



# Solar power plants for residential, commercial, utility and off-grid applications Part 2

Professor Chem Nayar



**INTERNATIONAL CONFERENCE 2014 POWER AND ENERGY SYSTEMS:  
TOWARDS SUSTAINABLE ENERGY, BANGALORE 13-15 MARCH, 2014**

# Outline

- ❑ Introduction
- ❑ Solar Energy – Facts
- ❑ Photovoltaic (PV)
- ❑ Power Electronics Converters
- ❑ Applications :
  - ❑ Residential
  - ❑ Commercial
  - ❑ Solar Farms

Background photo: [www.bso.vvs.be](http://www.bso.vvs.be)

# Photovoltaic market by segment

Segment	Application	Typ. Power Range	Nett Power Exporters
Off Grid	Remote applications without grid connection...	To 30kW	N/A
	Chargers for battery powered equipment – telecoms masts and traffic signage etc	<100W	N/A
	Mobile applications such as small boats	<1kW	N/A
Domestic	Rooftop ( without and with storage)	1-15kW	Possibly
Commercial	Office Windows and rooftop	10-150kW	Yes
	Public building rooftop	15kW-30MW	Yes
	Agricultural rooftop	15kW-5MW	Yes
	Industrial rooftop	20kW-5MW	Possibly
Utility	Industrial Roof	200-2000kW	Yes
	Field	500-500MW	Yes

# World Electricity Figures

The world's Electricity - installed generating capacity is equal to 5,144,000,000 kW

Datasource: CIA - The World Factbook

List of countries by Electricity - installed generating capacity					
Country Name  	View Data  	Global Rank  	Region & Regional Rank  	Electricity - installed generating capacity kW  	Year  
China  		1	East Asia & Pacific   1	1,146,000,000	2013
United States  		2	North America   1	1,025,000,000	2013
Japan  		3	East Asia & Pacific   2	284,500,000	2013
Russia  		4	Europe & Central Asia   1	223,100,000	2013
India  		5	South Asia   1	189,300,000	2013
Germany  		6	Europe & Central Asia   2	153,200,000	2013
Canada  		7	North America   2	131,500,000	2013
Italy  		8	Europe & Central Asia   3	122,300,000	2013
France  		9	Europe & Central Asia   4	119,100,000	2013
Brazil  		10	Latin America & Caribbean   1	106,200,000	2013
Spain  		11	Europe & Central Asia   5	102,500,000	2013
United Kingdom  		12	Europe & Central Asia   6	88,020,000	2013
Korea  		13	East Asia & Pacific   3	80,590,000	2013
Mexico  		14	Latin America & Caribbean   2	59,330,000	2013
Australia  		15	East Asia & Pacific   4	56,940,000	2013

<http://mecometer.com/topic/electricity-installed-generating-capacity/>



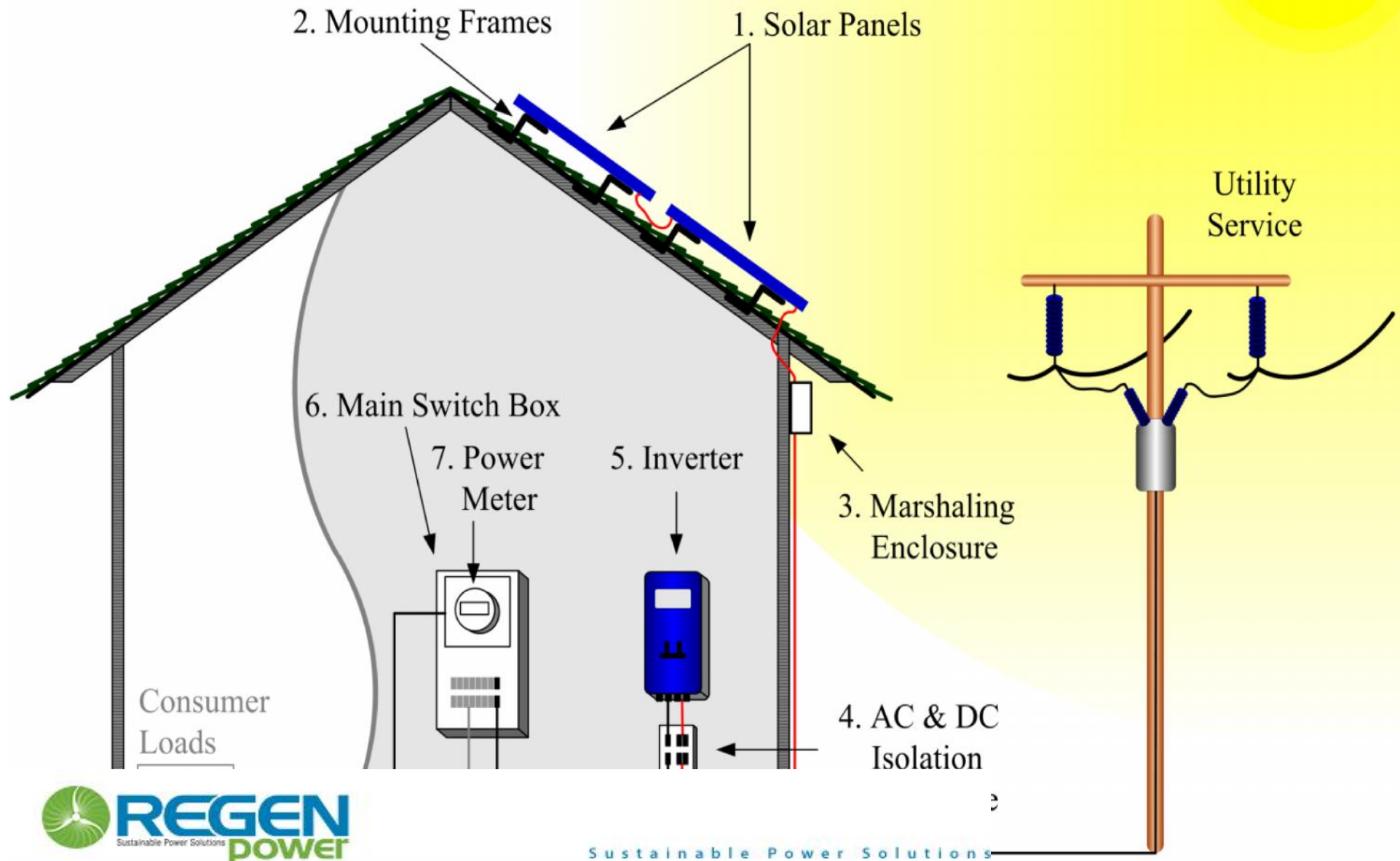


# Residential Rooftop Systems

- Grid-connected Photovoltaic (PV) differs from stand-alone
- Usually no batteries—power fed straight into grid
  - Cheaper
  - More reliable
  - More efficient
- Why install grid-connected PV if grid available?
  - provide consumers with a means of producing clean electricity
  - Limited peak shaving capability ( generation matches with air conditioning loads)
  - No transmission and distribution loss
  - The complementary nature of solar vs hydro-availability (for example in Kerala)
- Ideally suited to urban rooftops
- Very popular in Europe, Japan ,USA, Australia

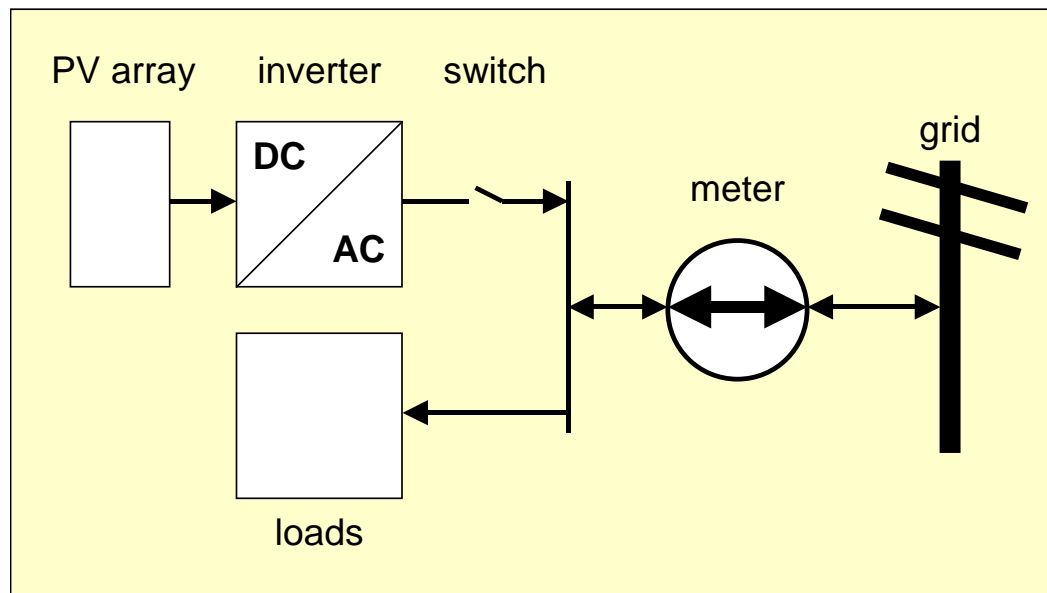


# Grid Connected Solar Power System

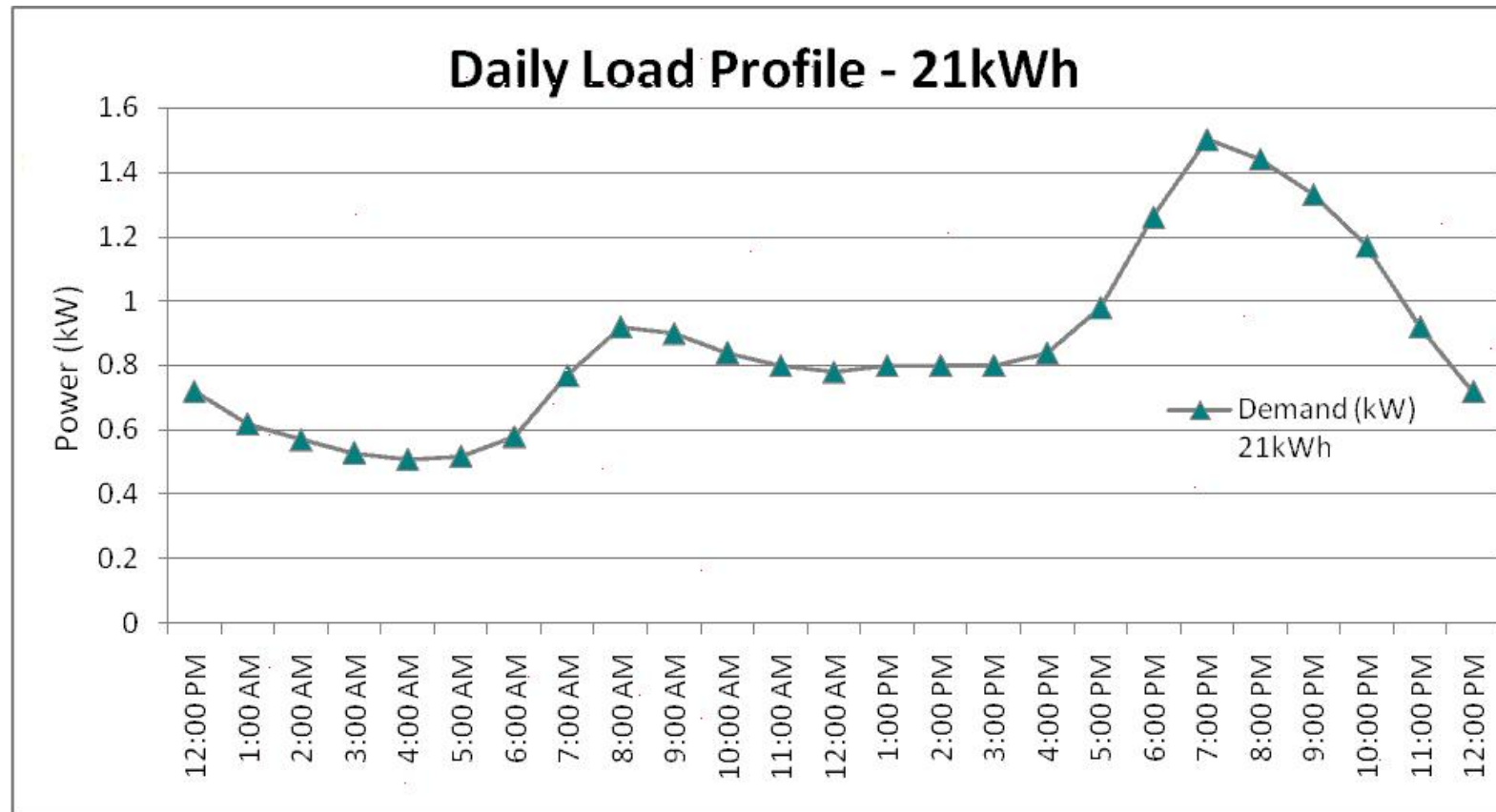


# Grid connected Solar Power System

- *Sunlight → PV → DC electricity → inverter → AC electricity → grid*
- System connected at same point as loads
- Loads supplied from grid in normal manner



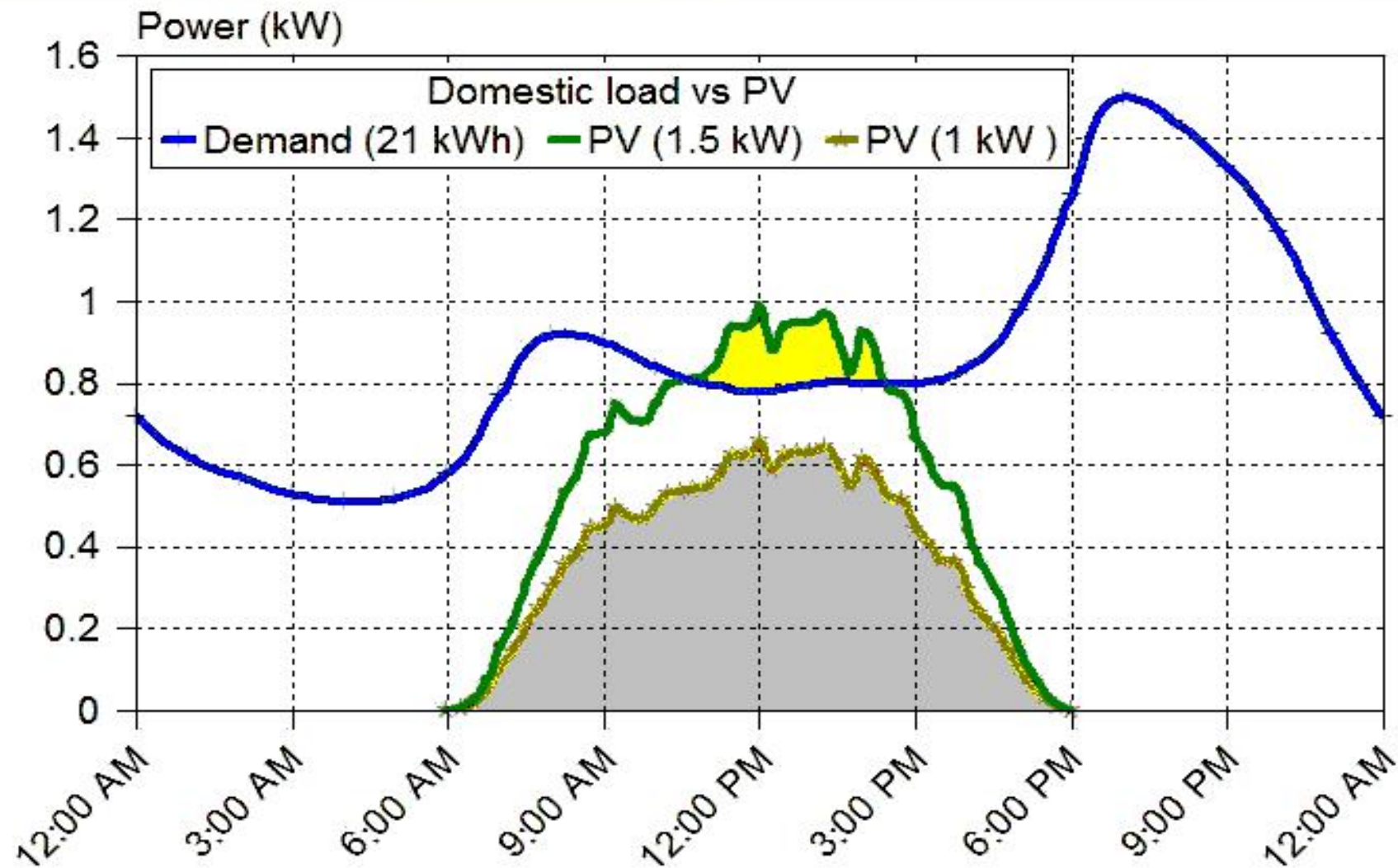
# Typical Average Daily Consumption, Australia



The carbon emission ( mostly CO<sub>2</sub>) is about 10 Metric tons per year.



# Typical Daily Power Consumption and Solar Availability



# Rooftop Solar-String Type

## Photovoltaic (Solar Cell) Modules

A photovoltaic module transforms solar energy into electricity.



## Inverter (Power Conditioner)

The inverter converts DC electricity generated by the photovoltaic module into AC electricity and automatically controls the entire system.

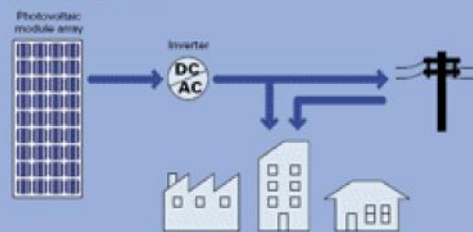
## Indoor Distribution Panel

The panel delivers appropriate electric loads to household electrical appliances.

## Watt-Hour Meters



## Grid-Connected Photovoltaic Power Generation System

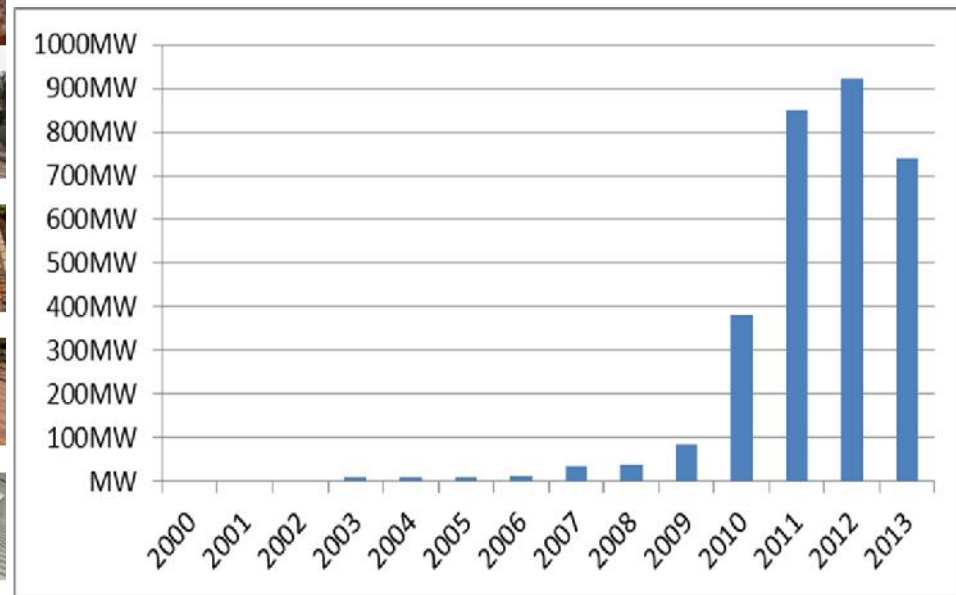




# Residential Solar Installations

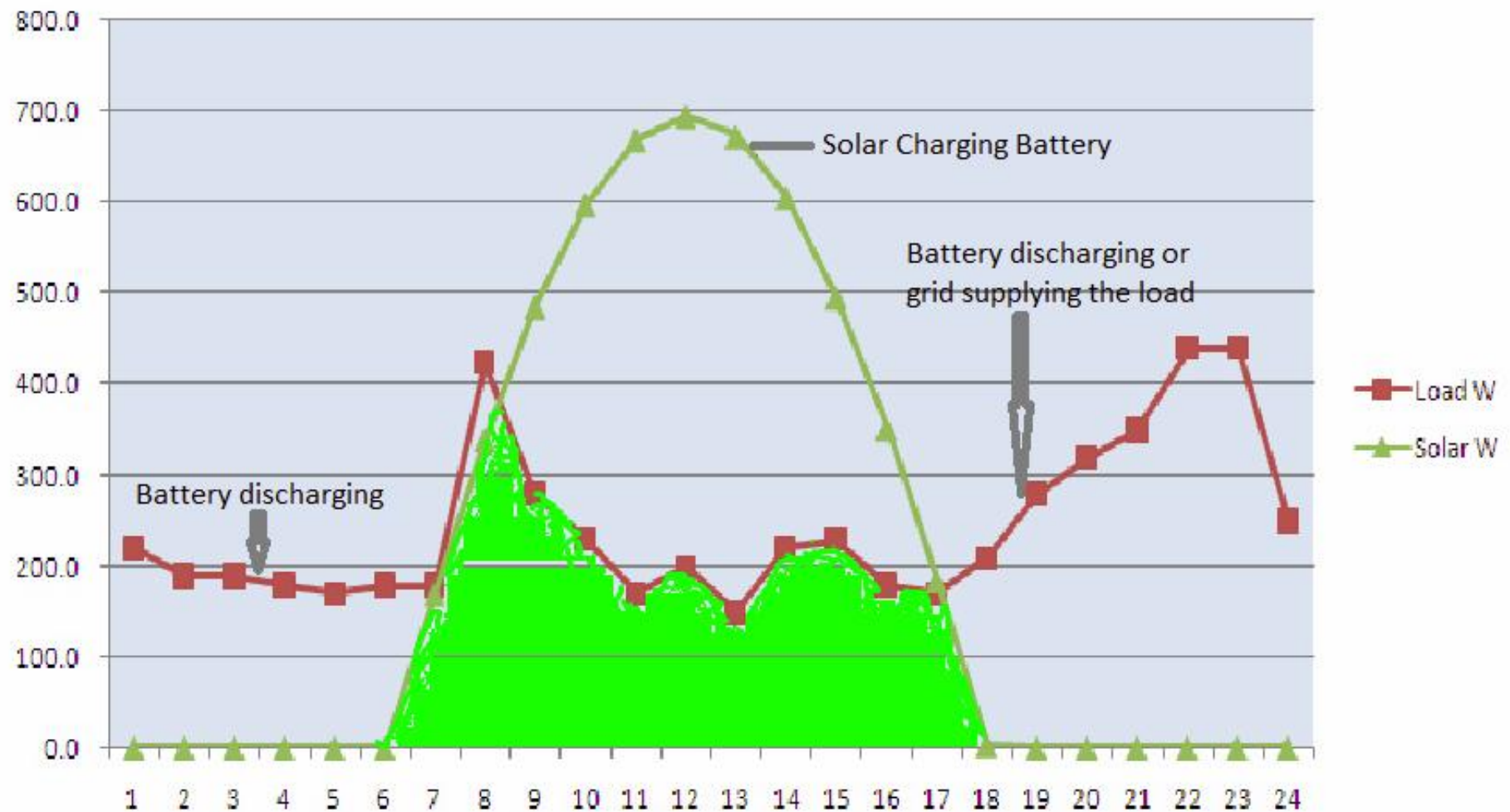


# Residential Rooftop Installations in Australia





# Typical Residential Load Profile ( Kerala) : Energy Balance



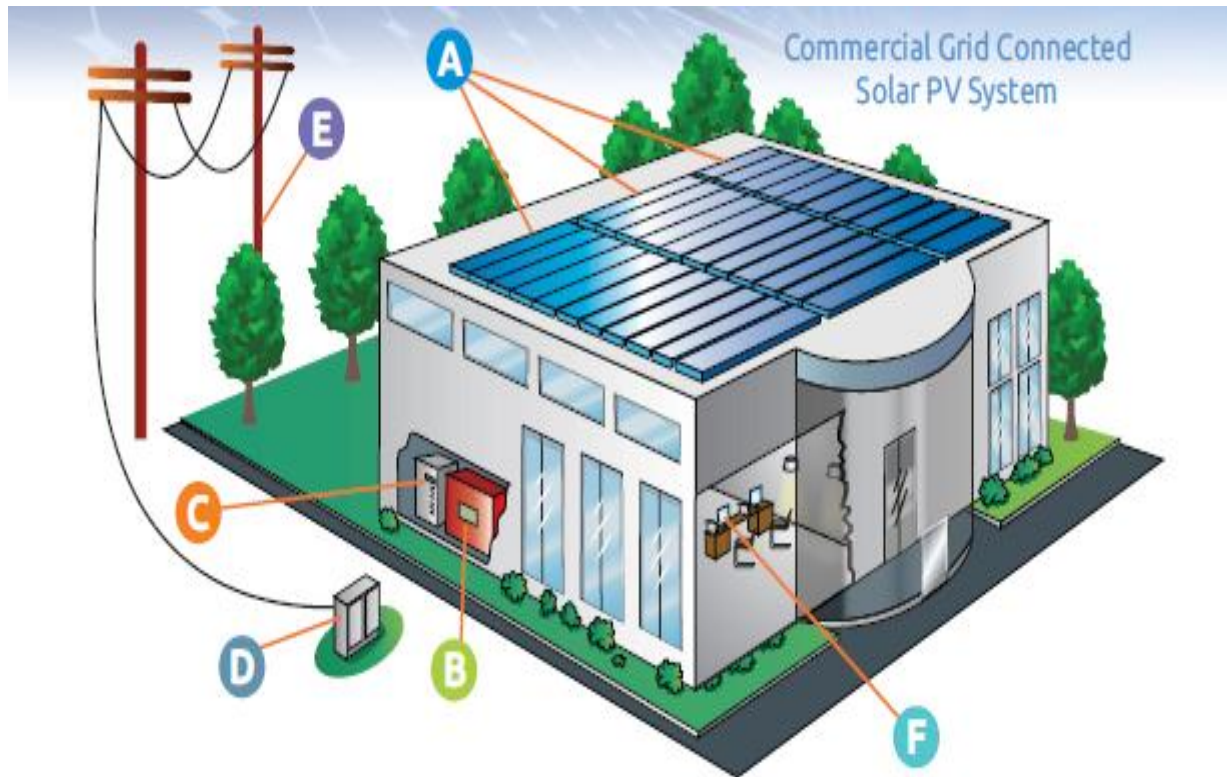
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Background photo: [www.bso.vvs.be](http://www.bso.vvs.be)

# Commercial Grid connected PV Systems

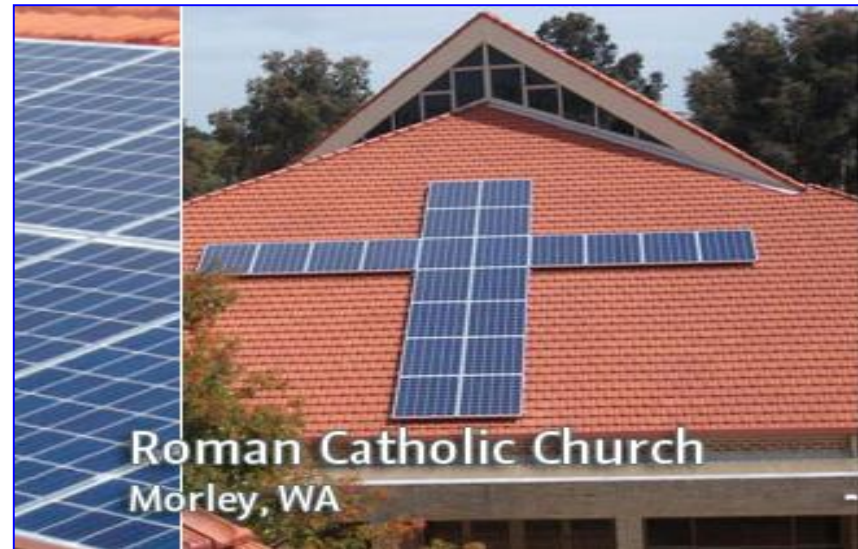
## Typical Grid Connect PV



A – Solar Panels.  
B – Inverter.  
C- Utility Meter.  
D- Electrical Panel.  
E- Utility Grid.  
F- Online System Monitor



# Community Solar

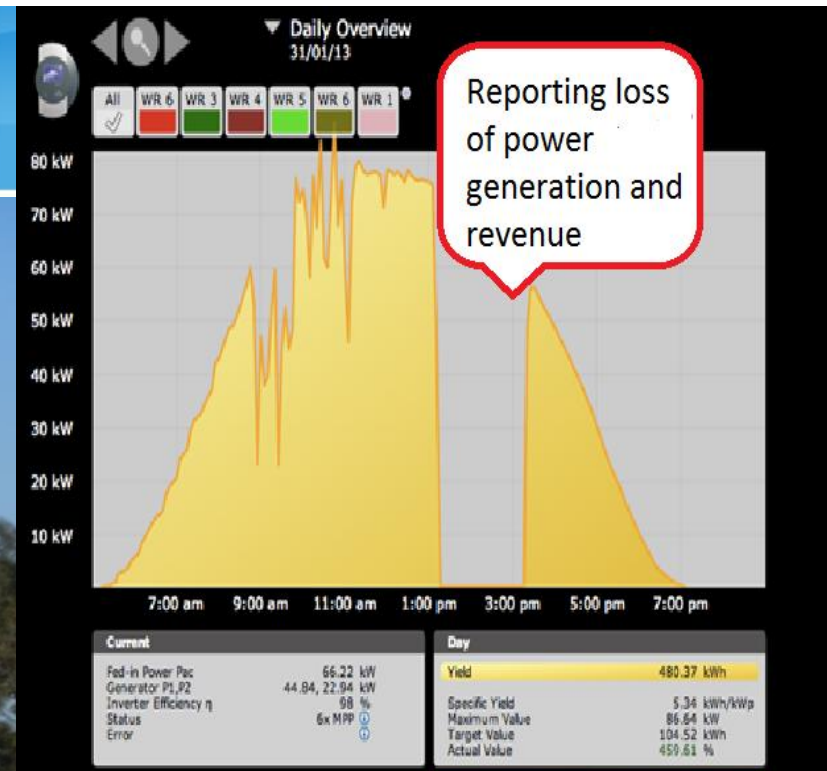




# Commercial Solar PV Installation-100kW, Sydney



- Rated as “Above and Beyond Standards” by GSES in the “The Good. The Bad and The Ugly presentation”, Clean Energy Council Conf., 2013

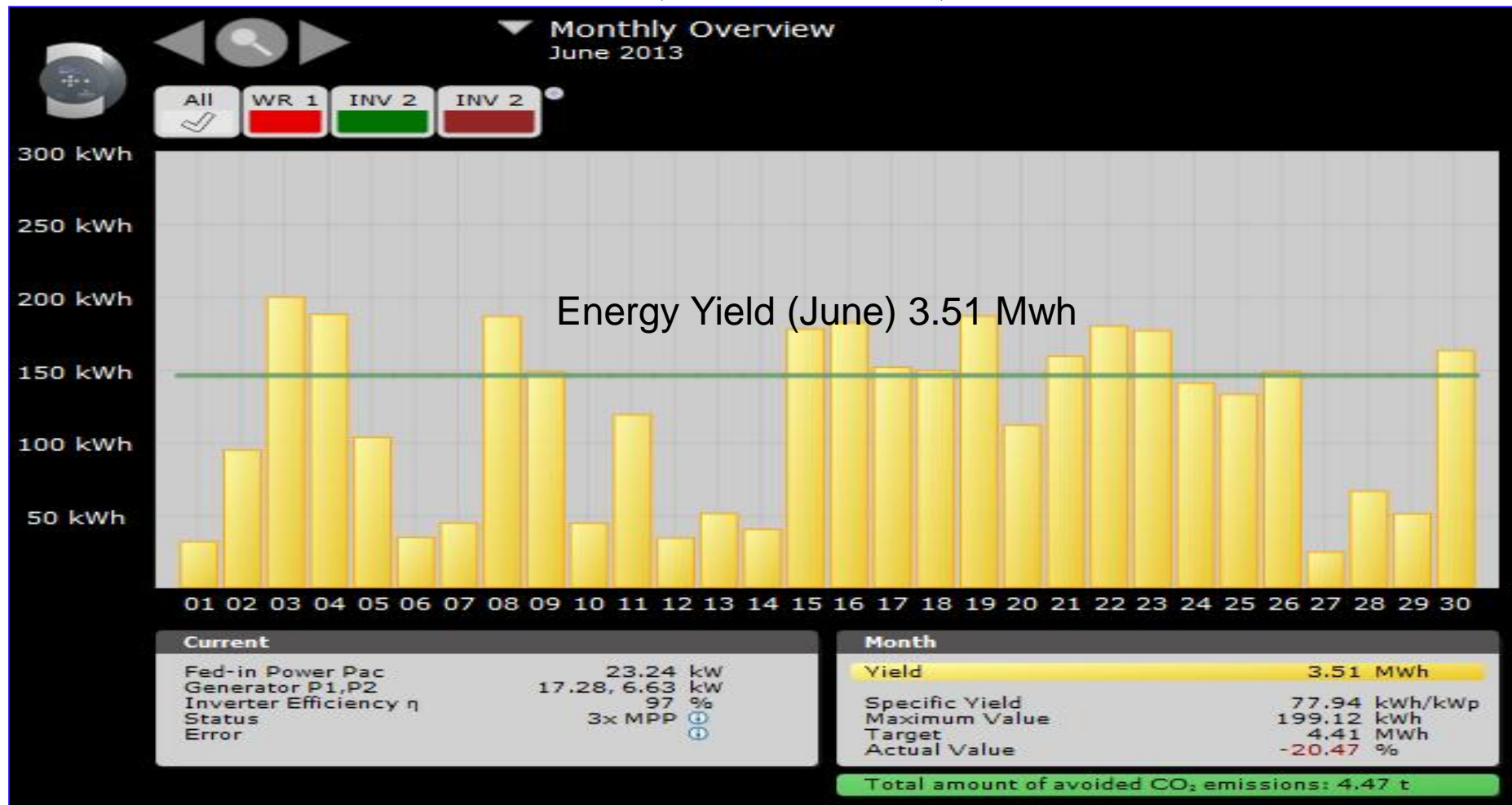




## 40kW Tilted Installation, Dubbo, NSW, Australia

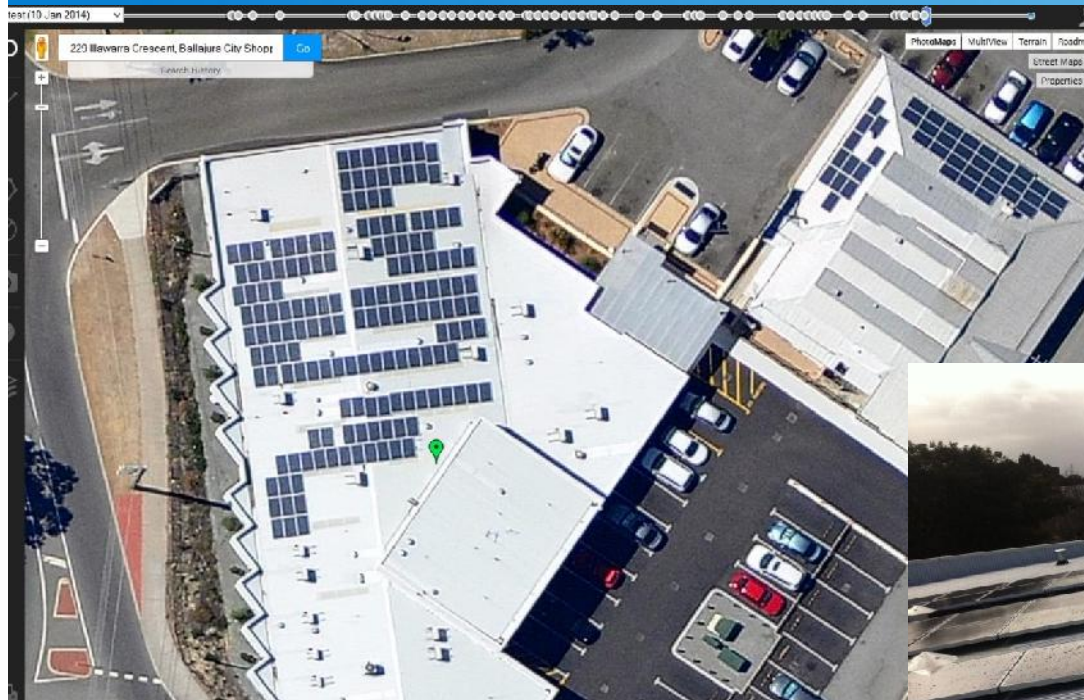


## 40kW – Worst Winter Month (Dubbo-NSW)



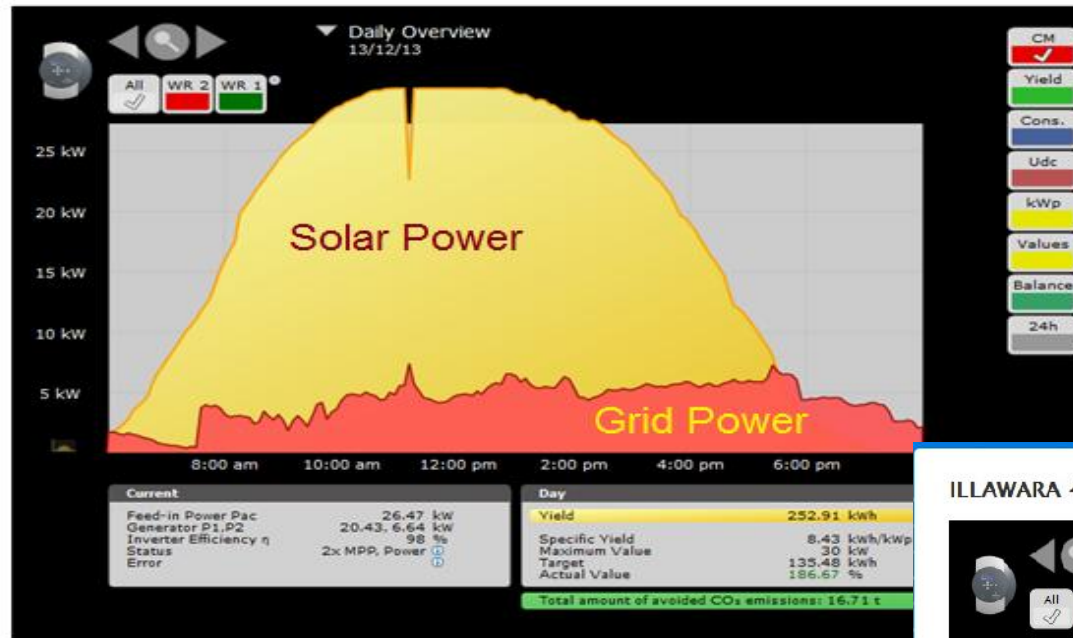


# 50kW Illawarra Medical Centre

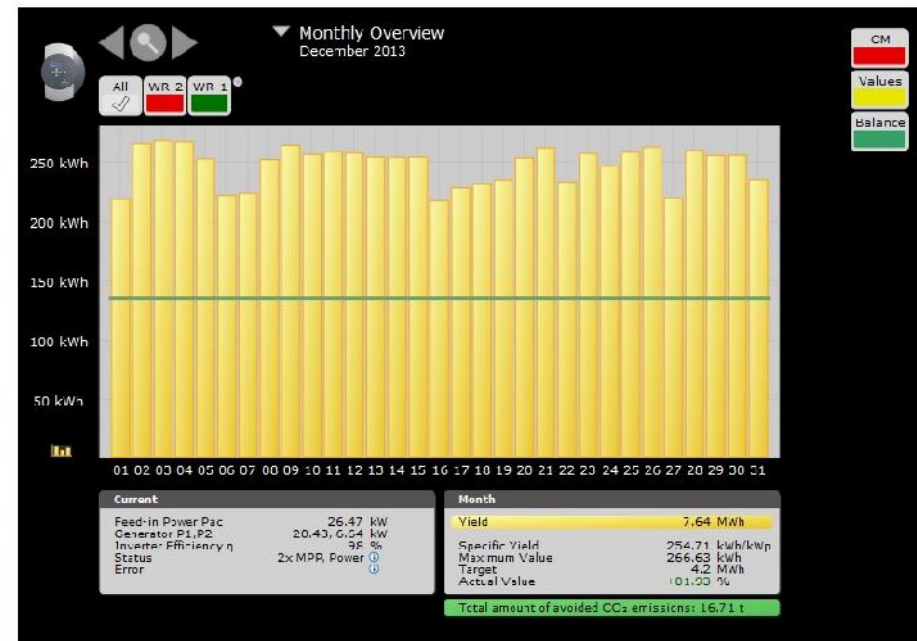


# Illawarra Medical Centre , Perth

## ILLAWARRA 40kW



## ILLAWARRA 40kW







# Grid-interactive systems With Battery





# Thangam Hospital, Palakkad, Kerala





# Thangam Hospital, Palakkad, Kerala





# Mar Basilus College, Trivandrum





# Mar Basilus College, Trivandrum





## 100kW Rooftop PV : Pushpagiri Hospital





# MACFAST College, Tiruvalla Grid connected Solar Power System





# MACFAST College, Tiruvalla Grid connected Solar Power System



# Remote Monitoring, Mar Basilus College of Engineering, 100kWp

**LEONICS**® Monitoring and Operation Center



LOGOUT



RdS-Macfast



Thangam Hospital



Pushpagiri Hospital



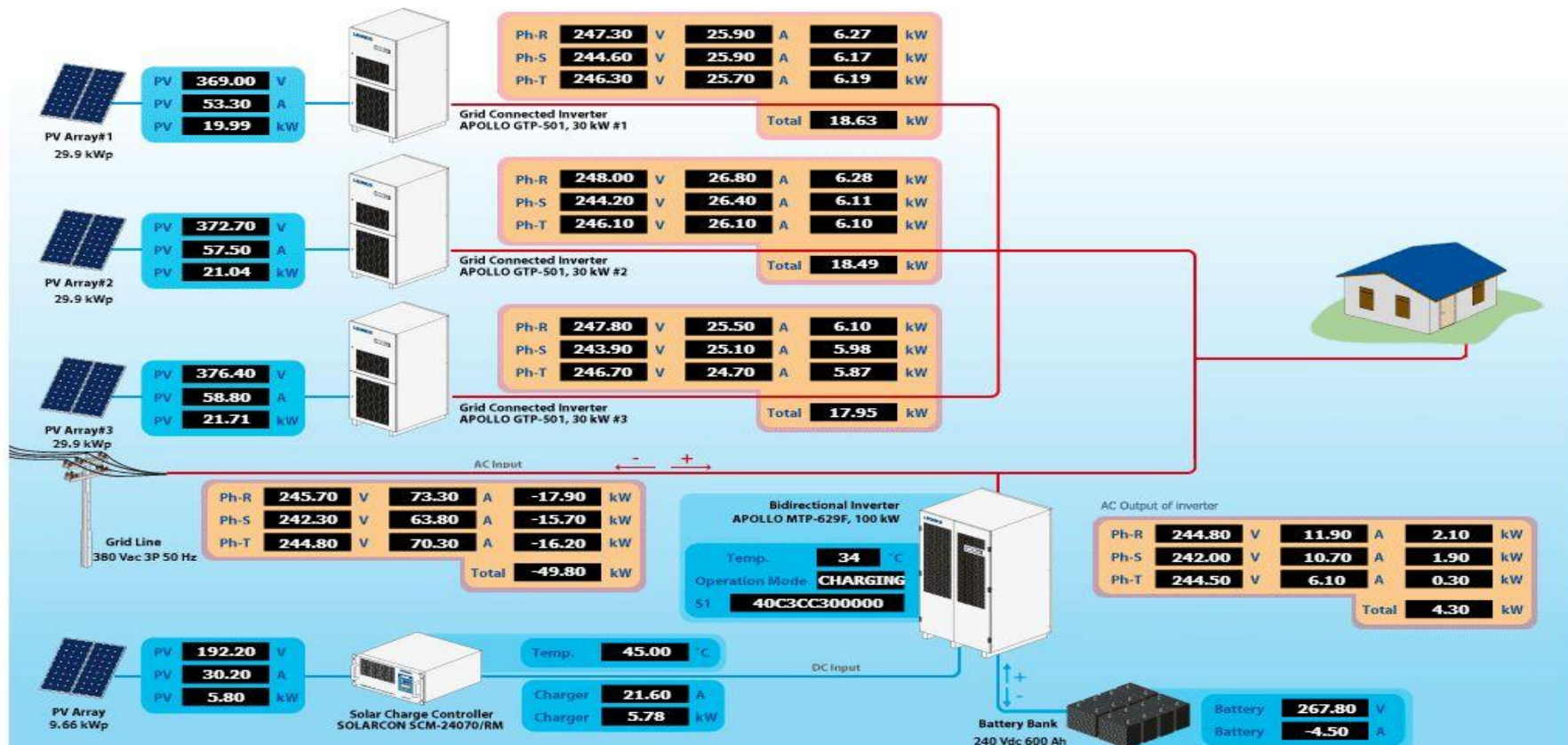
Sagar Group



MBCET

**Mar Basilius College of Engineering & Technology, Thiruvanthapuram, Kerala, India.**

Plant Energylog Graph



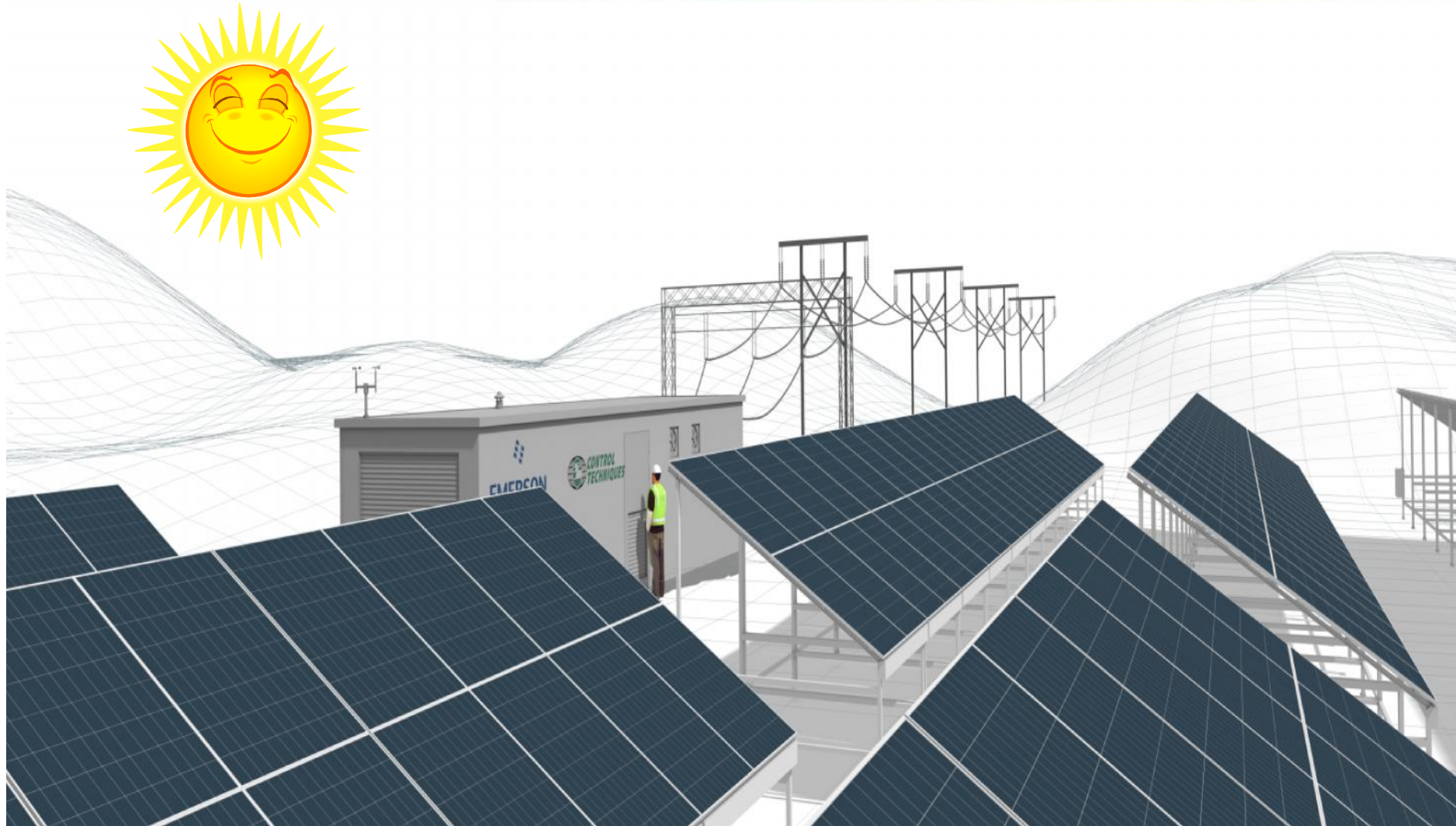
Date 11-Aug-13 Time 10:31:43

Alarm

LEONICS



# SOLAR FARMS





# PV Supply Chain – Large Commercial and Utility



Solar Panels

Inverters



Shelters

Stringbox



Transformers

SCADA



Monitoring



Installation Contractor

Technical/Commercial Consultants

Large Rooftop and Field Installations

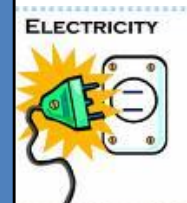
Developer

- System
- Land
- Finance
- Regulatory Approvals
- Insurance
- Grid Connection

Integrator  
EPC

- System

Owner  
Operator / Utility / Brokers



Integrator/Developer Relationship

- Transactional
- Initial system approval
- Systems Engineering etc

Developer/OO Relationship

- Whole life PPA
- Etc.

Integrator wants:

- Low component costs
- Short lead times
- Etc.

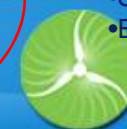
Developer wants:

- Highest possible yield
- Low life cycle costs
- Performance and availability guarantees
- Highest resale value
- Etc.

OO/Utility/Broker Wants:

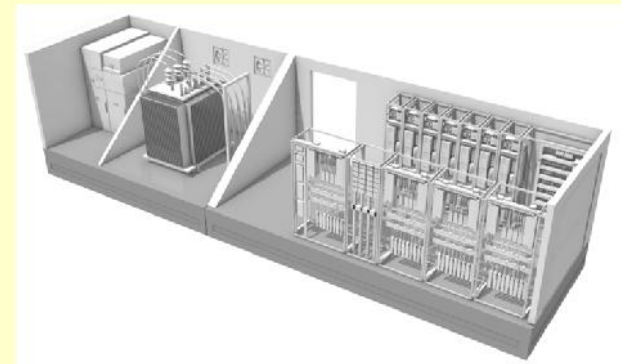
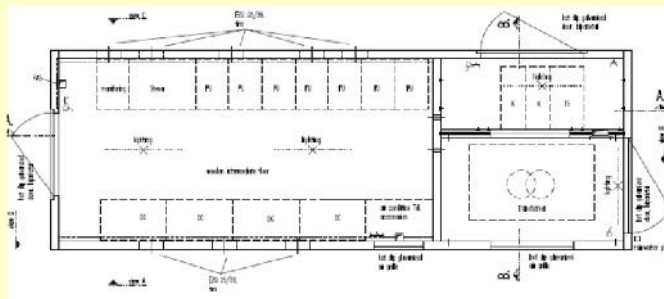
- Low cost of energy
- Reliable power delivery
- Short MTTR
- Etc.

CT Focus



**REGEN**  
Sustainable Power Solutions  
**power**

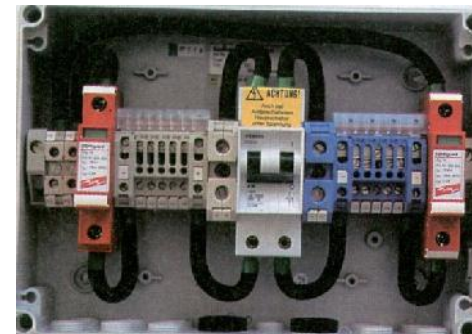
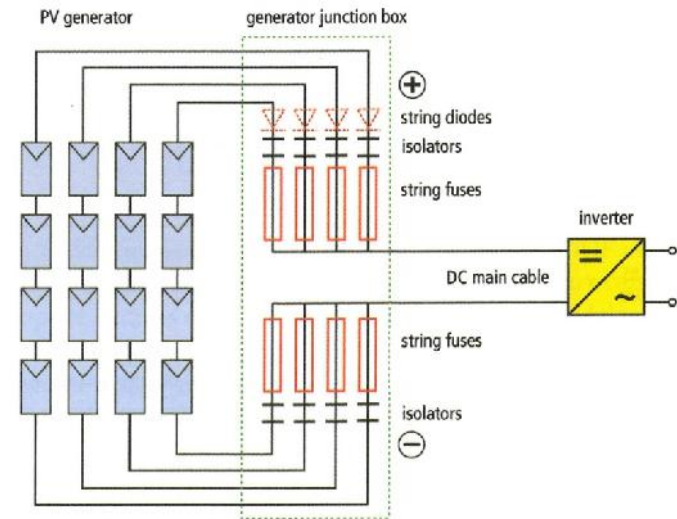
# Central Inverters comes with Shelters



Designs for Concrete & Steel Shelters

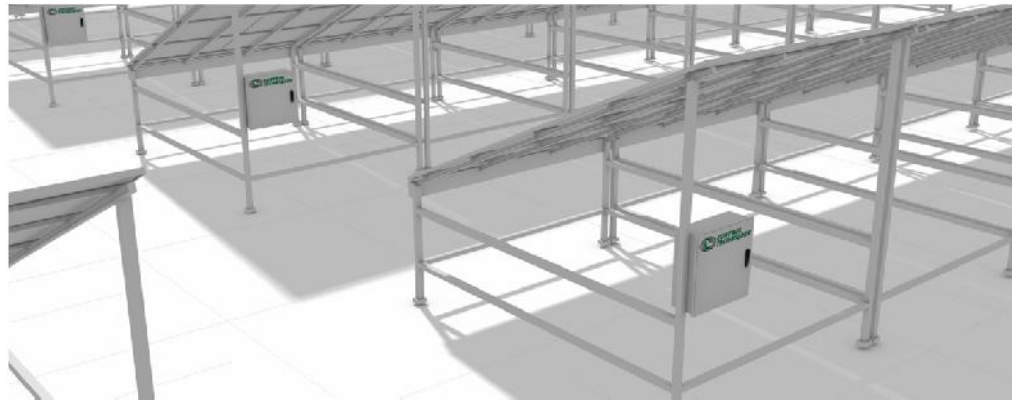
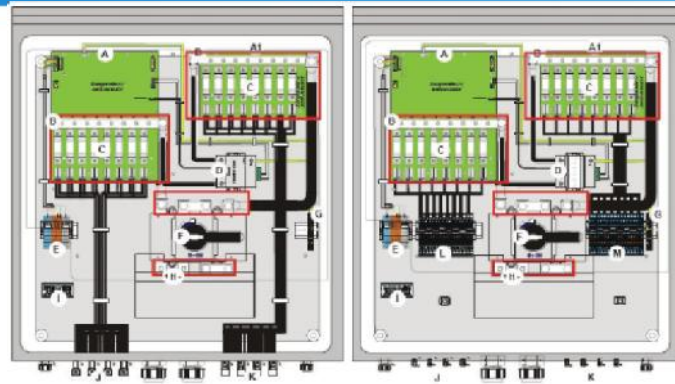
# String Connection Boxes

- Field mounted box which marshals / combines the currents from a number of strings (typically 10 – 24).
- Each string is protected by a fuse
- String diodes usually aren't fitted
- A main DC switch to open circuit the feed to the inverter is usually fitted.
- Overvoltage protection is fitted to guard against EMP due to lightning
- Often string currents are measured allowing the plant operator to localise failed modules

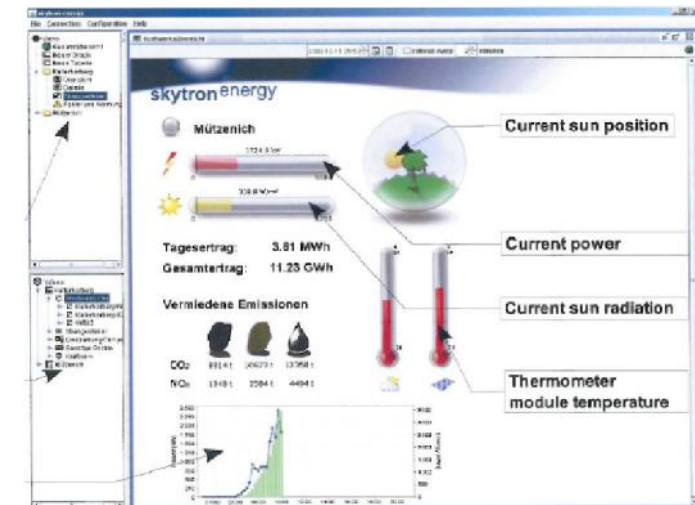




# String Connection Boxes & SCADA



String  
Boxes



SCADA System



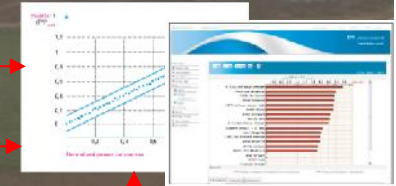


# Components of a 3MW Solar PV Field



PV Modules  
& Frames

Meteo  
Instruments



SCADA

String  
Boxes



Equipment  
Shelter



Inverter



MV  
Trans-  
former



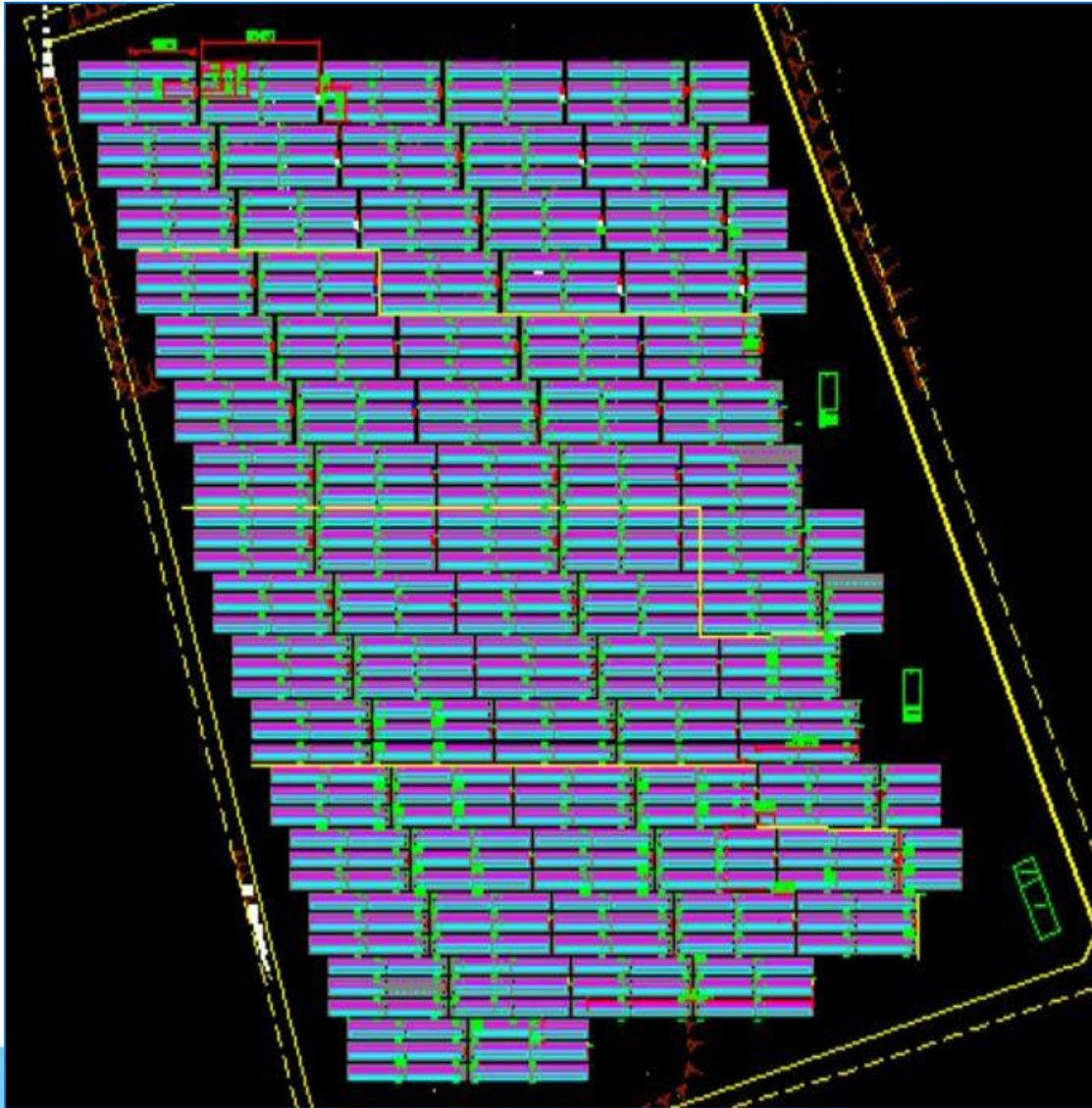
MV  
Switch







## 5.184MW Solar Project Malaysia under design and construction

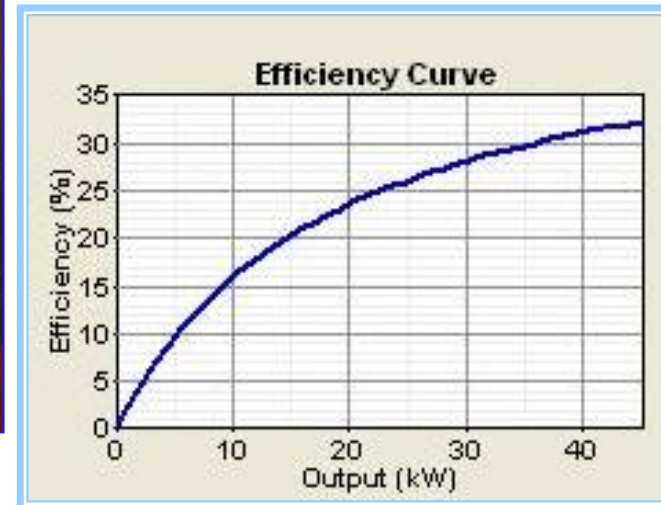
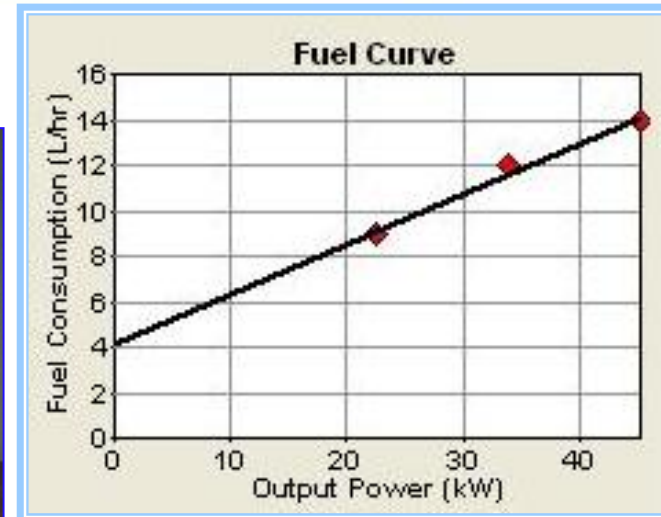






# Off-Grid Grid Applications

# Diesel Generator Fuel Consumption Characteristics





# Case study : The Republic of Maldives

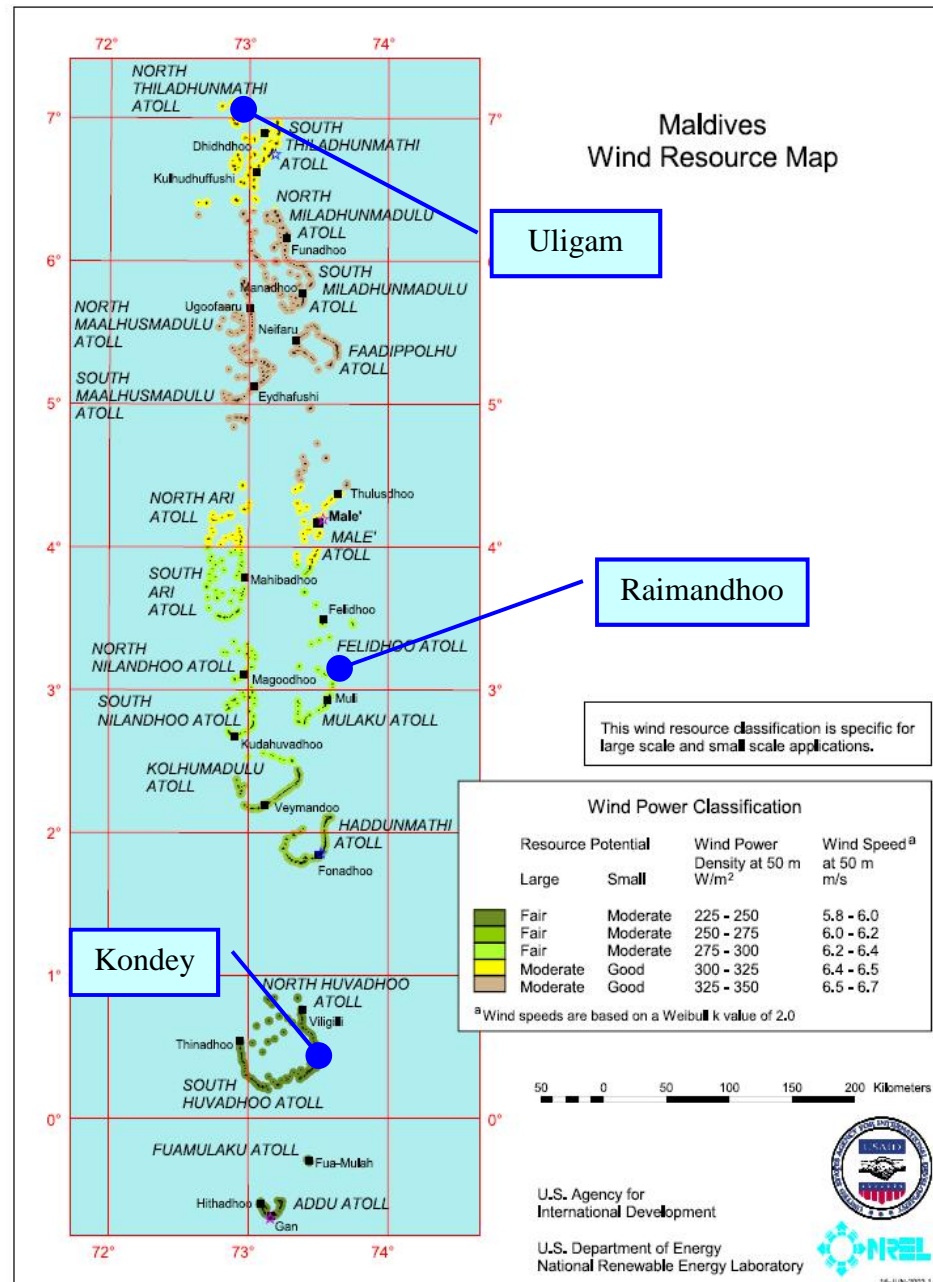


Figure 8-1









REPUBLIC OF MALDIVES

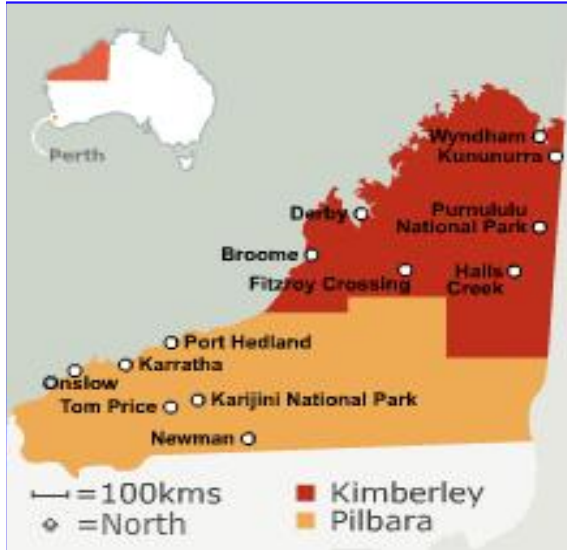
*With the Compliments of  
President Maumoon Abdul Gayoom*



30.07.2010

## Case Study : Eco Wilderness Resort , Broome, Western Australia

Location : 2 hours drive from Broome, 2200 km north of Perth



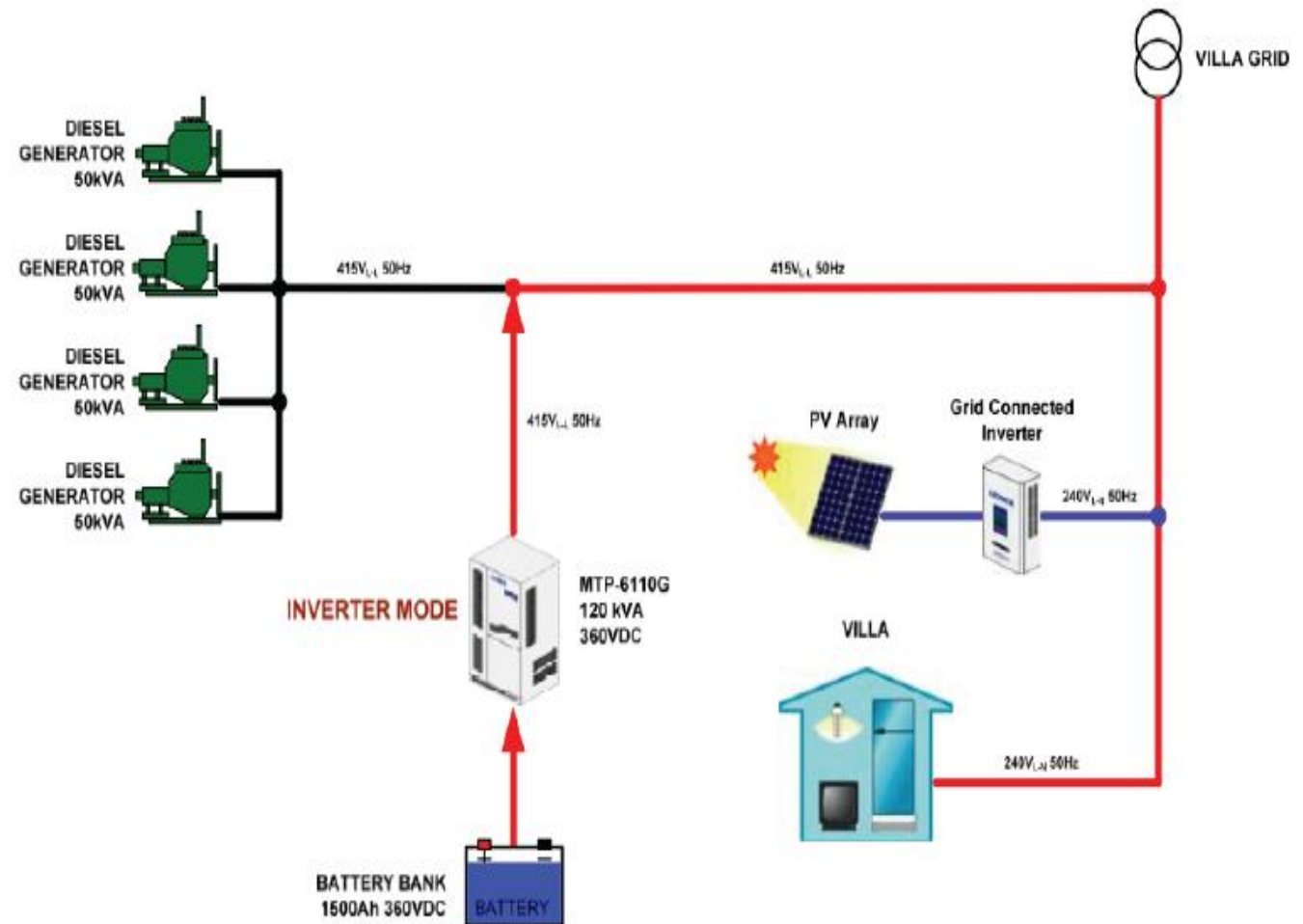
- 25 Villas
- 30 safari style tents



# ECO RESORT, W.A.



# Modes of operation : Inverter stand-alone







Fuel Efficient Variable Speed Generator

*International Patent :  
PCT/AU2011/001068  
, Power Management  
System and method  
for optimising fuel  
consumption,  
inventor : Nayar  
Chemmanogot ,  
REGEN  
TECHNOLOGIES  
PTY LTD*

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)	
(19) World Intellectual Property Organization International Bureau	
(43) International Publication Date 28 February 2013 (28.02.2013)	(10) International Publication Number WO 2013/026082 A1
WIPO   PCT	
(51) International Patent Classification: H02J 9/06 (2006.01)	(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
(24) International Application Number: PCT/AU2011/001068	
(22) International Filing Date: 19 August 2011 (19.08.2011)	
(25) Filing Language: English	
(26) Publication Language: English	
(71) Applicant (for all designated States except US): REGEN TECHNOLOGIES PTY LTD [AU/AU]; 33 Darian Drive, Willetton, Western Australia 6155 (AU).	
(72) Inventor; and (75) Inventor/Applicant (for US only): NAYAR, Chemmanogot Velayudhan [AU/AU]; 33 Darian Drive, Willetton, Western Australia 6155 (AU).	
(74) Agent: COLJA HAINES & FRIEND; Thomas Haines, PO Box 1417, West Leederville, WA 6901 (AU).	Published: — with international search report (Art. 21(3))
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,	



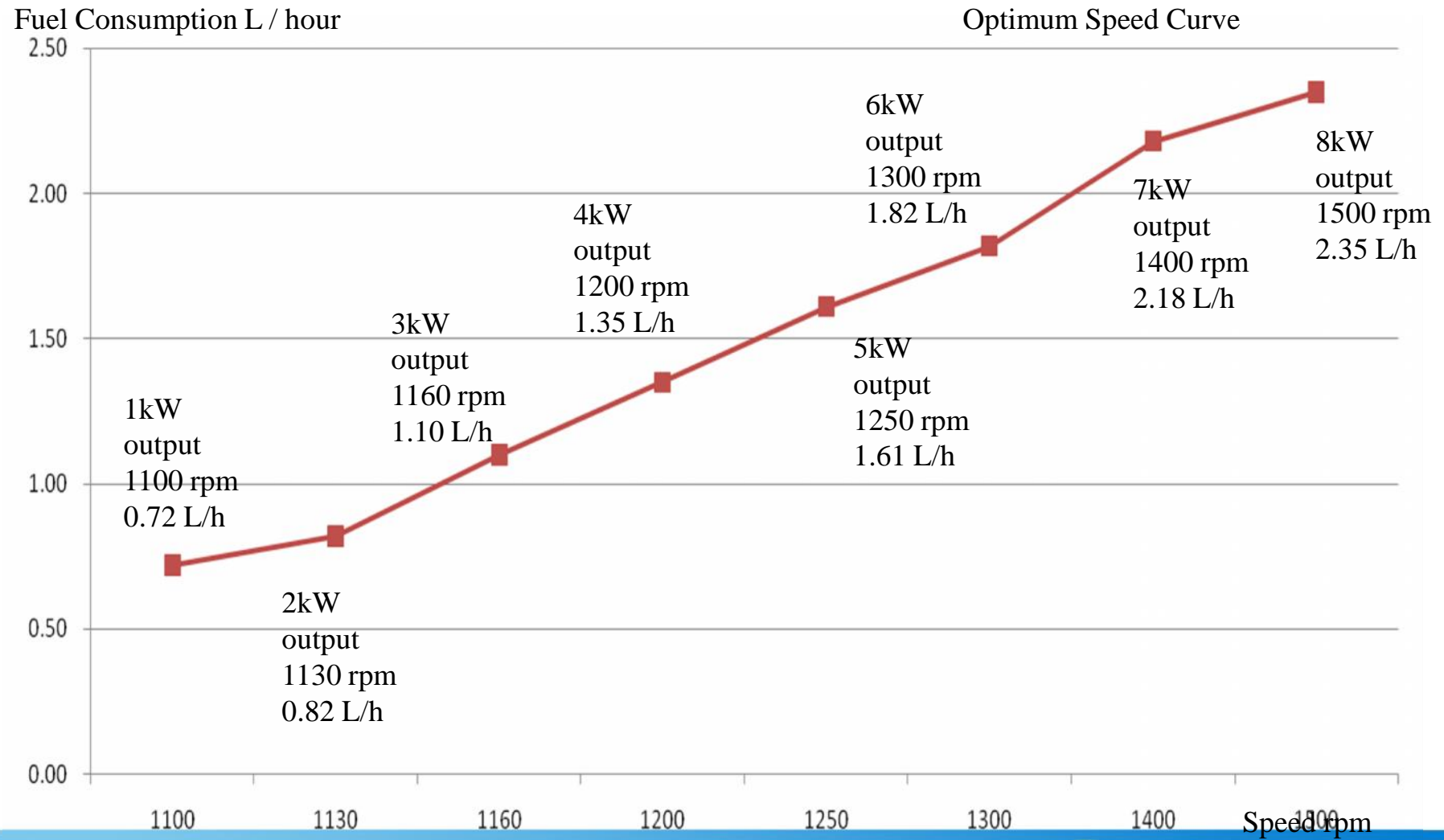


Hybridgen manufactured  
in India/China





# Hybrid-Gen Fuel Consumption



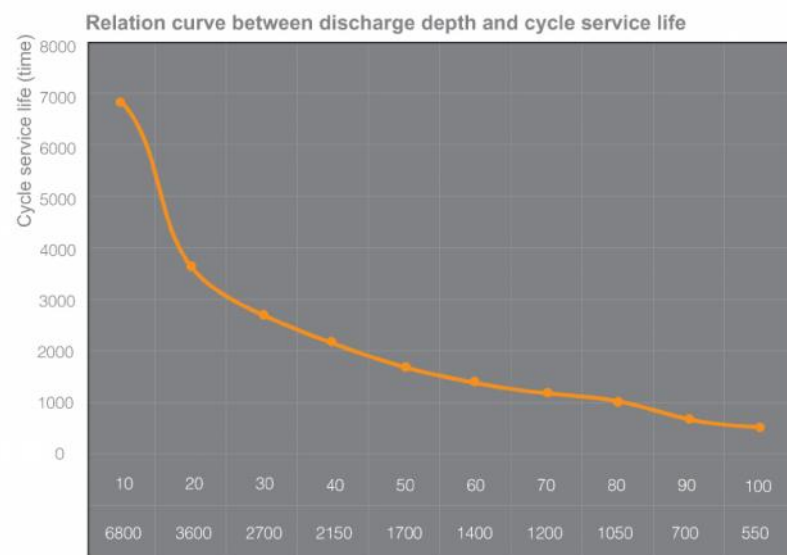
## Storage Battery

Model	Rated Voltage (V)	Rated capacity (Ah)	Number of terminal post with like polarity	Dimension (mm)				Weight (Kg)
				Length L	Width W	Height h	Total height H	
GFMJ-800	2	800	2	191	210	645	677	64.5

Constant current discharge table-continued

unit: A

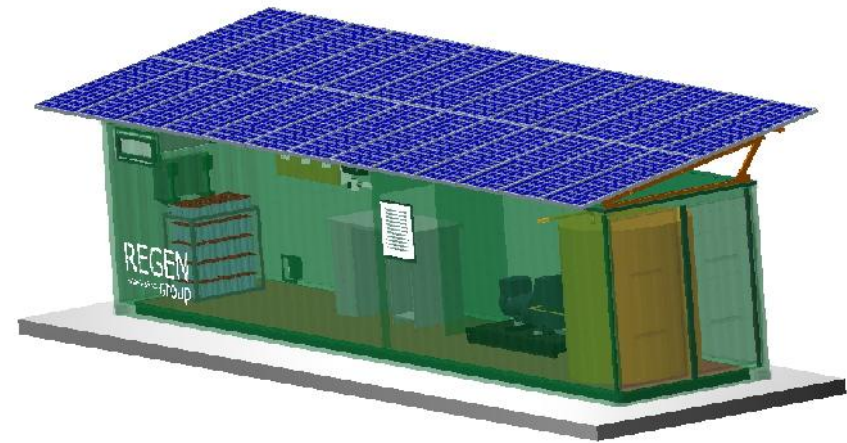
Model and specification	Final voltage (V/unit)	Discharge time (min)					Discharge time (h)											
		5	10	15	30	45	1	1.5	2	3	4	5	8	10	20	100	120	
GFMJ-800	1.90	684	599	404	392	376	312	248	220	172	144	124	86	72	37.08	9.67	8.20	
	1.85	721	630	470	440	399	344	272	236	183	152	130	90	75	40.78	10.18	8.64	
	1.80	773	762	649	560	448	416	344	266	200	164	139	96	82	42.81	10.53	8.94	
	1.75	804	778	744	624	497	448	378	278	208	168	141	98	83	44.52	10.79	9.16	



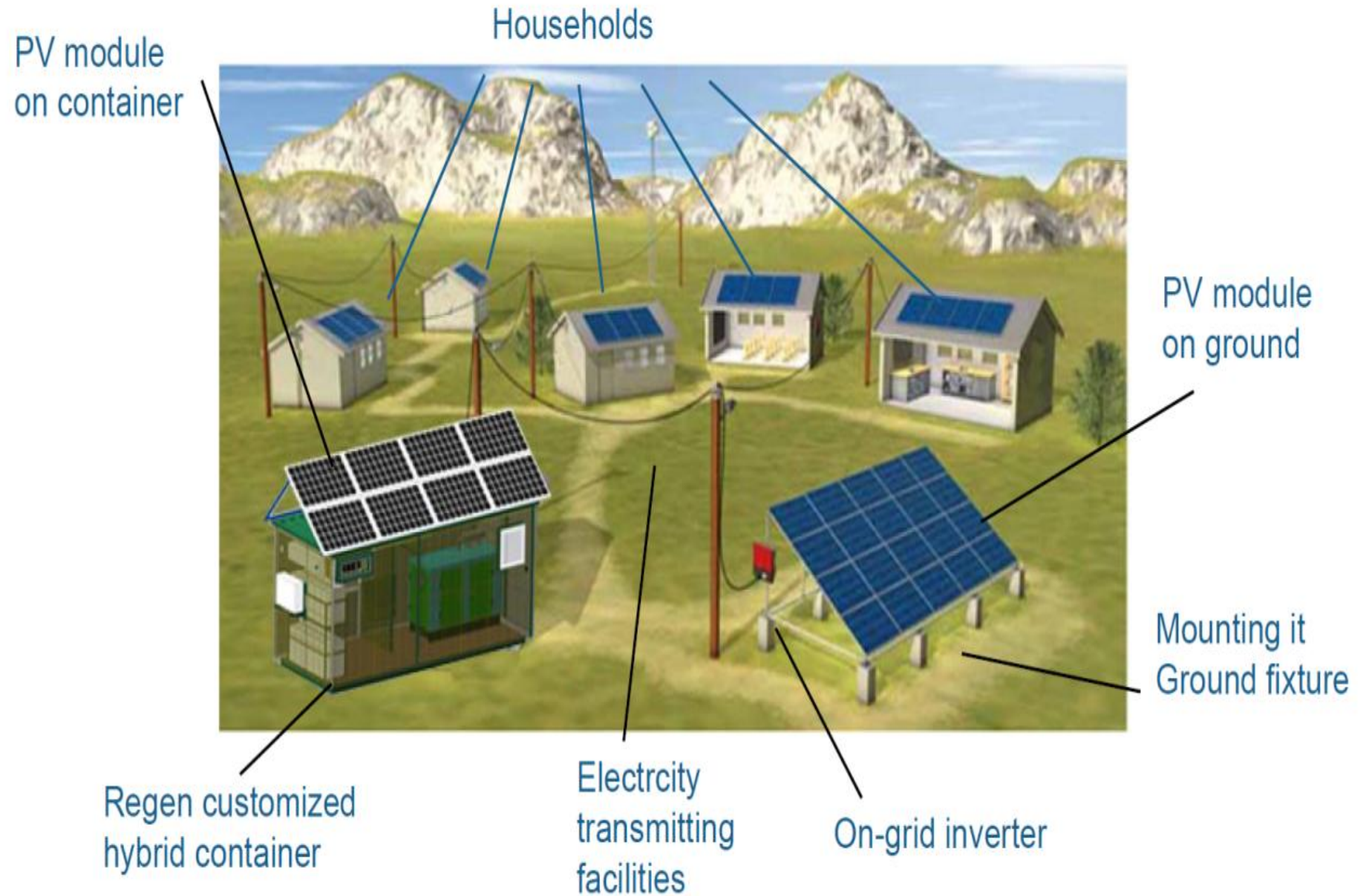
VRLA Gel Battery  
Shoto OpzV 800



# Containerised Power Supply

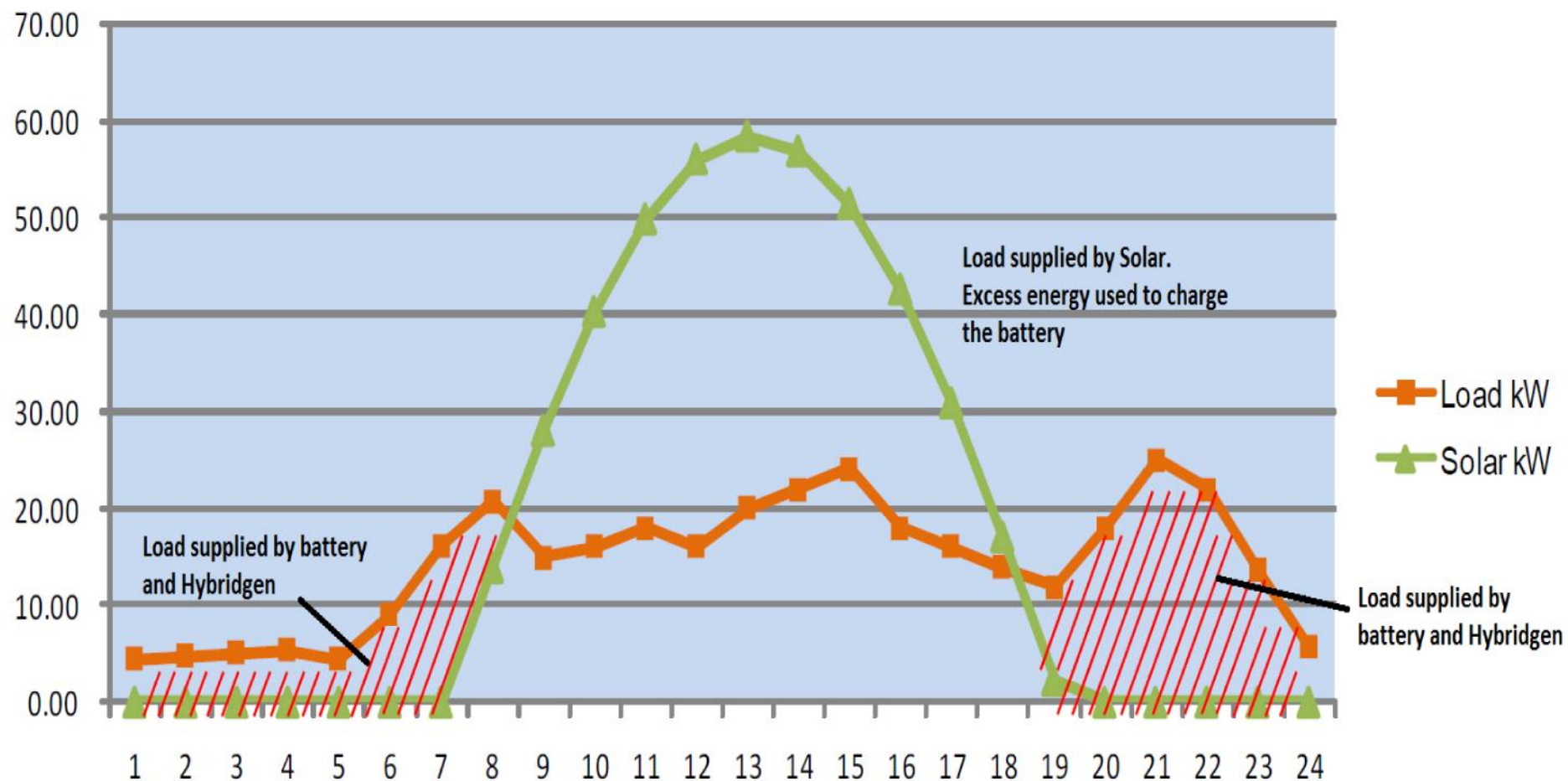


# Micro Grid





# Energy Balance in a Micro-grid System



# Mt Gambier TAFE , South Australia : Solar/Wind Installation





# Veterans Retreat Western Australia





Welcome To Pulau Ubin





# Pulau Ubin Microgrid

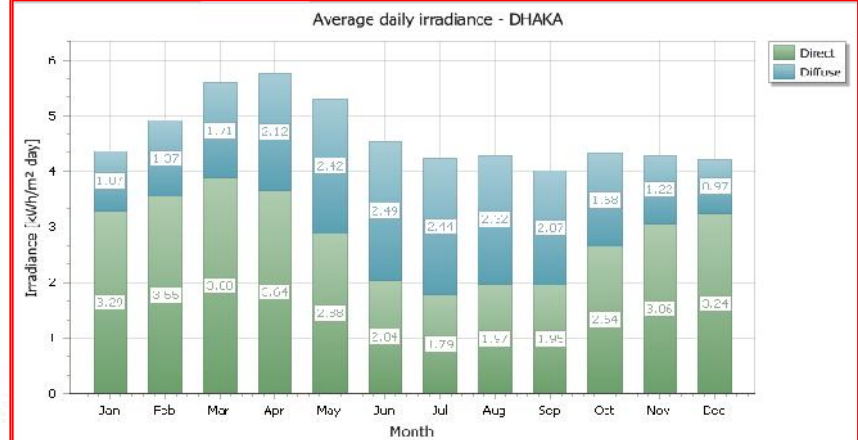
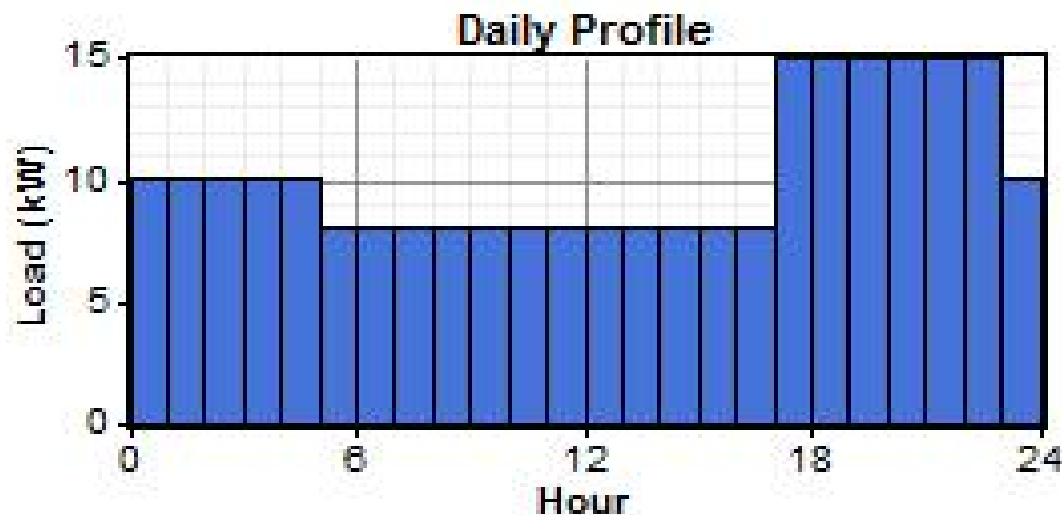


# Pulau Ubin Microgrid



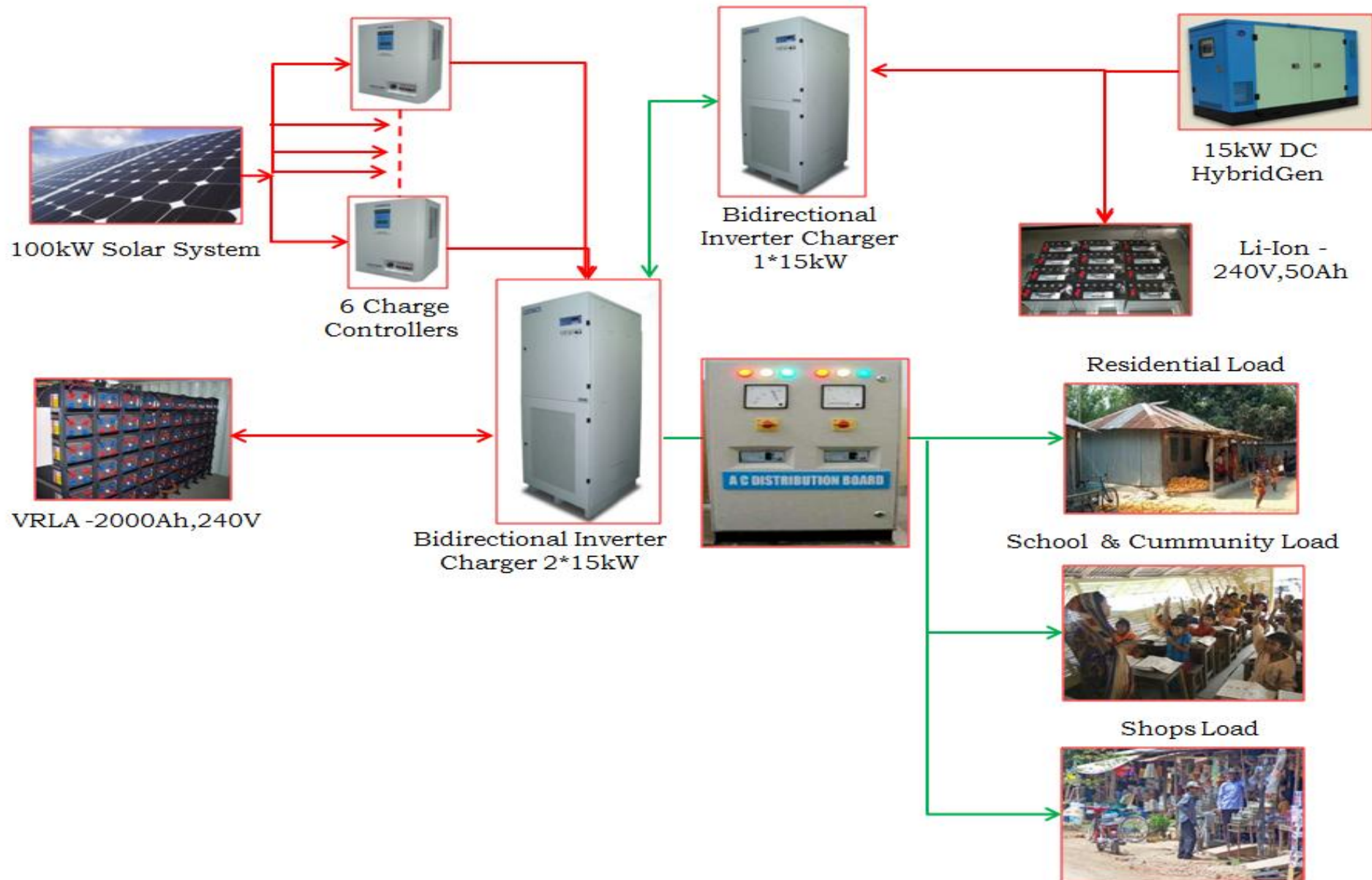


## Design example ; 100kWp –Bangladesh village



200 household and 150 shops is as shown above. The maximum load is taken as 15kW and energy consumption is around 250kWh/Day.

# General Schematic of 100kW PV Hybrid System for Bangladesh







# Hybrid Off-Grid Power System Telecom Application



## Case Study : Sri Lanka





# Replacement of normal gen-set at established site



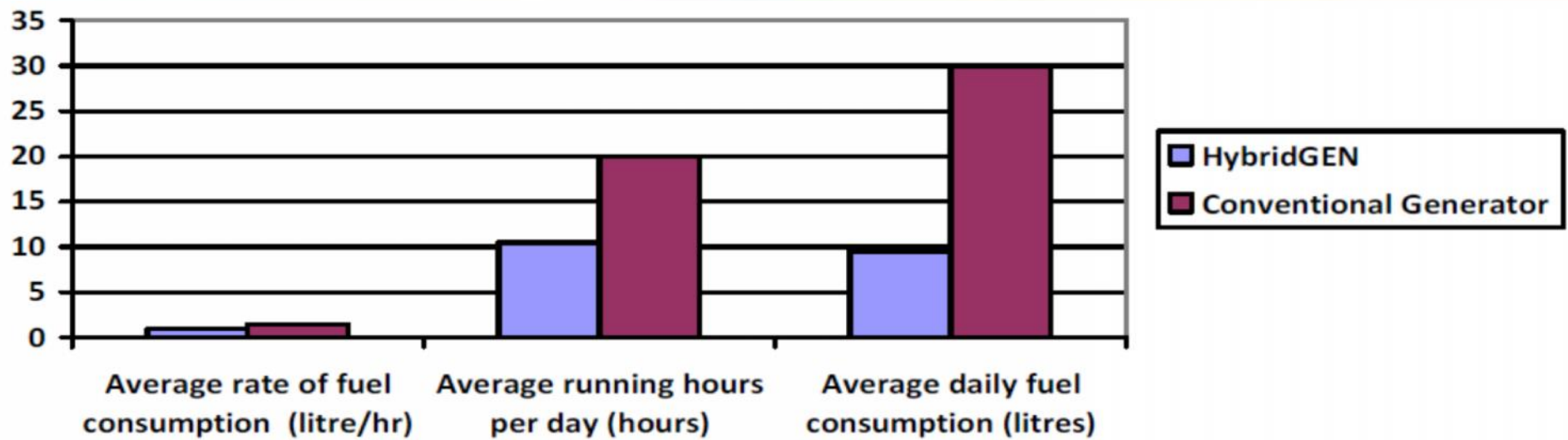
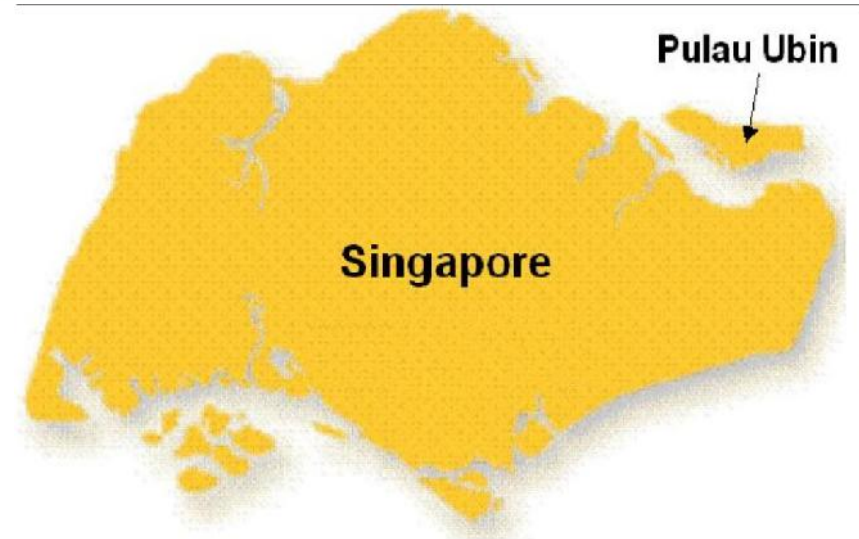


Figure 8-1: Graph on fuel consumption analysis



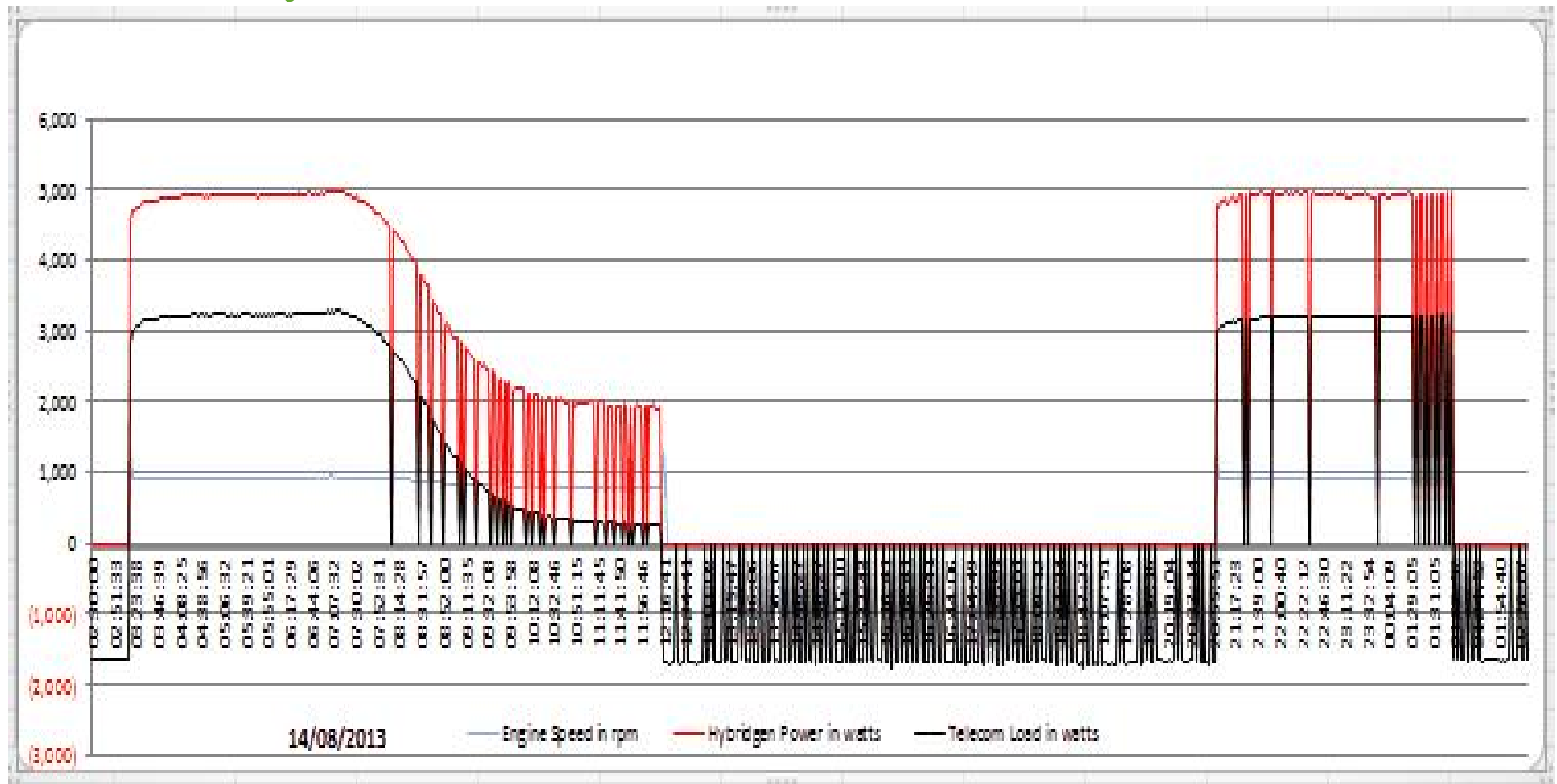


# Telecom Tower , Pulau Ubin , Singapore



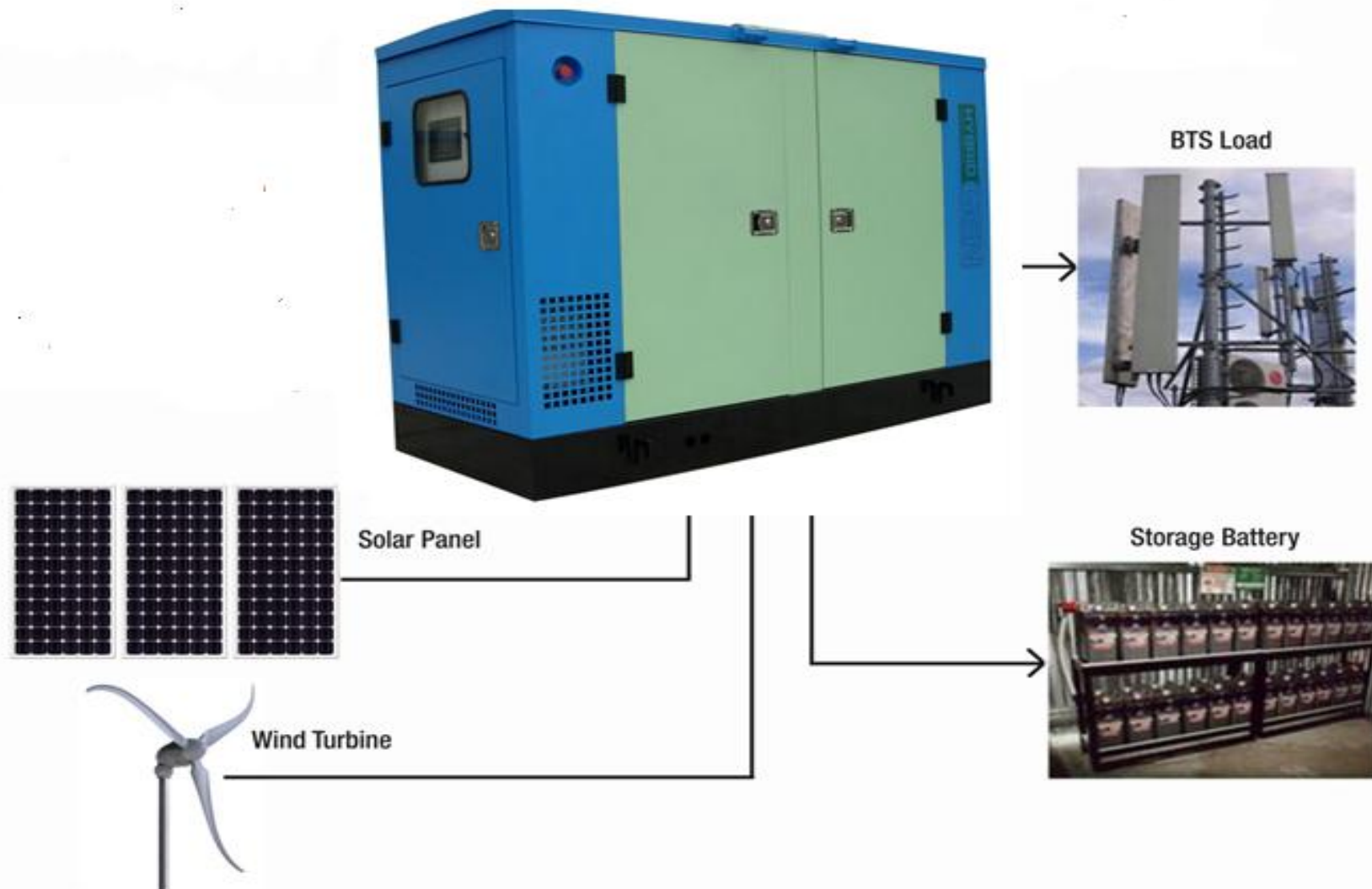
## Typical daily system performance , Pulau Ubin Island, Singapore

- System installed in Sept 2011
- Battery bank size : 1200Ah.

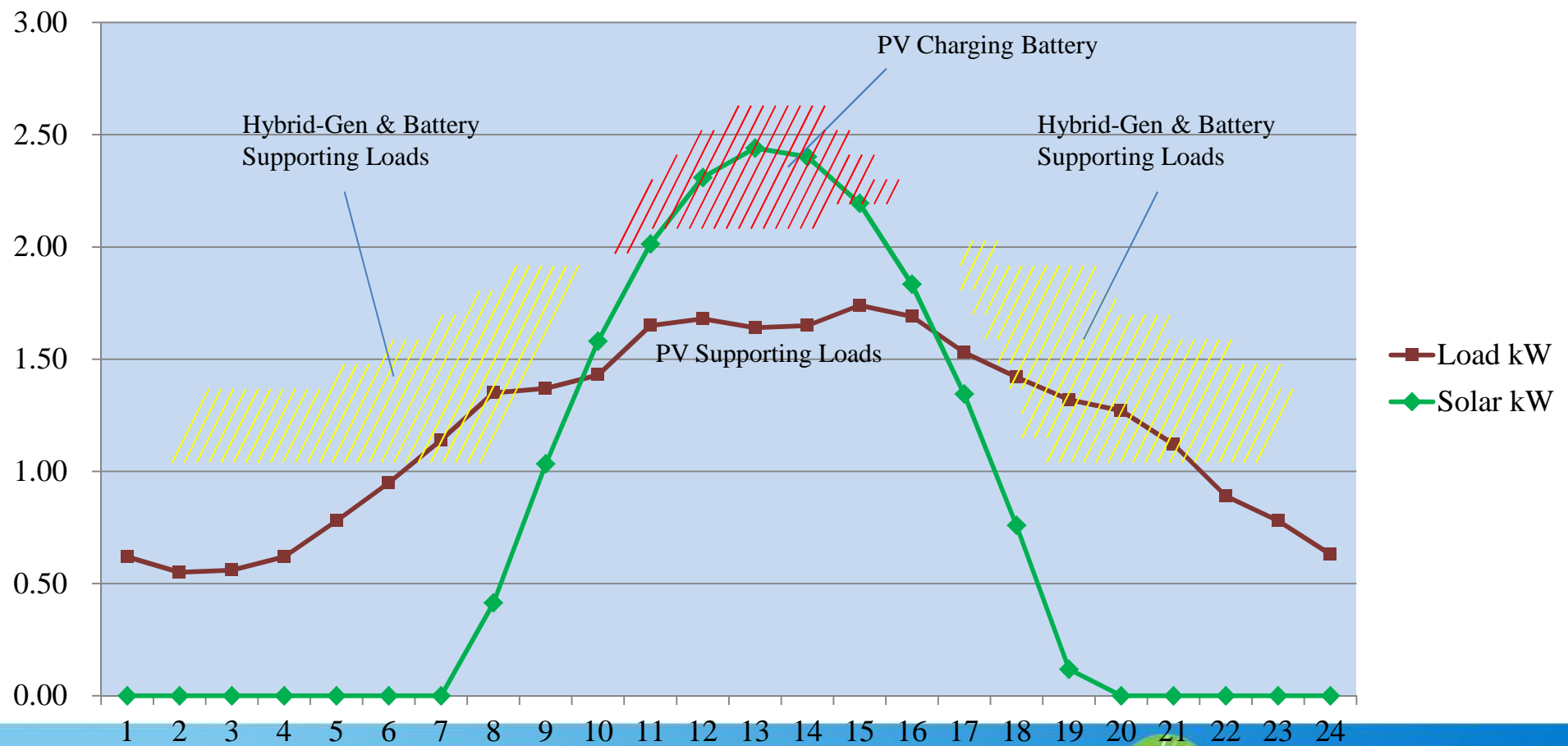




# BTS Schematic diagram



# Energy Equilibrium



PV & Load Curves August (worst month)

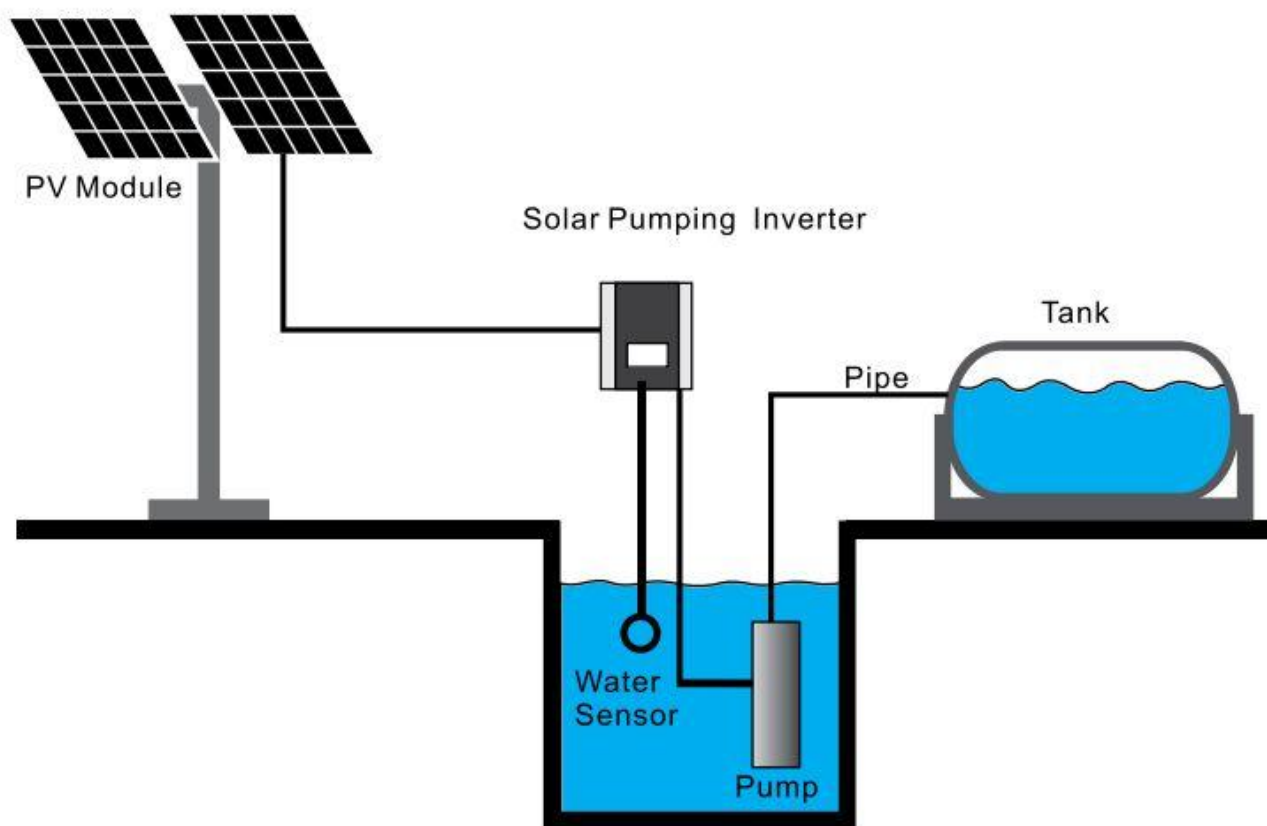




## **Solar Hybrid Drinking Water Plants for Remote Communities**



# Solar Water Pumping



Solar Pumping System



# Solar Powered Swimming Pool Pump



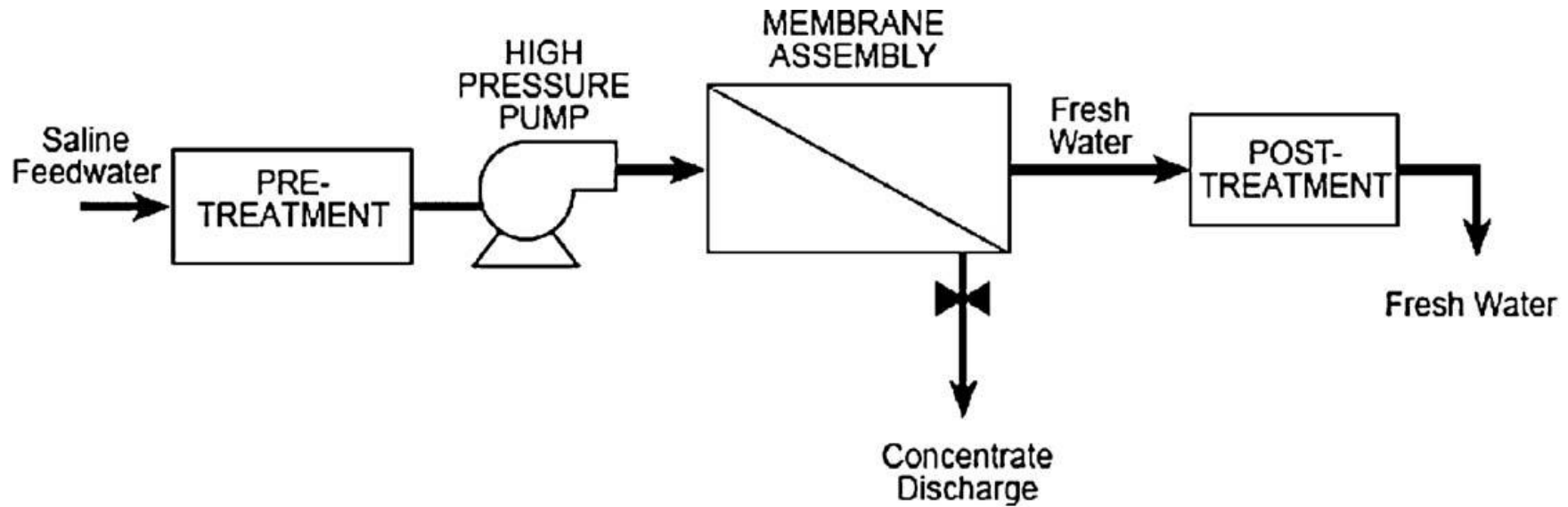


# Solar Powered Swimming Pool Pump





# Schematic of a simple RO Plant



Removes :

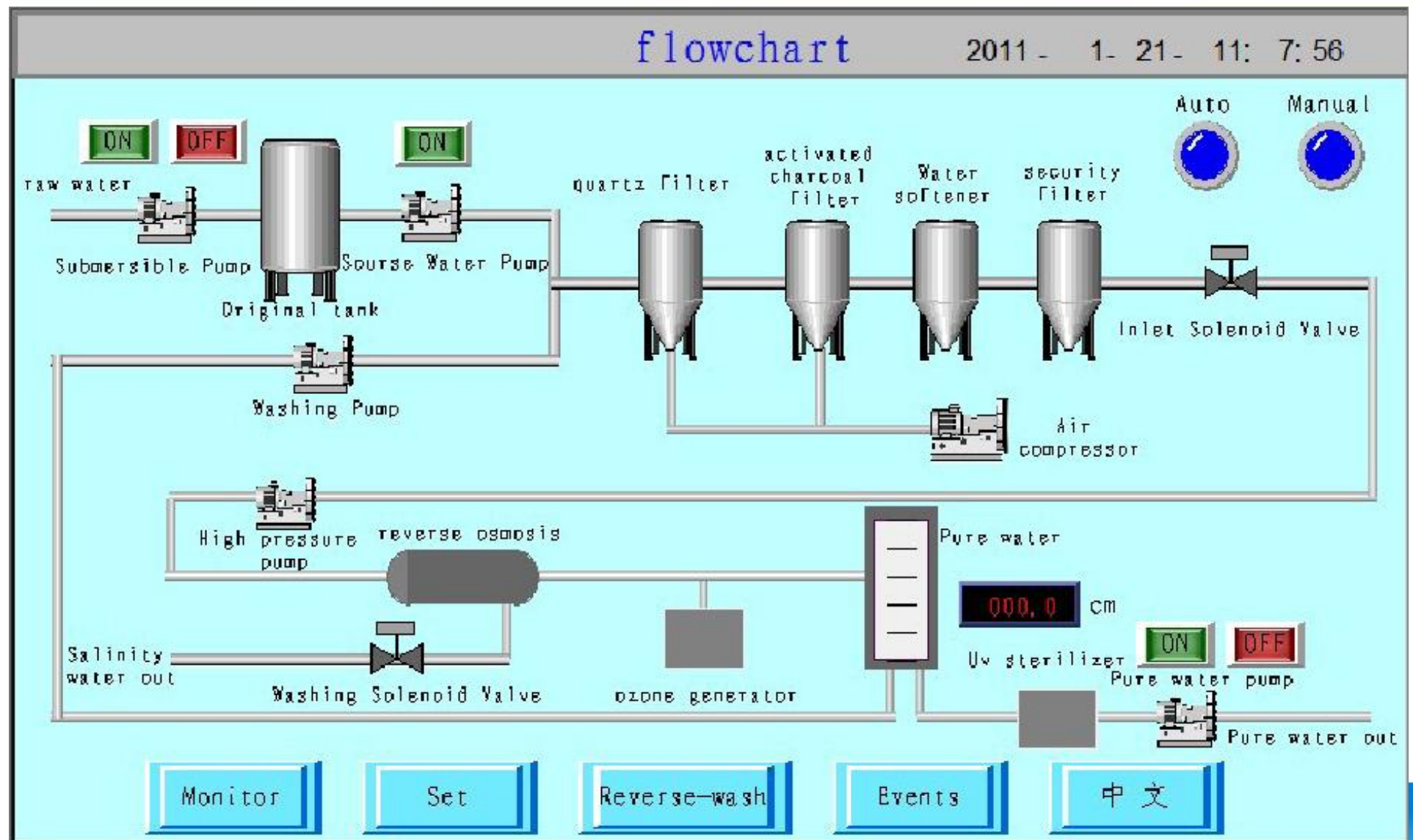
- \* more than 96% dissolved solids
- \* more than 99% organic substances
- \* more than 99% colloid
- \* nearly 100% bacteria

## AquaSmart : Solar Powered drinking water for remote communities





# Major Components



Go Solar - Hope for Energy Security.....

Thank you