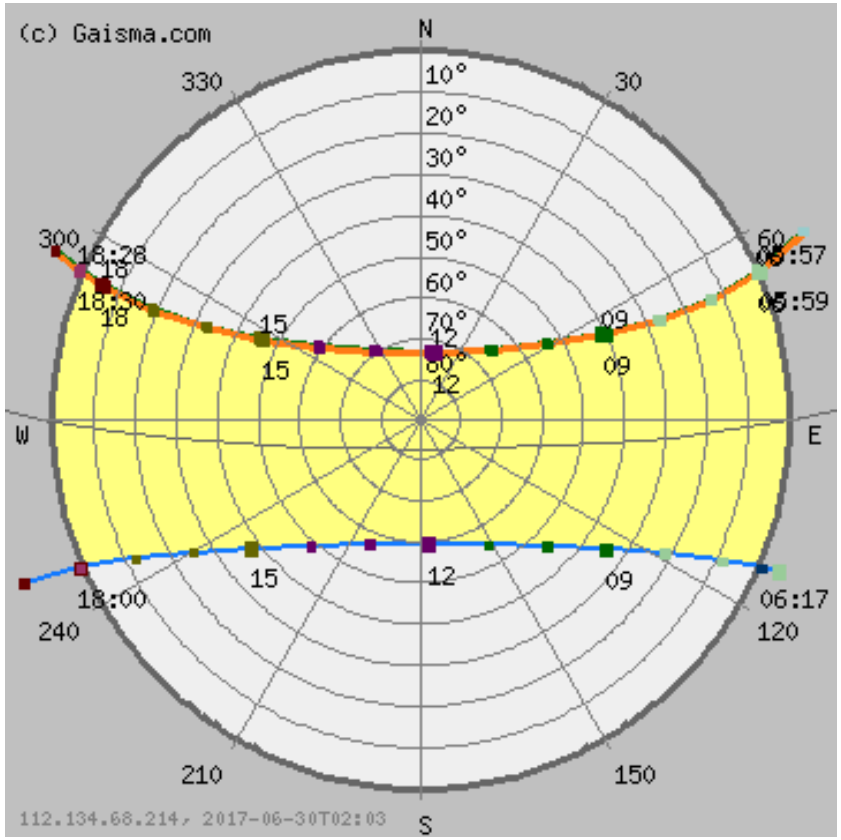
How Solar Energy is Felt in Sri Lanka

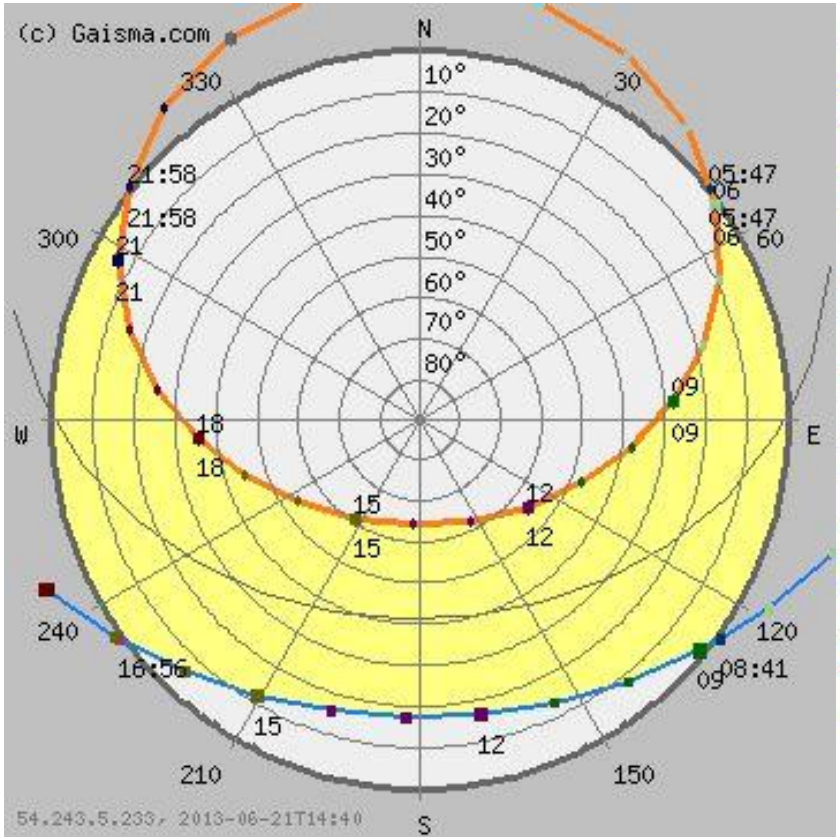


Latitude 60N - Helsinki

Latitude 6N - Hambantota

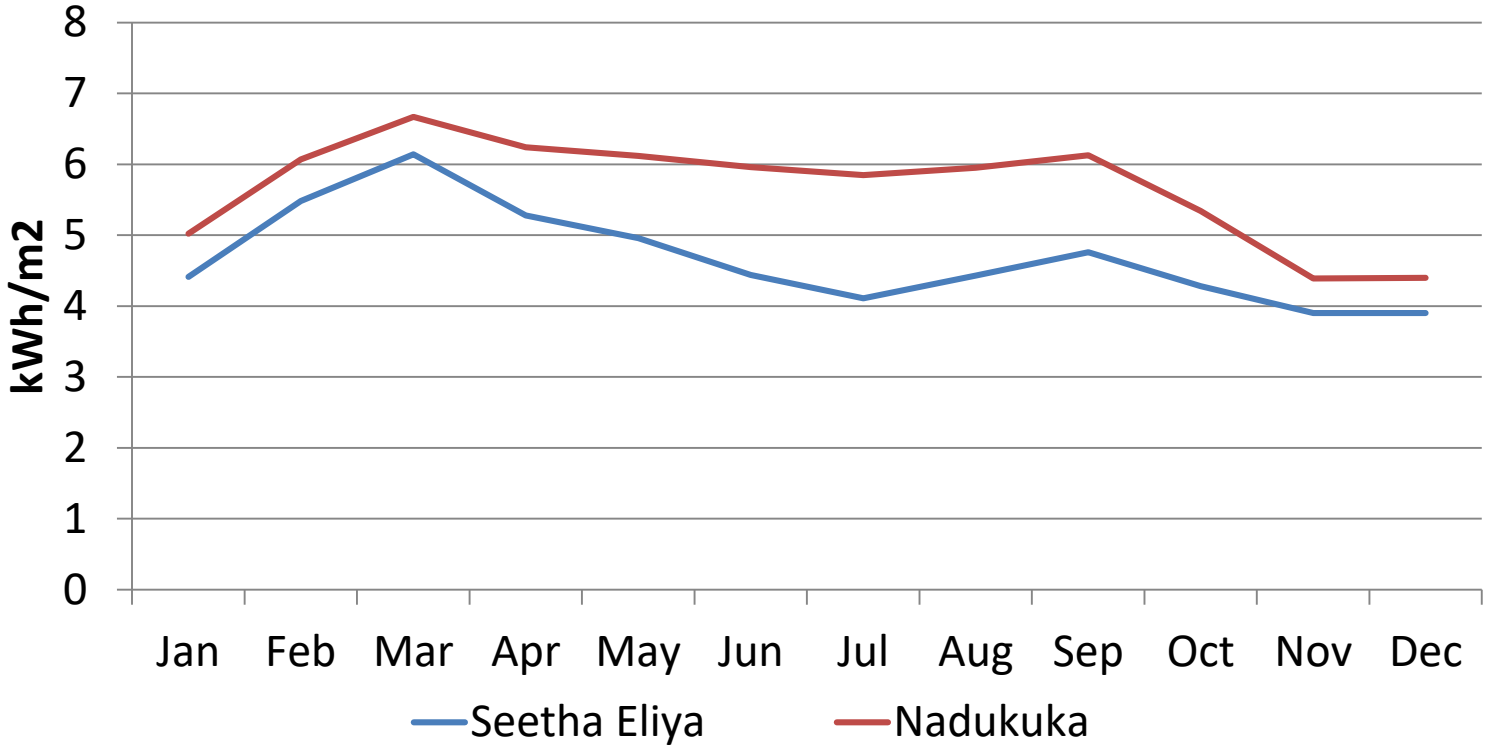
Sun Path Diagrams Colombo / Paris



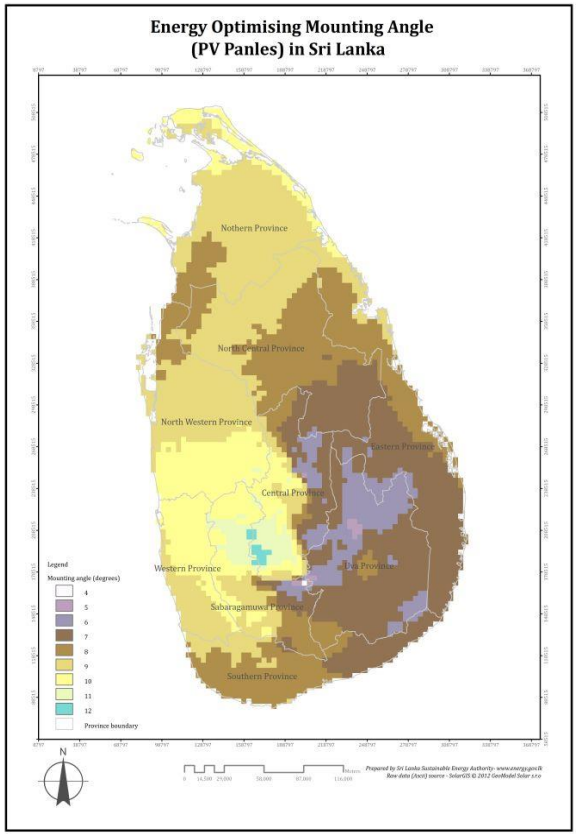


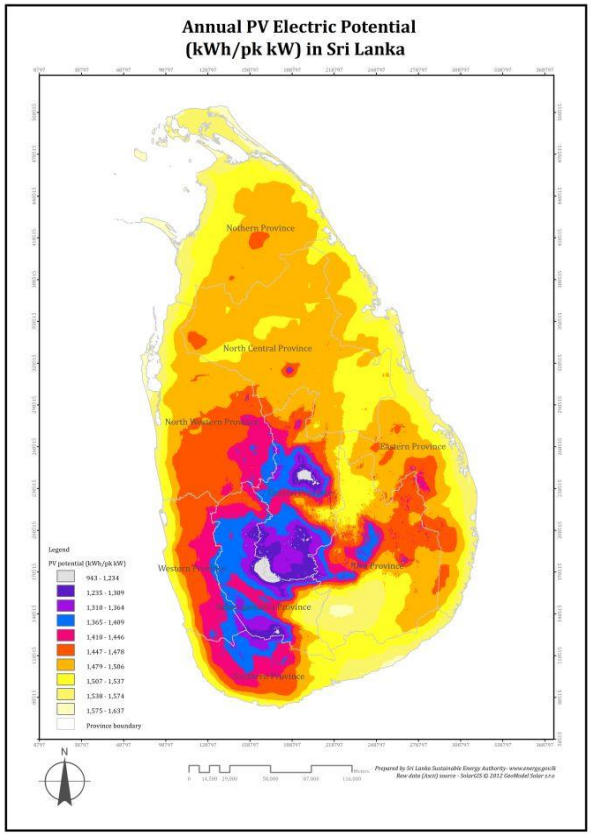
Comparison of good / bad locations

- Daily sum of GHI



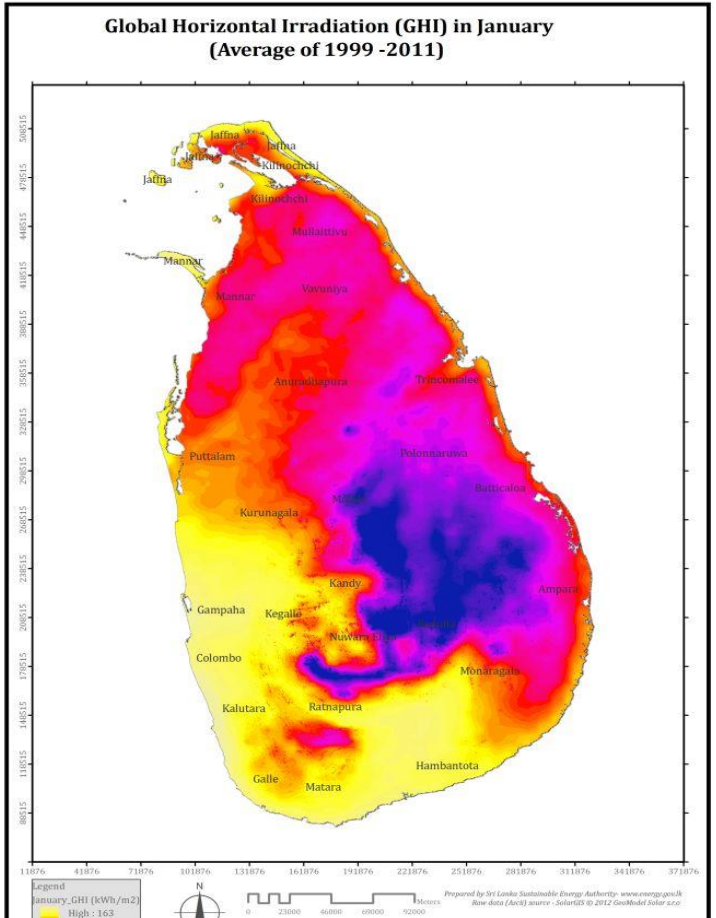
Solar potential



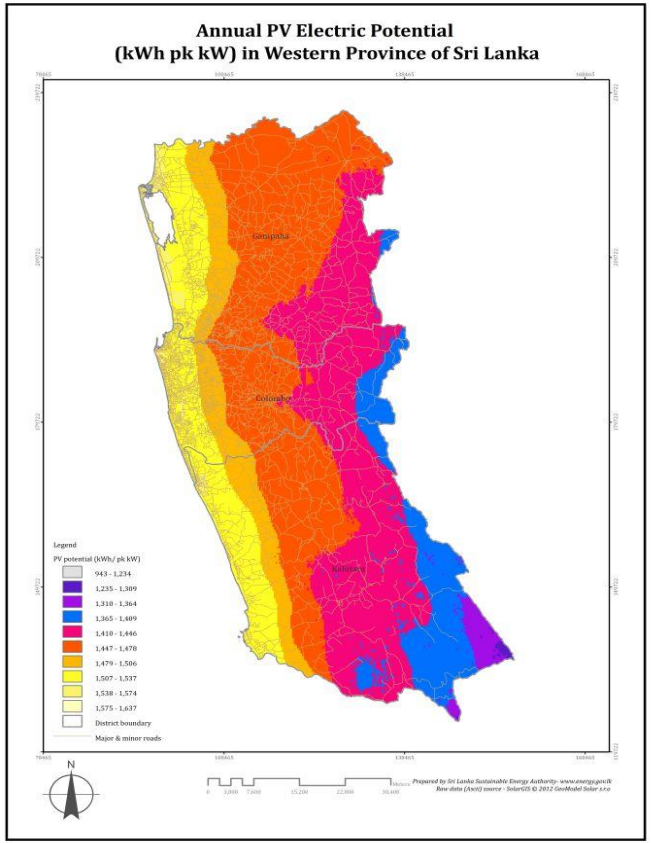


Annual variation of sunshine

- The year round sunshine needs a closer look
  - Very prominent shifting based on the monsoons
  - No area in Sri Lanka is under year round sunshine

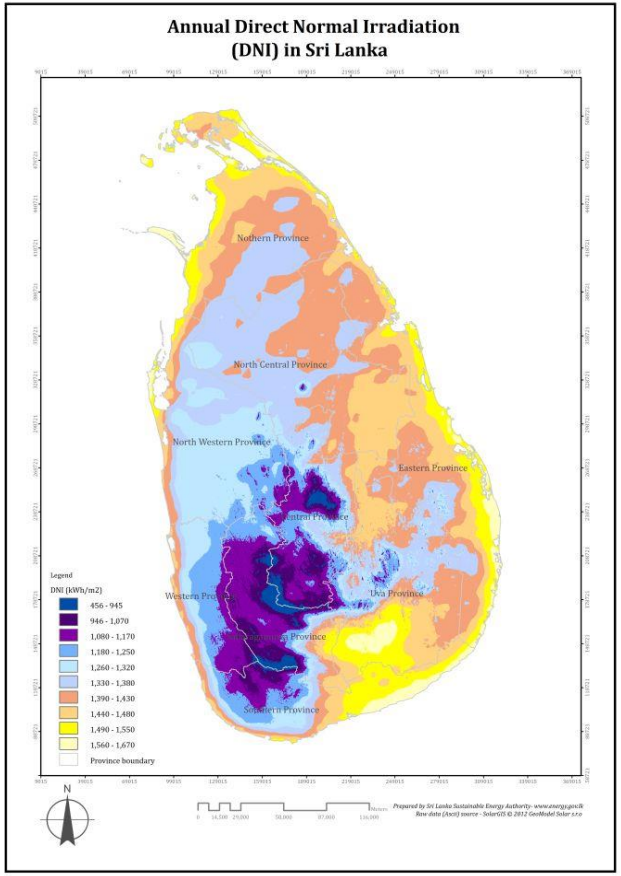


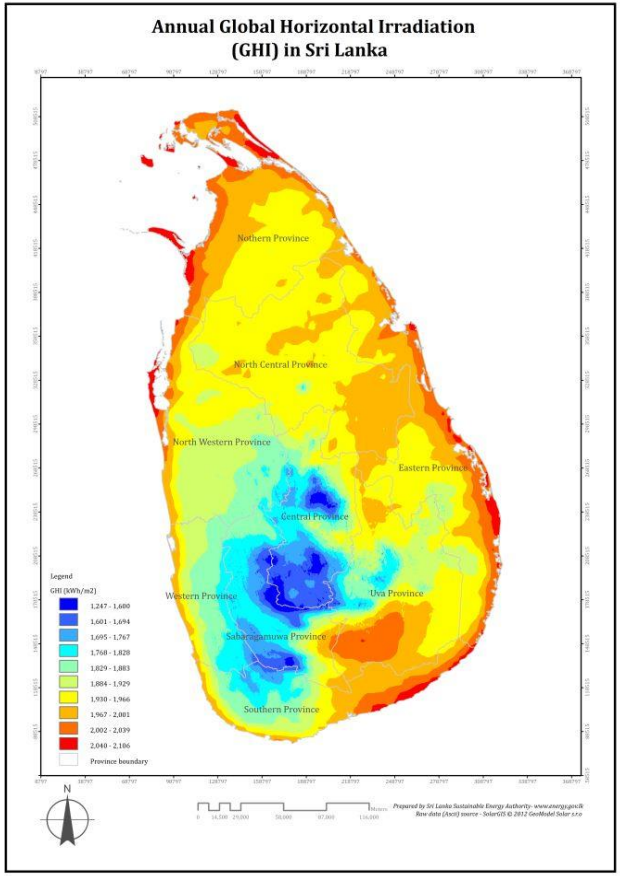
A glimpse of western province



- Even areas a little bit inward from the coast line shows a lower radiation level

Solar resources





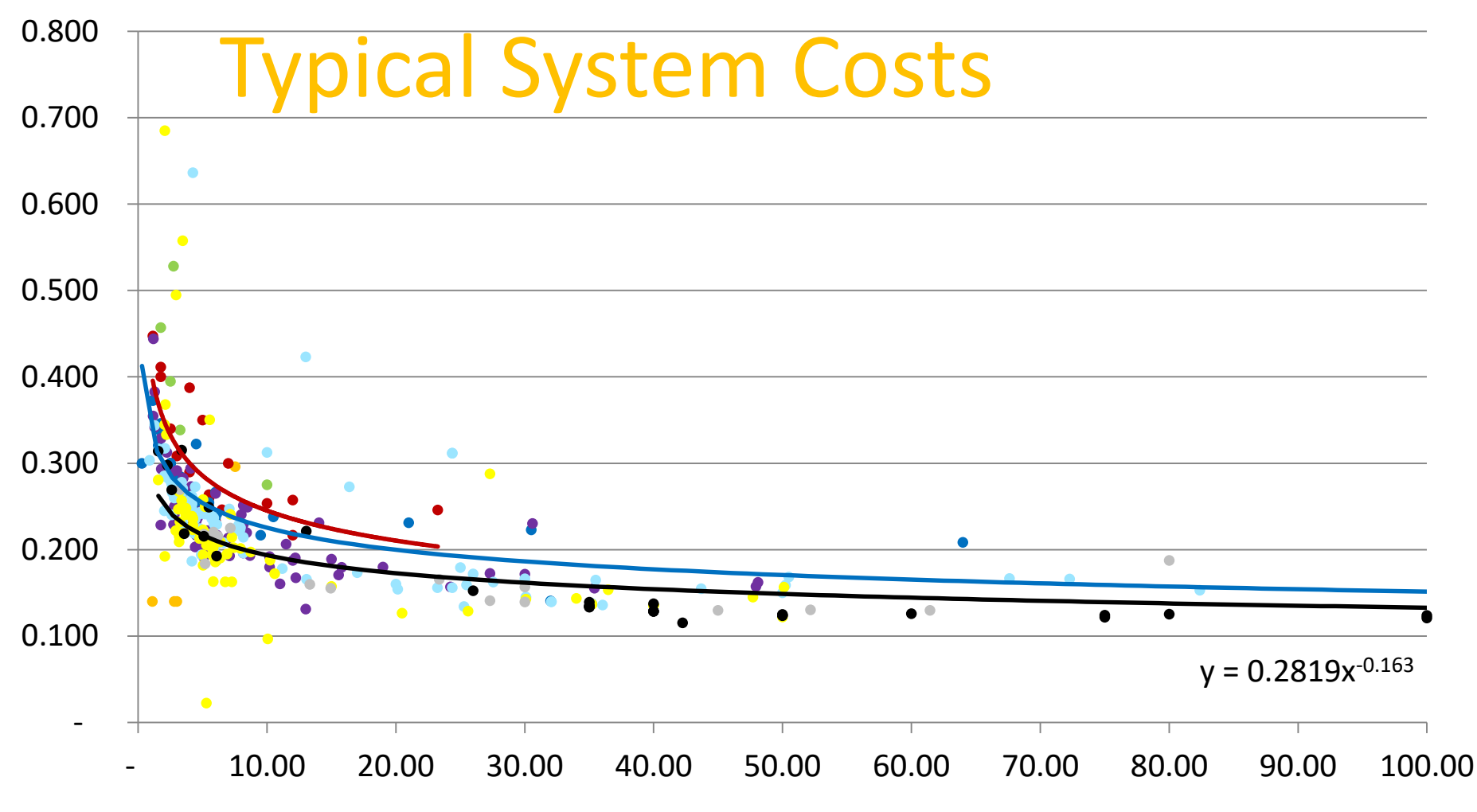
Some basic numbers

- 1kW of solar PV capacity would mean 3-4 panels of size 1.6m x 1.0m
  - Approximately 6.5m^2 per kW (but safer to assume 10m^2)
  - Also stated as 70 sq.ft. per kW
- Mounted in a location unshaded throughout the year
  - At a south sloping section of the roof
  - Ideal angle for Colombo 7 degrees, Jaffna 10 degrees
  - We settle for 15 degrees instead

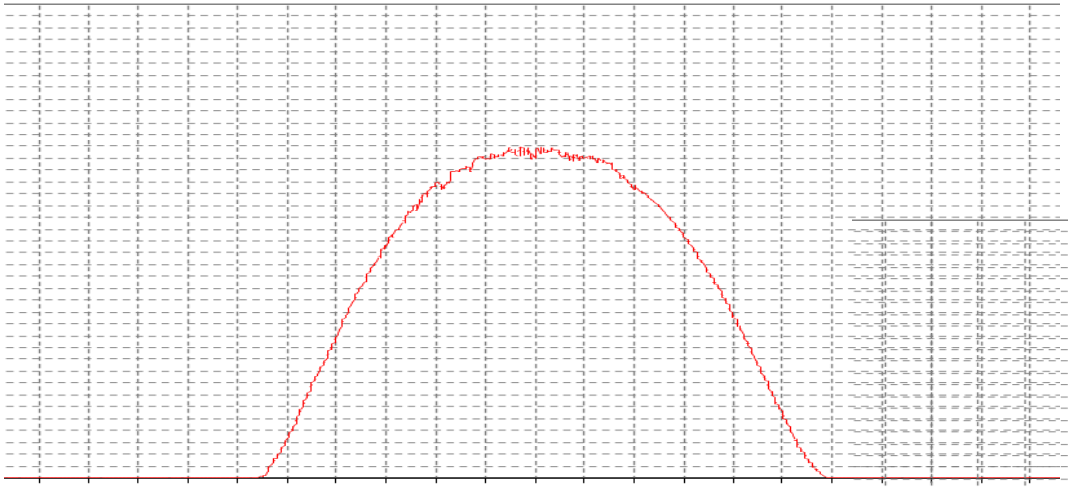
Energy yield

- A kW of capacity can yield 4kWh in an average day
  - It can yield nothing on a heavy rainy day
  - It can yield 5.5kWh on a cloudless day
- The magic number is 120kWh/kW of capacity per month
  - It means an income of LKR2,640/- per month
  - On LKR200,000 cost, this means a 6+ year simple payback

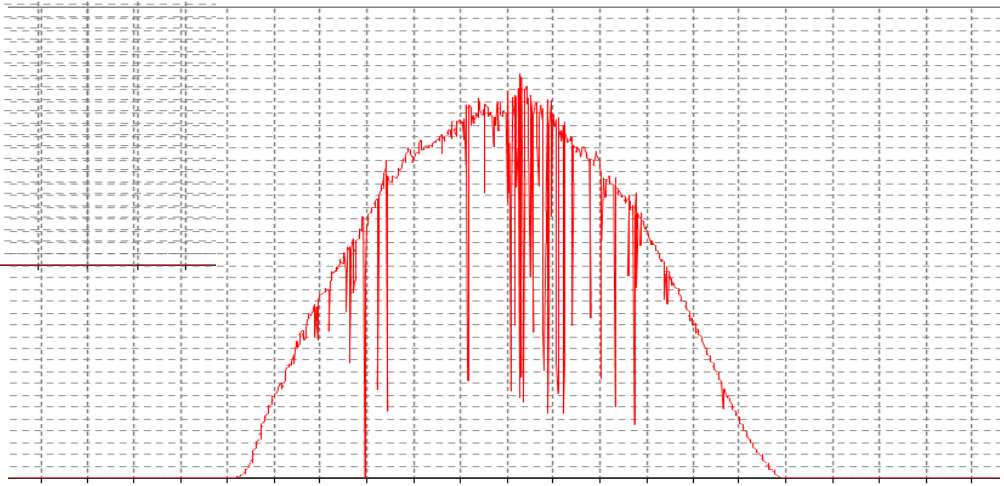
Typical System Costs



Daily Variation



A clear sky



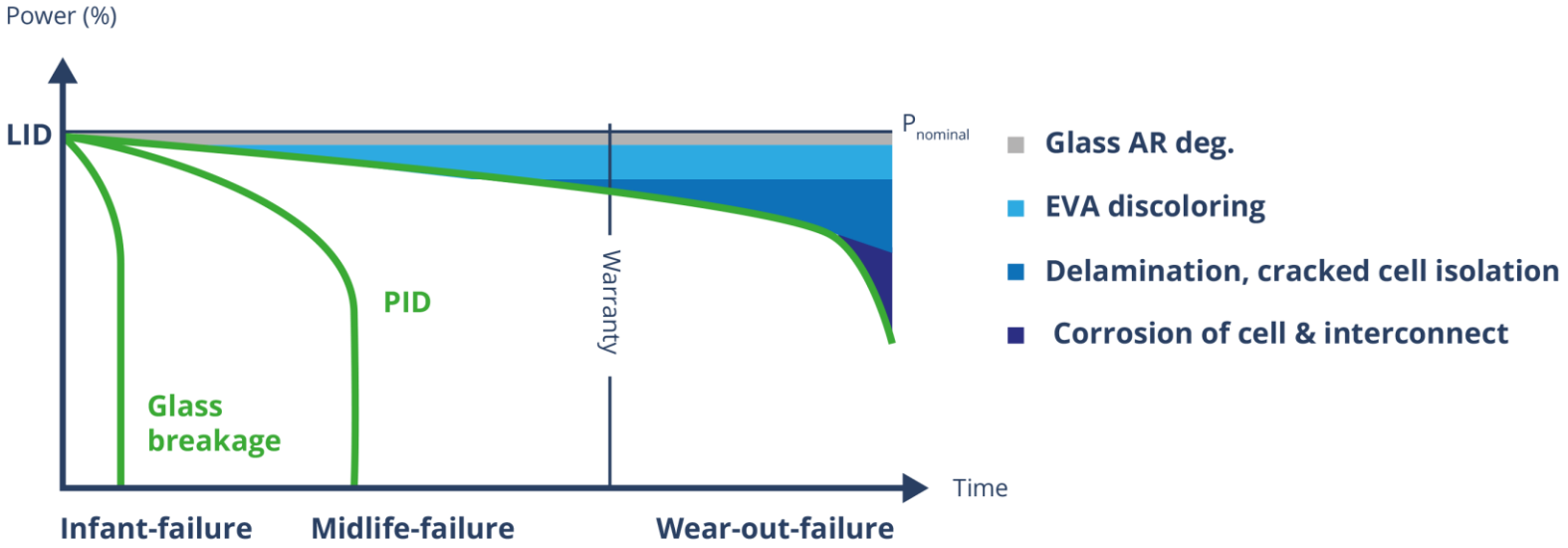
A cloudy sky

Factors affecting generation

- degradation
- connectivity issues
- monthly/seasonal variations
- mounting angle
- Dust deposition / soiling
- temperature

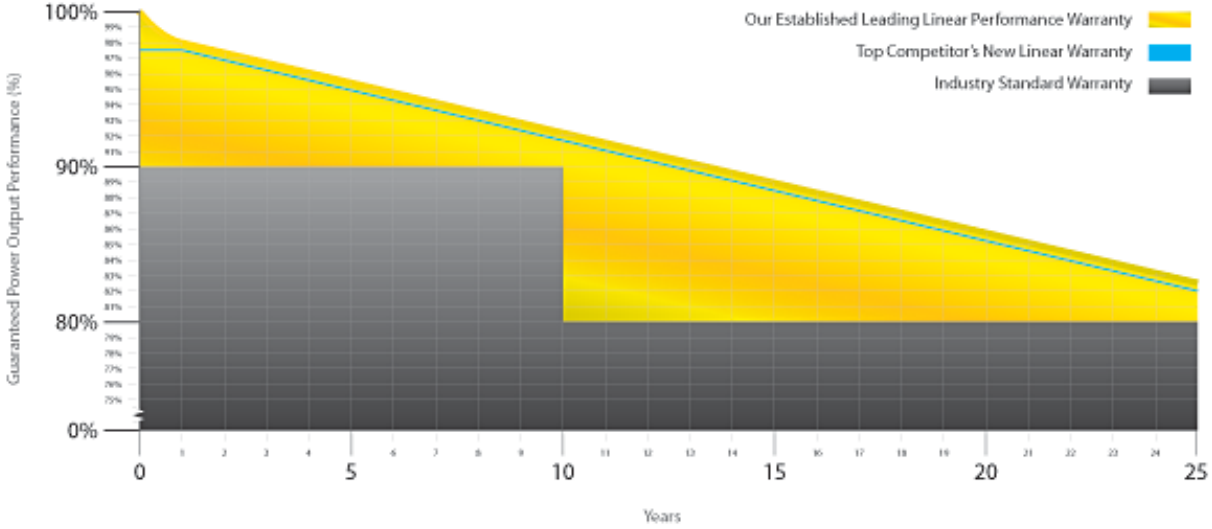
Degradation

- Solar PV panels is a composite, with many material which can change with long exposure to solar radiation



LINEAR PERFORMANCE WARRANTY

BEST Industry Leading Warranty Offered



Potential Induced Degradation

- Potential Induced Degradation (PID)
  - Resulting from high potential (voltage) used in present day strings
    - Common to see voltages in 1,000V range
  - Sodium atoms drawn to semiconductor material affecting the functioning
  - Aided by moisture and temperature

Connectivity

- Cell level soldering can fail prematurely
- Panel to panel connections too can fail due to local conditions
  - Humidity and sea spray
- Cable termination at inverter or junction boxes
  - Ingress protection is required
  - Proper cable termination
  - Routine inspection and correction

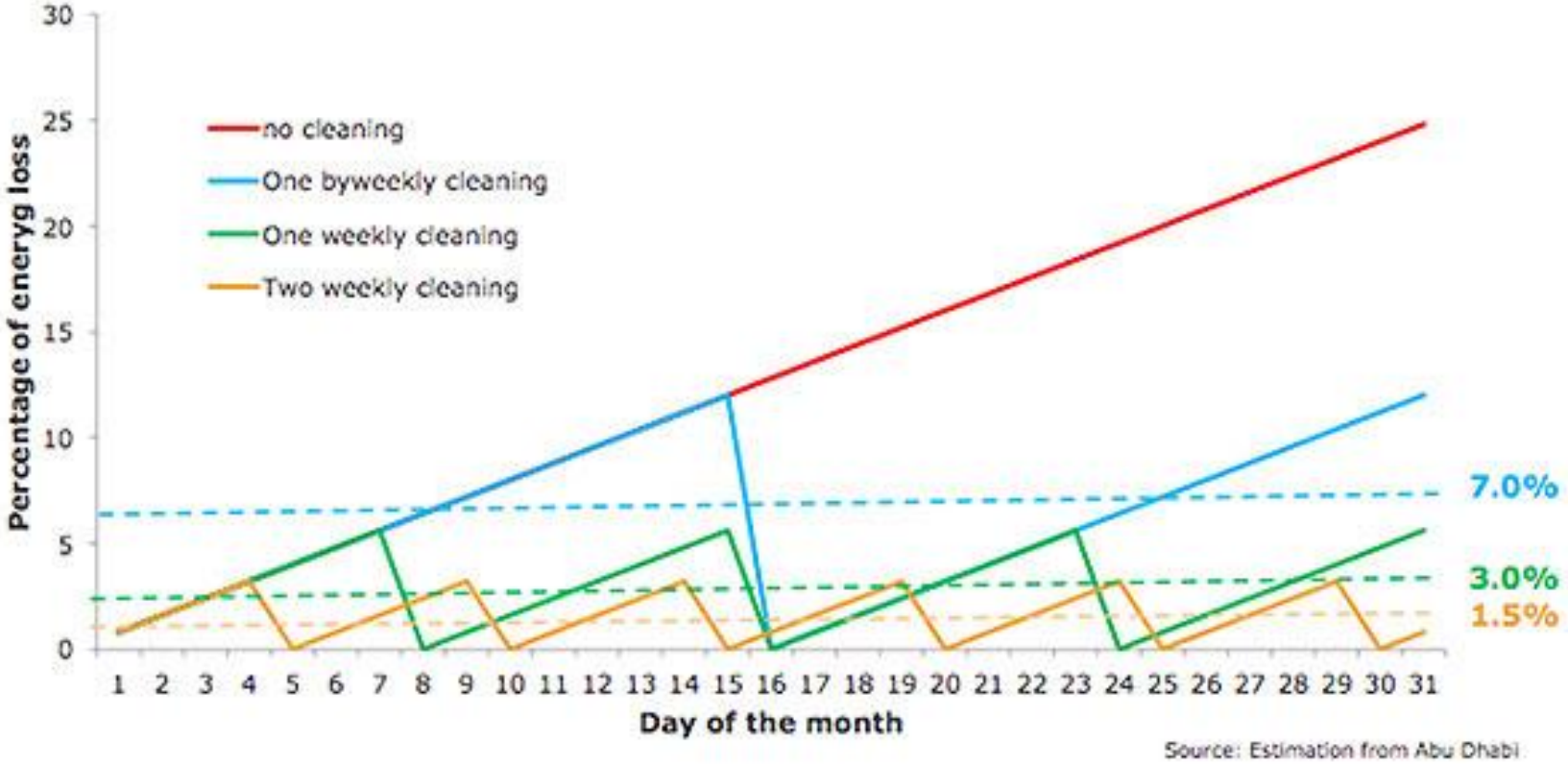
Mounting angle

- For maximum capture of solar radiation, an optimal angle is defined
  - Usually taken as the tilting towards South, in an angle equal to the latitude of the location
  - Hambantota 6°, Colombo 7° and Jaffna 10°

Dust deposition / soiling

- Most roofs are located near roads
  - Dust deposition is a serious issue
- Mostly taken care of… by frequent rain
  - If the mounting angle is kept at least 10°
  - Not so easily in the case of bird droppings
- Sri Lankan conditions are favourable
  - Quarterly cleaning is the norm
  - Advisable to do it on a monthly basis

Impact of periodic cleaning



Panel temperature

- Panel temperatures are discussed in 60°C, in most text books
  - Sri Lankan conditions can mean 70°C and in some cases 85°C
- Many effects due to higher than optimal temperature
  - Panel outputs are given under standard test conditions

- Consider a panel of 270W (meaning it will generate 270W under STC) operating at 45°C
  - Lost energy % = (45-25) x -0.43 = -8.6%
  - (100% - 8.6%) x 270W = 91.4% x 270W = 246.78W
- Same panel under 85°C
  - Lost energy% = (85-25) x -0.43 = 25.8%
  - (100%- 25.8%) x 270W = 74.2% x 270W =200.34W

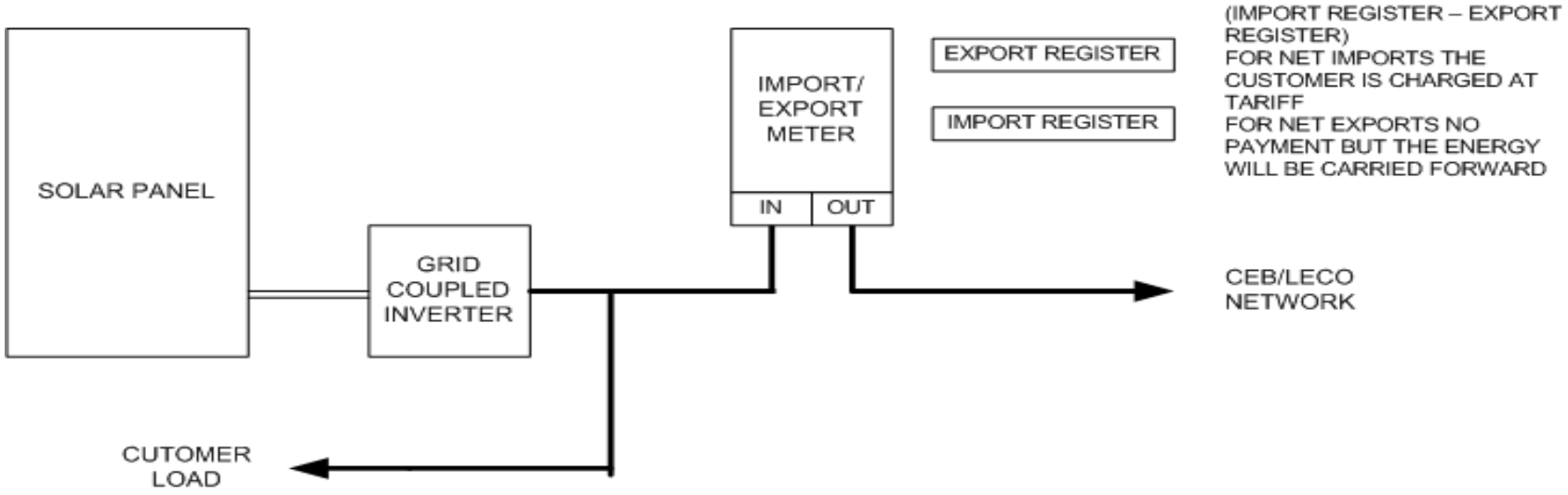
Assurances needed

- Panel warranty – usually 10 years minimum
  - Also 85% of capacity at 20th year of operation
- Inverters – usually 5 years
  - Need product registration, international cover and if possible extended warranty up to 10 years
- System warranty – given by the local installer
  - Coupled with an energy guarantee (ideal if given in a 20 year schedule with money back guarantee)
  - Insist on an O&M contract with the installer (large systems)

Rooftop Scheme

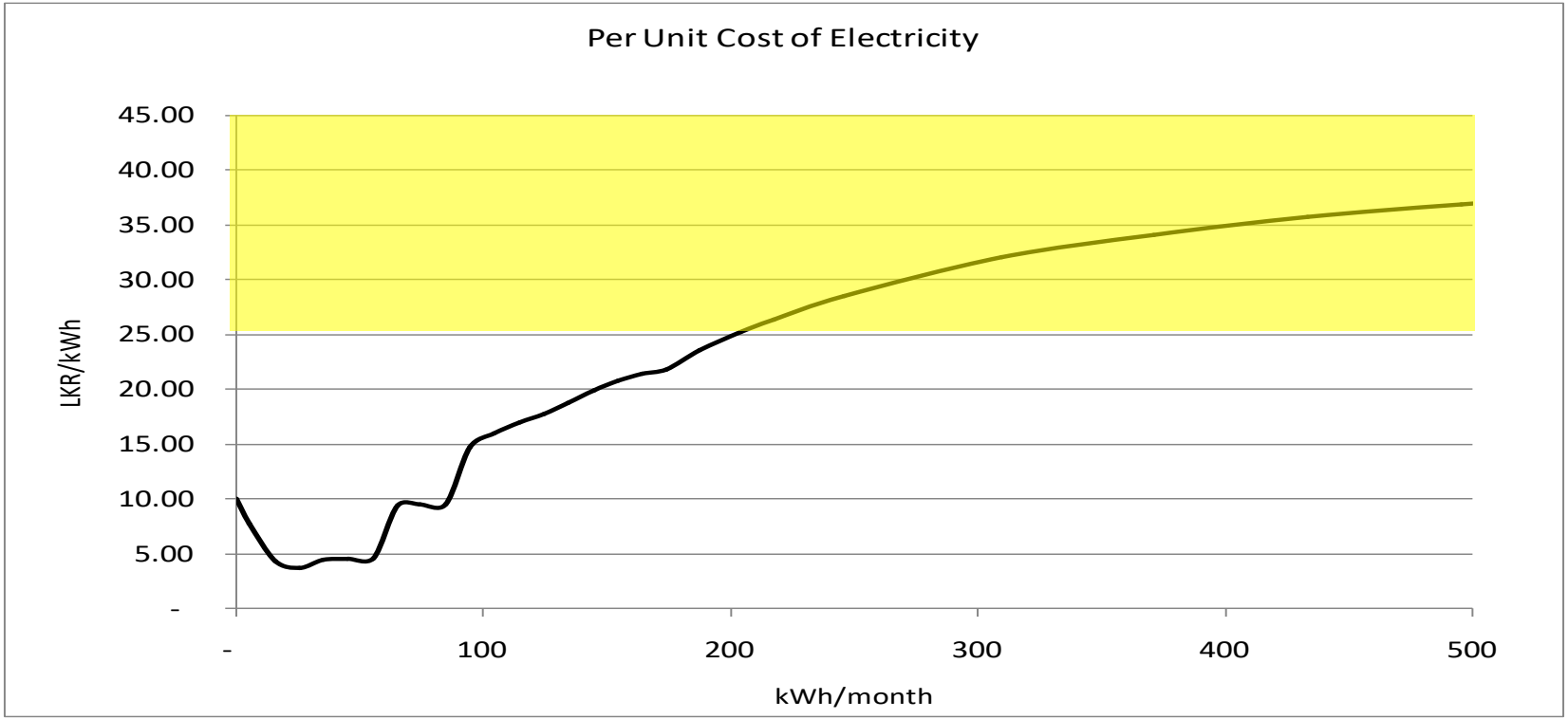
- Net Metering (Old Scheme)
  - Energy to energy cancellation, no payment involved
- Net Accounting
  - Slightly reduced bill due to own use of solar electricity, excess exported and paid at LKR19.82/kWh LCoE (translated to LKR22.00/kWh in first seven years and LKR15.50/kWh for the next thirteen years)
- Net+Plus
  - No relationship to electricity connection, total solar electricity exported and paid at LKR19.82/kWh LCoE

Net Metering



SCHEME I – NET METERING

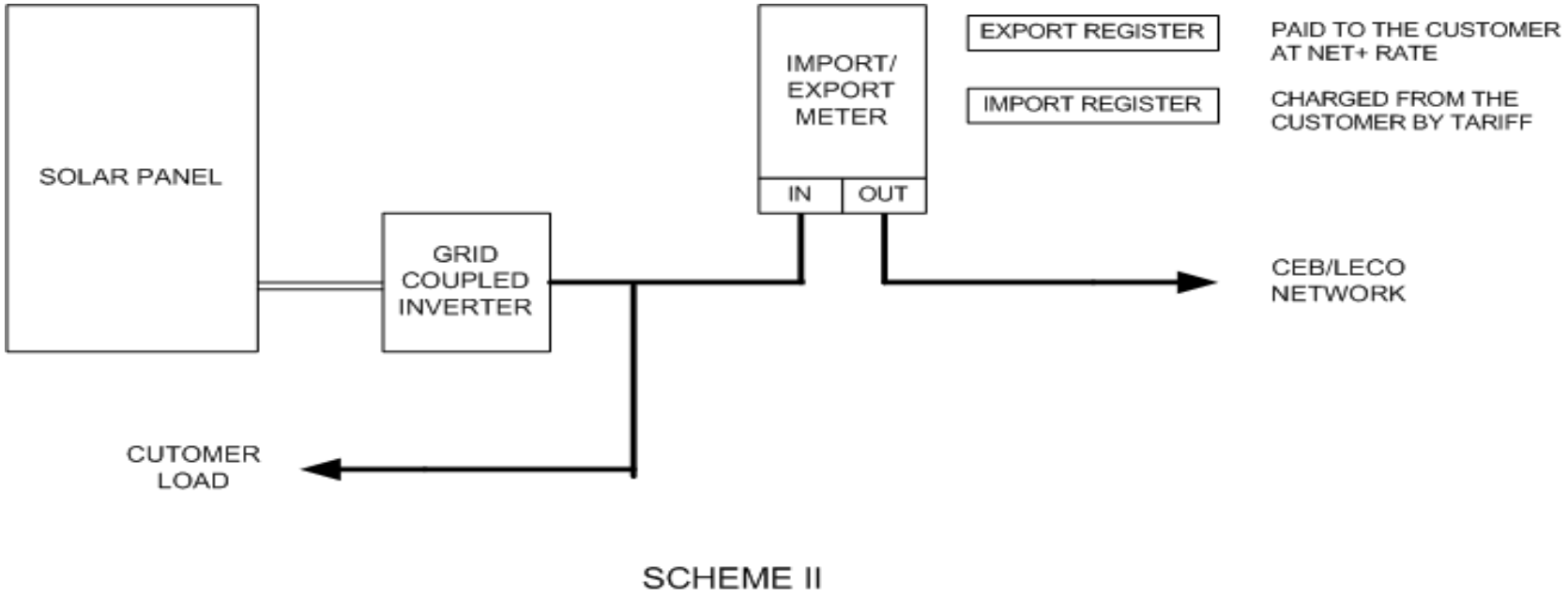
Why Solar PV Net-metering ?



Result from 1kW system

- Original electricity bill 119kWh/month (LKR2,056)
- Reduced electricity bill 3kWh/month (LKR38
- Earnings from exported electricity - none (LKR 0)
- Total profit LKR2,018
- Simple payback period 7.4+ years

Net Accounting

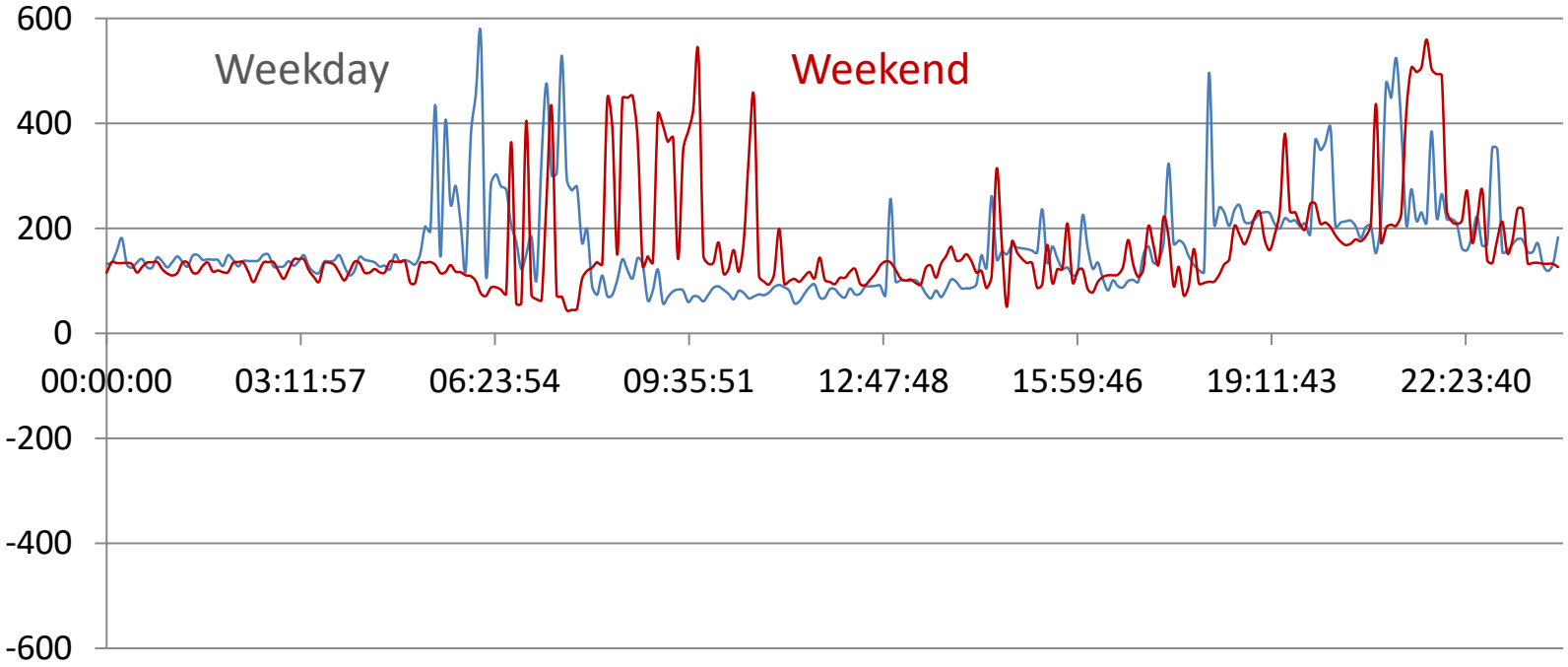


SCHEME II

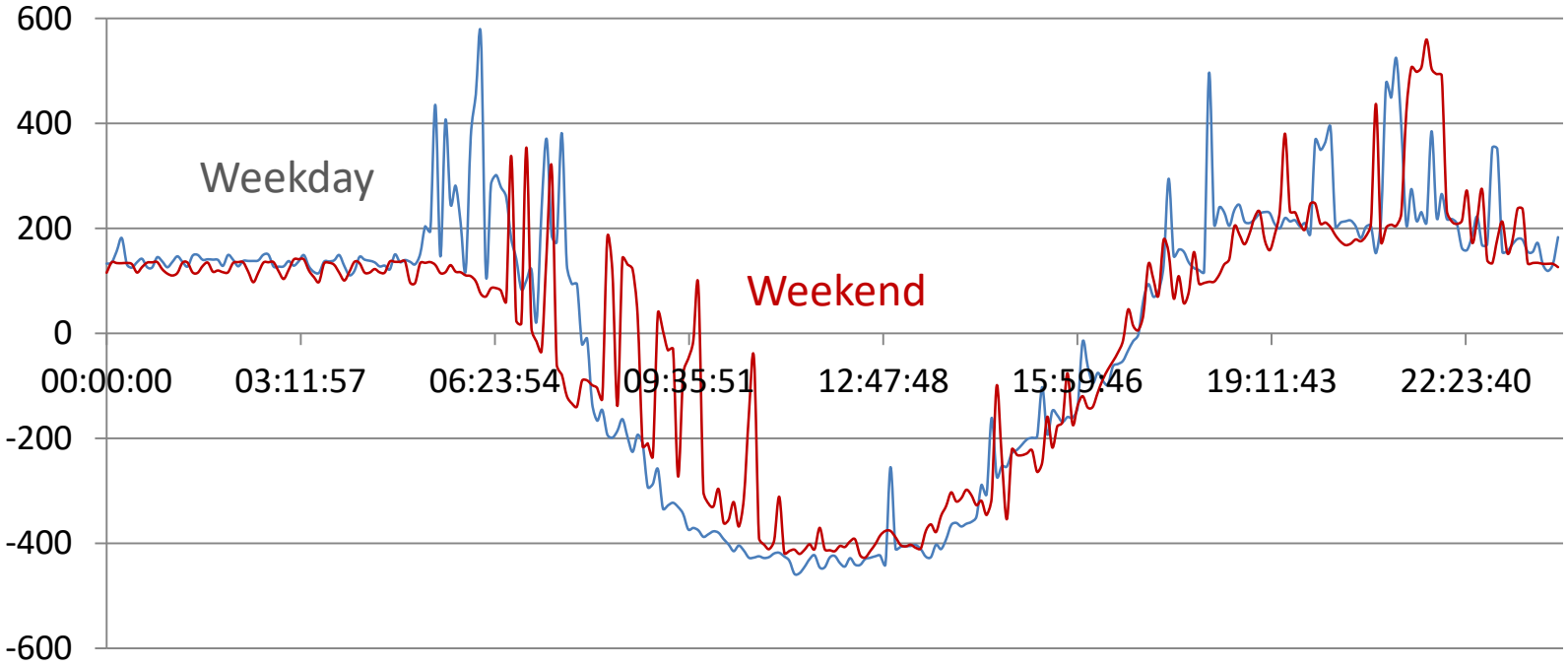
Net Accounting

- Benefits depend on the ratio between day time electricity use / total electricity use
  - For a typical home, 20% - 35%
- There can be a significant difference between weekend and weekday use
  - Weekdays, most probably only the refrigerator
  - Balance is exported
  - Weekends, many activities at home
- Depends entirely on the family composition and activities

Typical Home Use (No Solar)



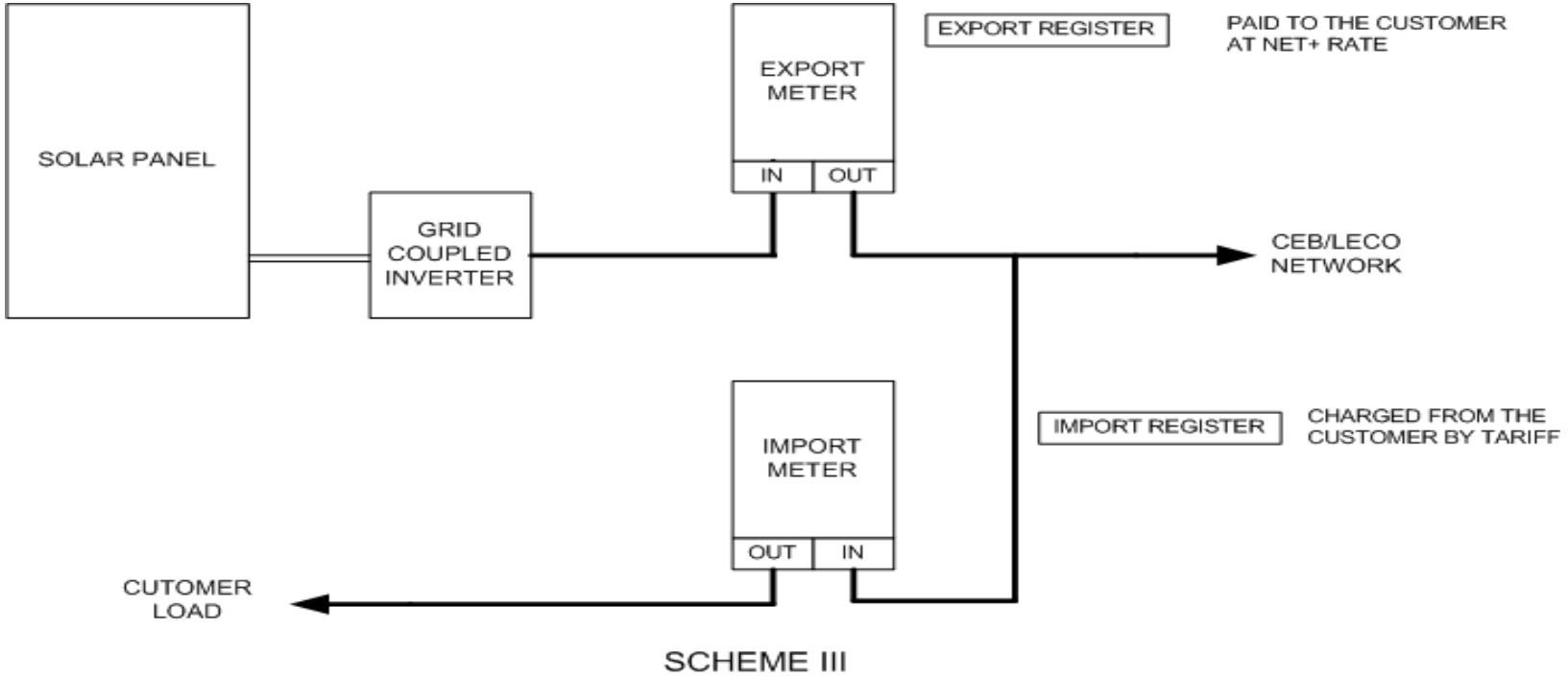
Typical Home Use (With Solar 1kW)



Result from 1kW system

- Original electricity bill 119kWh/month (LKR2,056)
- Reduced electricity bill 81kWh/month (LKR771)
- Earnings from exported electricity 78kWh (LKR1,546)
- Total profit LKR2,831
- Simple payback period 5+ years

Micro Power Producer



SCHEME III

Results

- Original electricity bill 119kWh/month (LKR2,056)
- New electricity bill 119kWh/month (LKR2,056)
- Earnings from exported electricity 116kWh (LKR2,299)
- Total profit LKR2,299
- Simple payback period 6.5+ years

Net Result of the Schemes

Description	Net-metering	Net-accounting	Net+Plus
Electricity use kWh/month	119	119	119
Original bill value USD/month	13.71	13.71	13.71
Post project bill value USD/month	0.25	5.14	13.71
Bill reduction USD/month	13.45	8.57	-
Earnings from exports USD/month	-	10.31	15.33
Total gain USD/month	13.45	18.87	15.33
Simple payback period years	7.4	5.0	6.5

Identifying a suitable scheme

- A difficult task, depending on many factors
- A basic guide will be to compare the average cost of electricity (in LKR/kWh) with LKR22.00 paid for exported electricity
  - Most domestic accounts will be benefited from Net-metering and net-accounting schemes (average cost >> LKR22.00) – avoid paying high cost to purchase electricity
  - Industrial accounts will favour net plus scheme – buy cheap electricity and earn handsomely by selling all you produce

Real Comparator

- A spreadsheet solver is being developed for the purpose
- The output result is not yet verified
- A sneak preview….

Thank you..!

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