ILF Consulting Engineers (Asia) Ltd.

3rd Thai-German Community-based Renewable Energy Conference 2018

Frank Zimmermann, Bangkok 8rd February 2018

Frank Zimmermann - Biography

■ Dipl.-Ing. MBA Frank Zimmermann

Education: Universität Karlsruhe (TH) · Schiller International University · UNSW The University of New South Wales

Experience:

1997 – 2002	GWU solar	Sales: Wholesale and Consumer Sales- and Project engineer Export Manager, Fürth, de
2002 – 2005	Suntech	Export Manager, Wuxi, cn
2005 – 2009	SPS Sustainable Power Solutions	Managing Director, Singapore, sg
2009 – 2014	SPS Solar GmbH	Managing, Haslach i.K., de
Since 2014	ILF Consulting Engineers	Business Development Manager South East Asia for Renewable Energies, Senior Project Manager Photovoltaics of ILF Asia based in Bangkok, th

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Sachverständiger für Photovoltaik (TÜV)
Certified Expert for Photovoltaic Equipment (TUV)

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ILF at a Glance

ILF CONSULTING ENGINEERS

50	2,000	100
Years of experience	Employees worldwide	% family owned

ILF Asia

- Regional presence for ASEAN in Bangkok, Thailand
- Core competencies : Renewable energy and hydropower

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ILF Group

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Service Portfolio

Project Life Cycle	Appraise	Select	Define	Execute	Operate	Close
	Business Identification	Project Framing	Project Definition	Project Realisation	Business Control	Business Closure
ILF Services	Pre-/ Feasibility Studies	Due Diligence Conceptual Design Environmental & Social Impact Assessment Execution Strategies	Permit Application Design Basic Design, FEED, Tender Design Environmental & Social Impact Assessment Project Management Procurement Documentation for Investment Decision	Supply Chain Management Detailed Design Design Review Project Management Construction Supervision Commissioning & Trial Operation	Operations Audit Due Diligence Optimisation Studies Modification Planning Rehabilitation Planning Maintenance Support	Due Diligence Decommissio-ning Planning Commissioning

◆ Decision Gates

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INTRODUCTION

Introduction

Group introduction

- Who are you?
  - Community Members / Community Leaders
  - Business Owners
  - Farmers
  - Developers
  - Entrepreneurs
  - Technician
  - Politician
- Where are you from?
  - North / East / South / West / Abroad
  - Remote Locations / Islands
- What is your industrial areas / types
- What is your background?
- What do you expect from this seminar?

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BASIC KNOWLEDGE

Basic Knowledge

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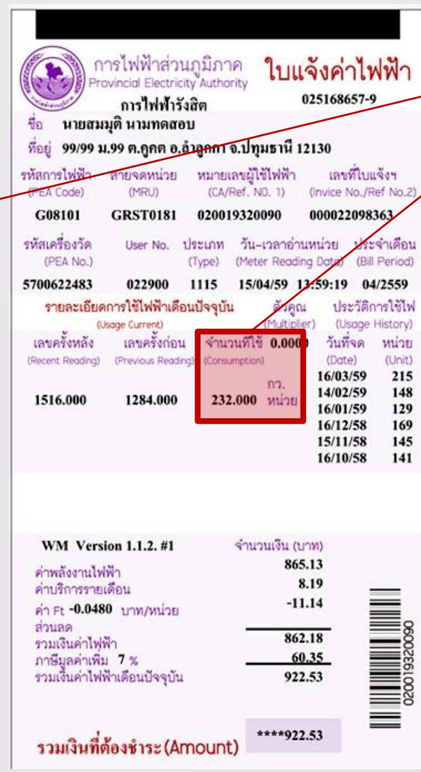
Power VS Energy

MEA

PEA



- Electricity bill per month = (kWh) × (electricity price per kWh)

What is kWh?

Power VS Energy

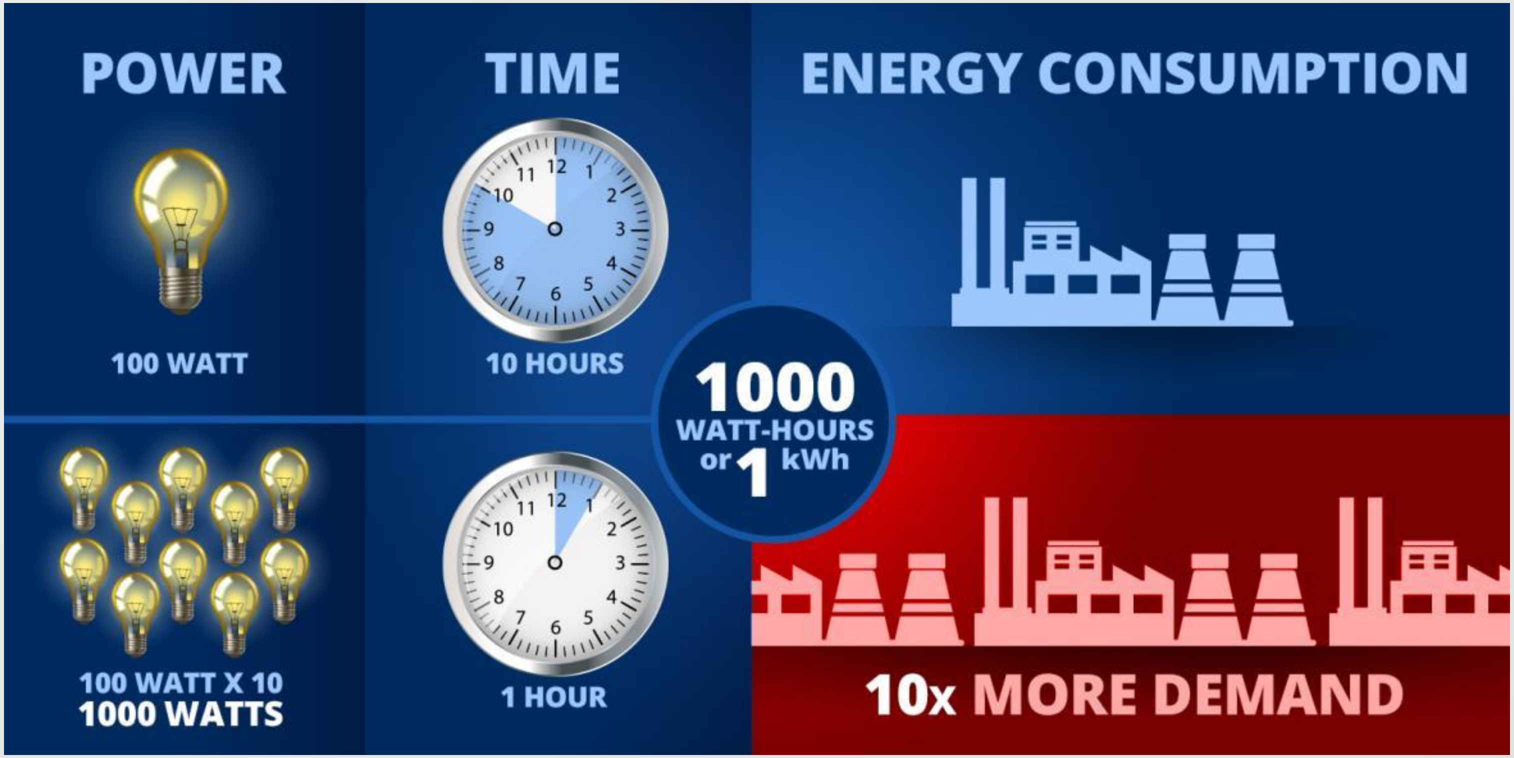
Turn on for
3 hours

13 W × 3 hrs = 39 Wh = 0.039 kWh

POWER **ENERGY**

Power VS Energy

- Power x Time = Energy Consumption



What is hybridization?

What to hybridize:

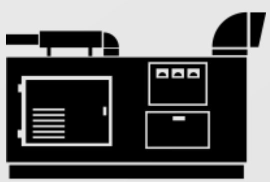
- Diesel
- Gas
- Heavy fuel oil
- Waste-to-energy
- Biomass-to-energy

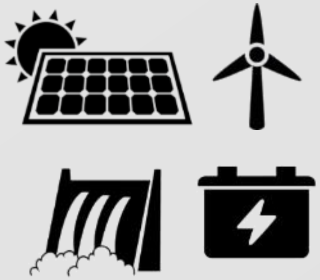
Hybrid system types:

- Stand-alone (islands)
- Mini-grid
- Micro-grid
- Remote grid

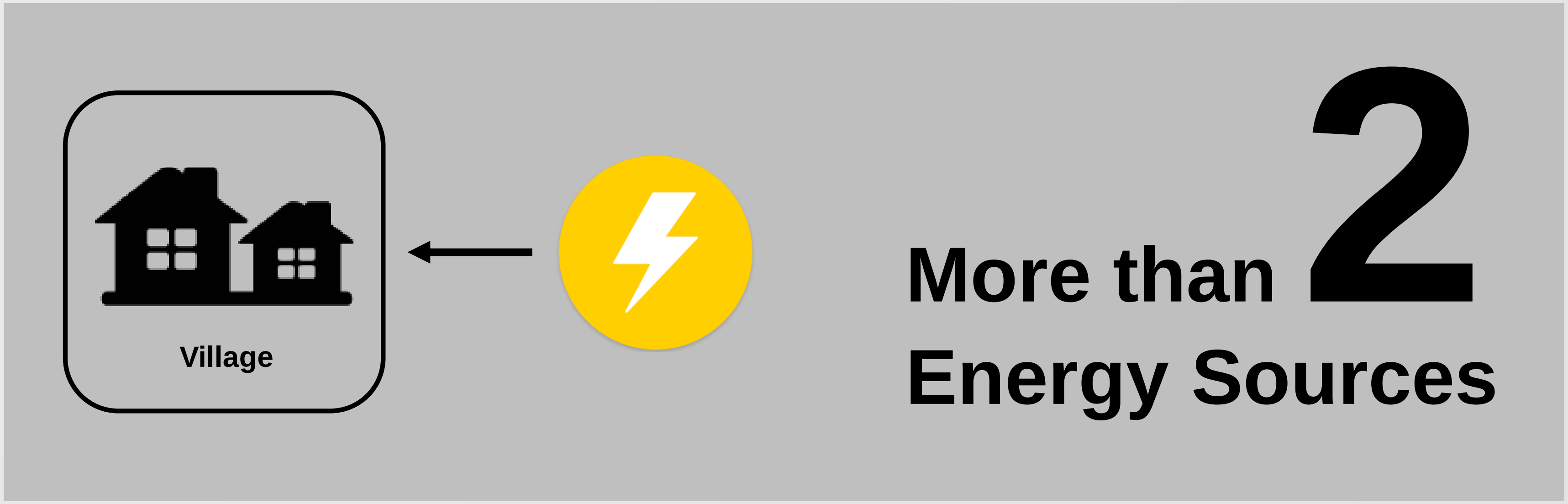
How to hybridize:

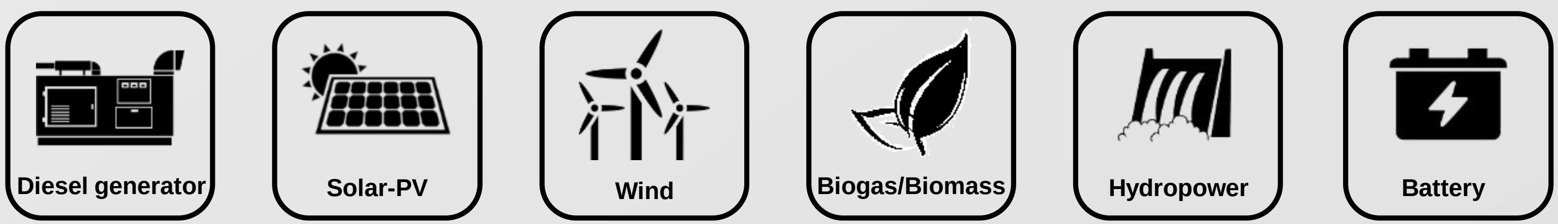
- Photovoltaic (PV)
- Wind
- Hydro power
- Battery





Hybrid system components





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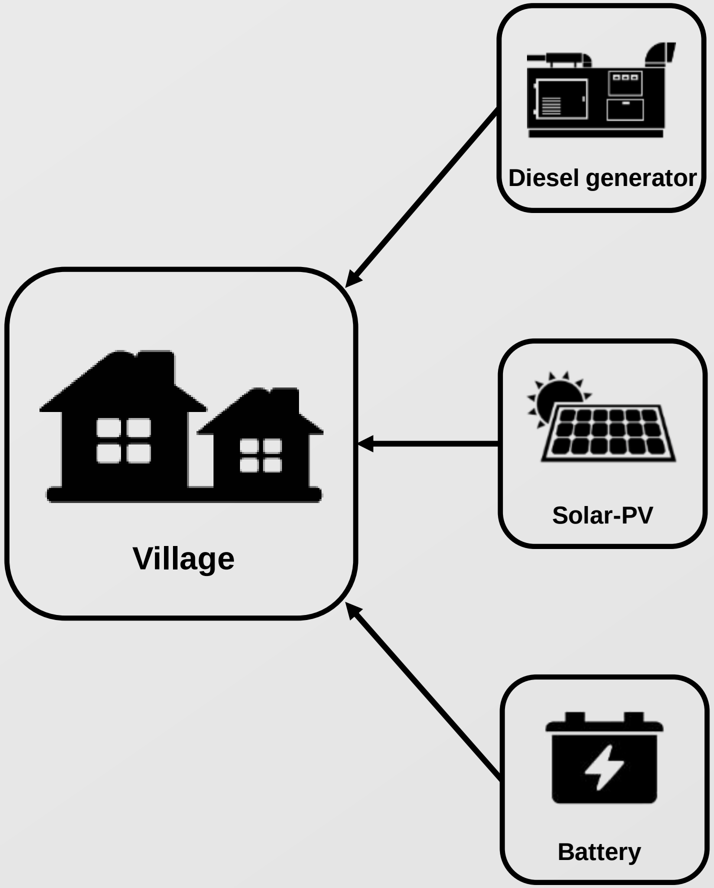
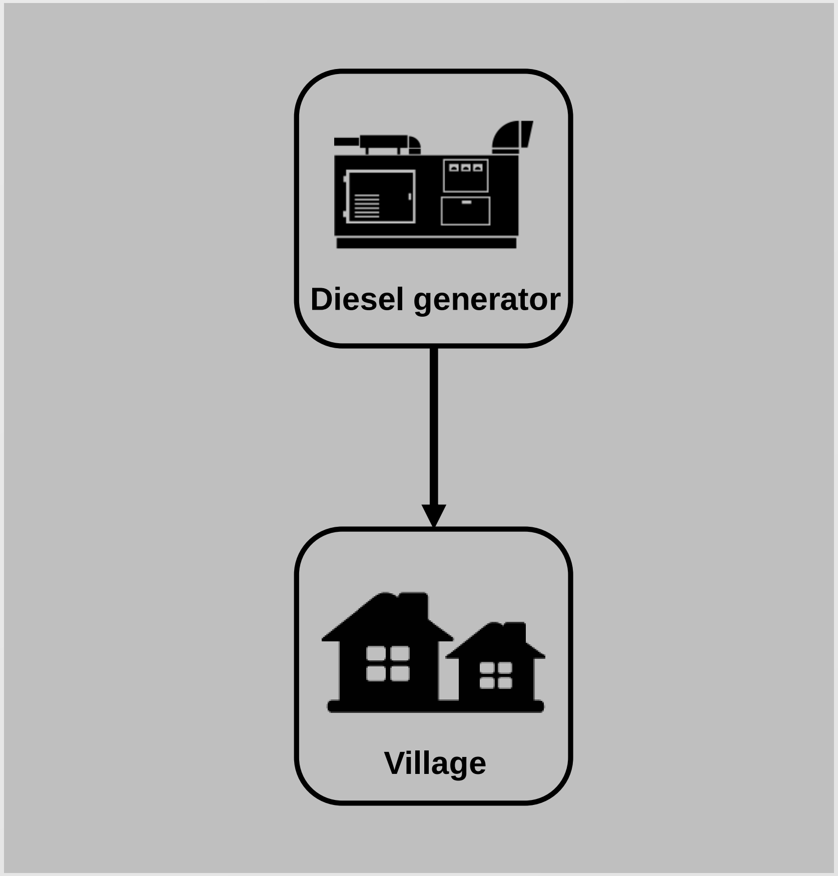
Hybrid system components (example)



- Generate electricity from fossil fuel
- Generate electricity from sun's light
- Store the electricity produced by either solar or diesel generator

Why a hybrid system?

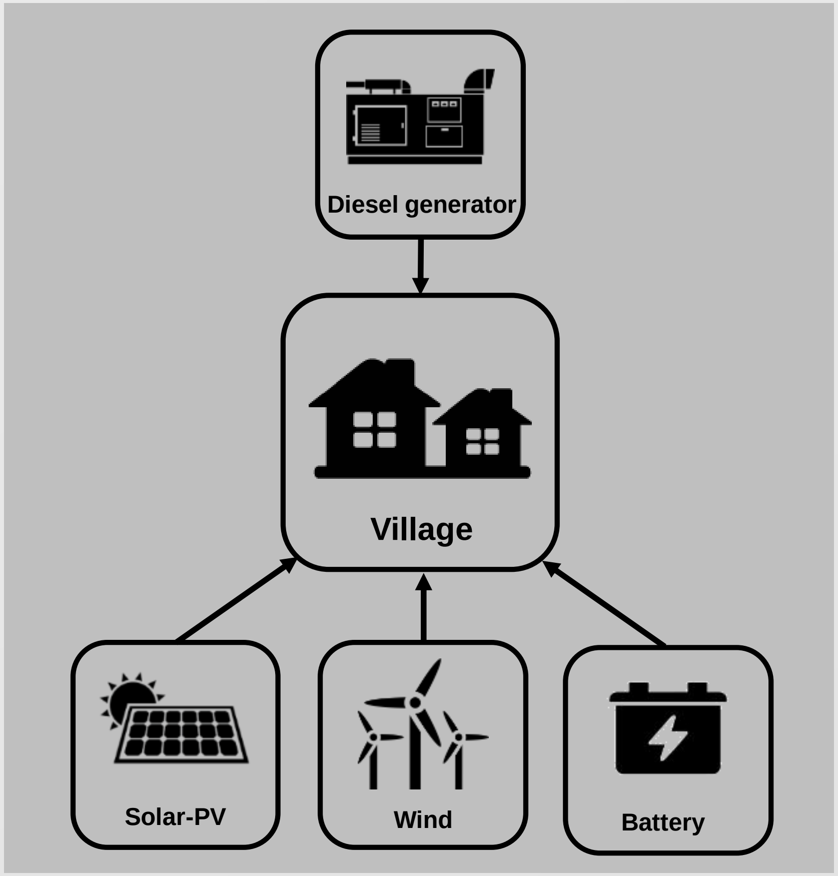
Conventional system



- **A few hrs** Electricity available
- **High** fuel cost (incl. transportation)
- **High** Operation & Maintenance cost
- **High** Share of generator operation
- **High** CO_2 emission

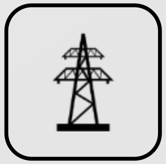
Why a hybrid system?

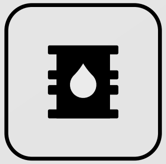
Hybrid system




Decrease PV module & battery price

24 hrs electricity available


Increase grid stability


Less fuel consumption maintenance


Scalable in the future

Exercise

Flipchart-Exercise

- How much do you pay for your electricity bill per month?
- How many kWh do you use per month?
- What is the price of electricity per kWh?
- How many appliance do you have?
- How long / what time each appliances do you use?

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Exercise

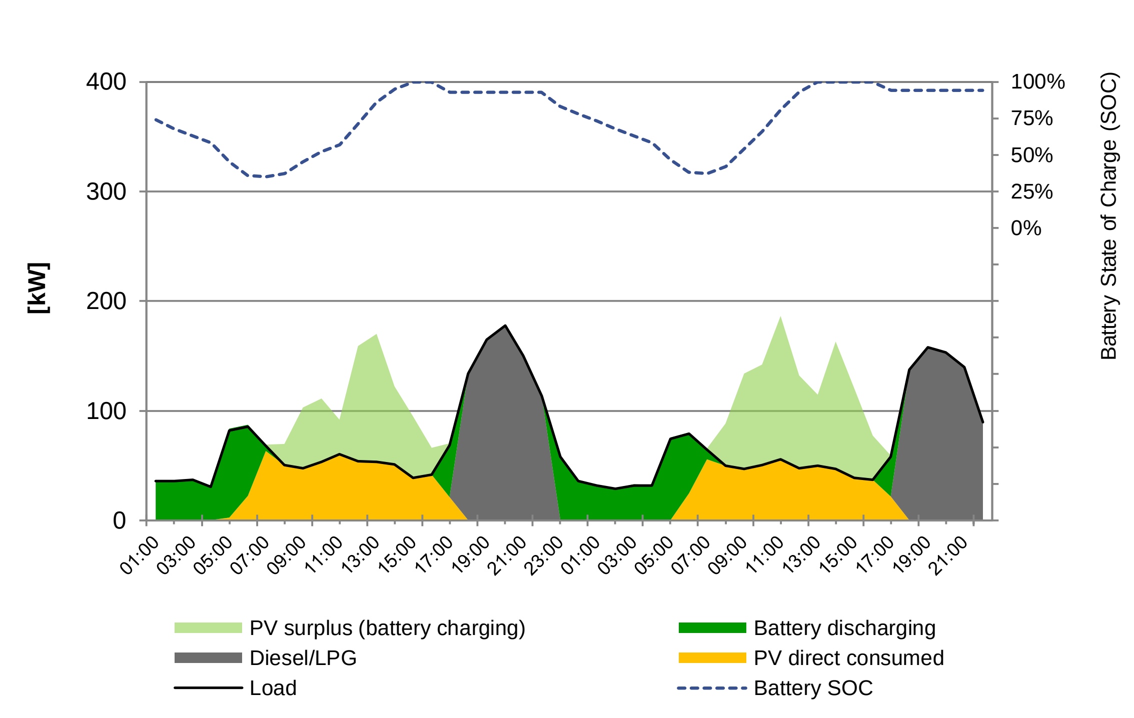
Flipchart-Exercise

Appliance	Number	Power	Hours of utilization per day
TV	1	25	4
Light bulb	3	10	4
Fan	1	70	3
Air conditioner	1	1,200	6

How much energy consumption per day?

Answer: 7.63 kWh

How the hybrid system works



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Q&A

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SIZING & OPTIMIZATION

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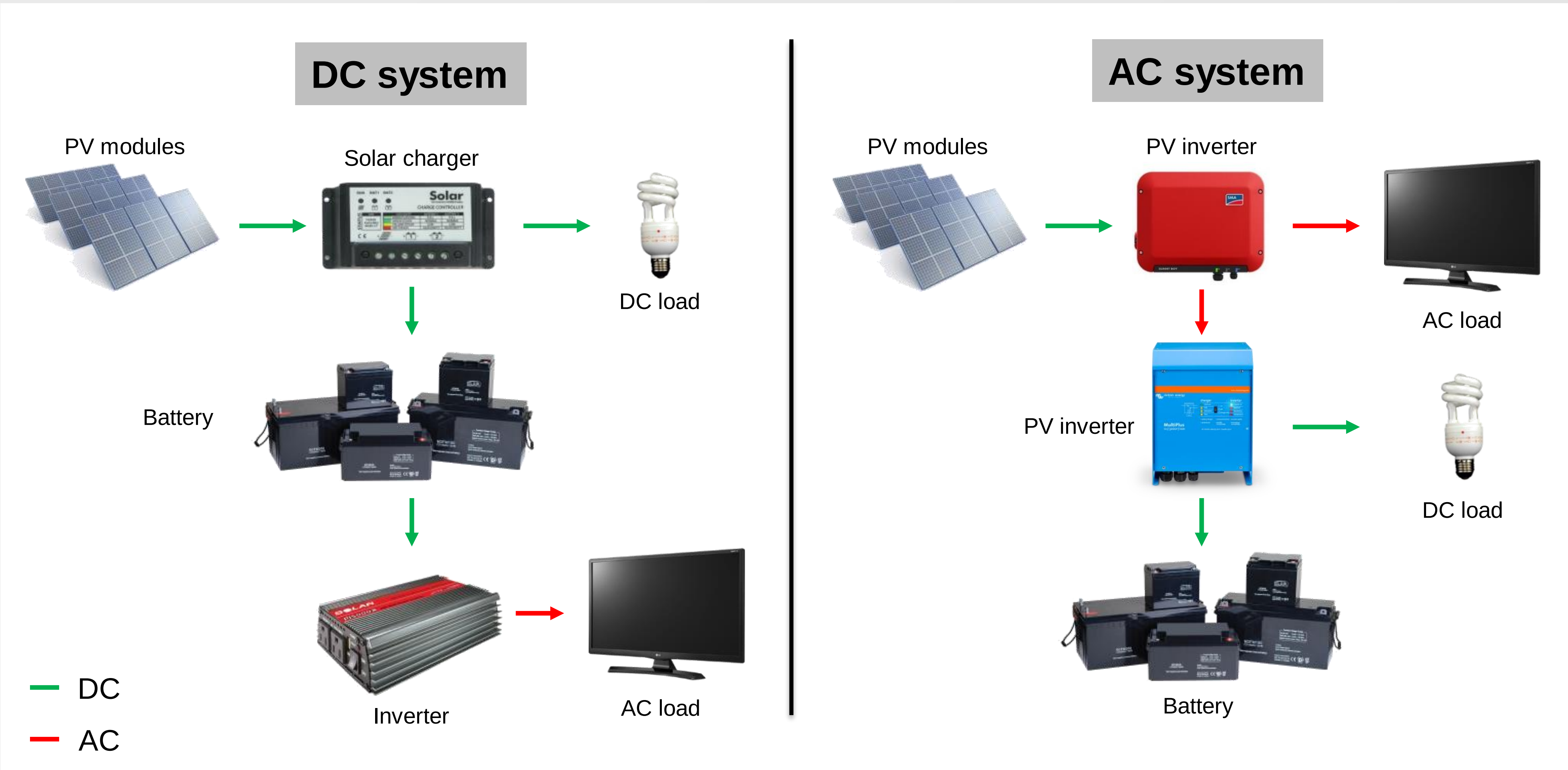
■ Solar Home System – DC system VS AC system



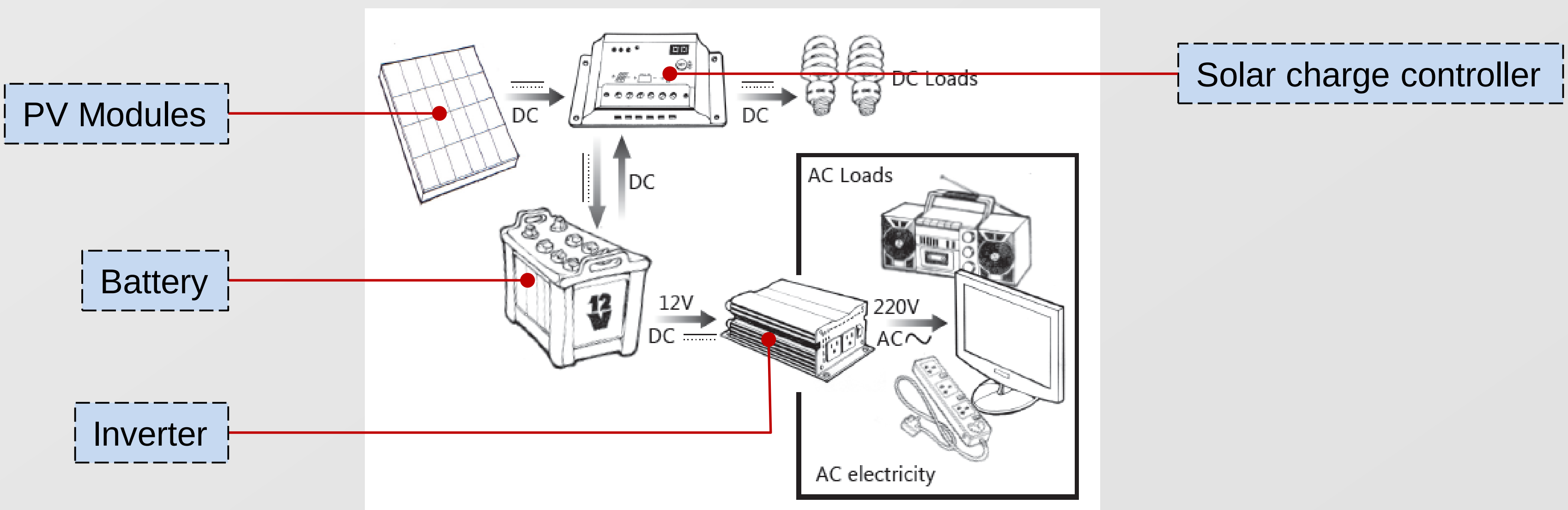
Sizing & Optimization

■ Simple examples to understand sizing in-principle (Solar Home System)

Appliance	Number	Power	Hours of utilization per day
TV	1	25	6
Light bulb	3	10	8
Fan	1	70	5

Energy consumption

740 Wh/day



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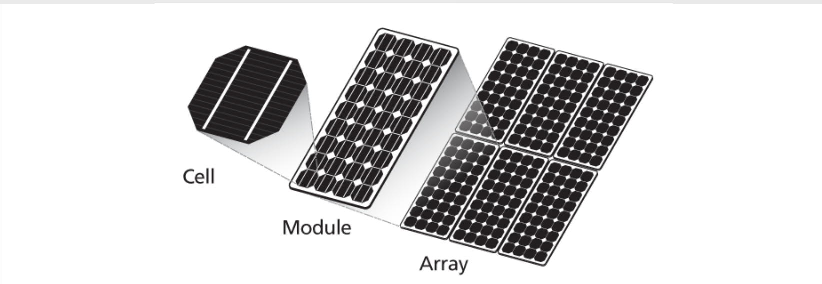
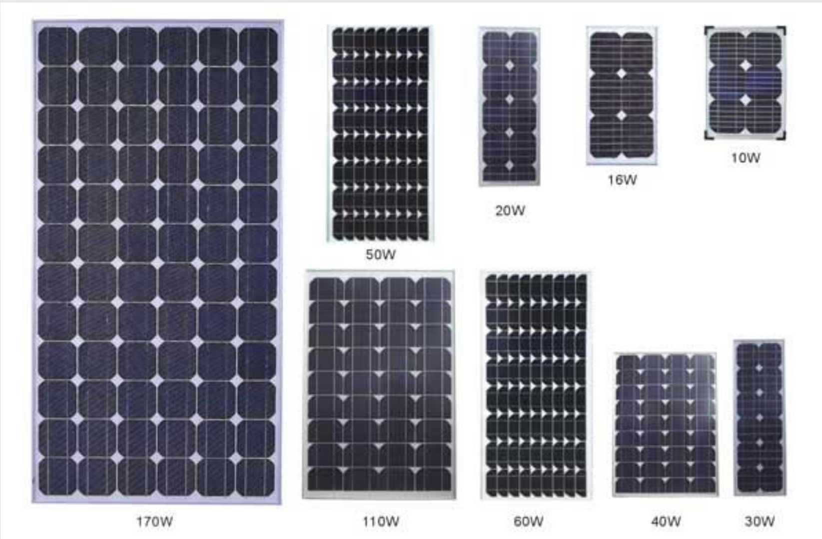
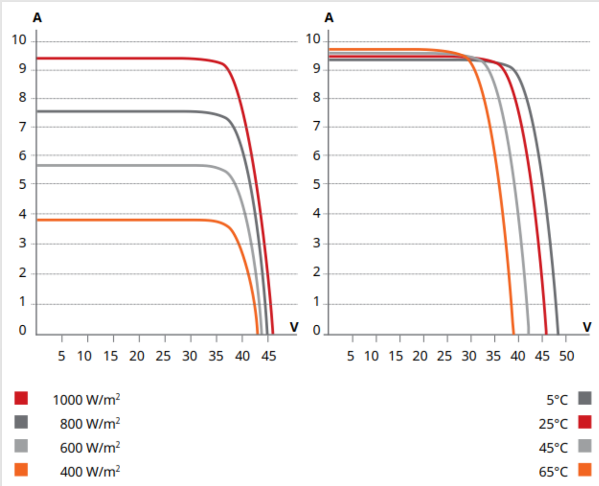
PV module





CS6P	260P	265P	270P
Nominal Max. Power (Pmax)	260 W	265 W	270 W
Opt. Operating Voltage (Vmp)	30.4 V	30.6 V	30.8 V
Opt. Operating Current (Imp)	8.56 A	8.66 A	8.75 A
Open Circuit Voltage (Voc)	37.5 V	37.7 V	37.9 V
Short Circuit Current (Isc)	9.12 A	9.23 A	9.32 A
Module Efficiency	16.16%	16.47%	16.79%
Operating Temperature	-40°C ~ +85°C		
Max. System Voltage	1000 V (IEC) or 1000 V (UL)		
Module Fire Performance	TYPE 1 (UL 1703) or CLASS C (IEC 61730)		
Max. Series Fuse Rating	15 A		
Application Classification	Class A		
Power Tolerance	0 ~ + 5 W		

* Under Standard Test Conditions (STC) of irradiance of 1000 W/m², spectrum AM 1.5 and cell temperature of 25°C.

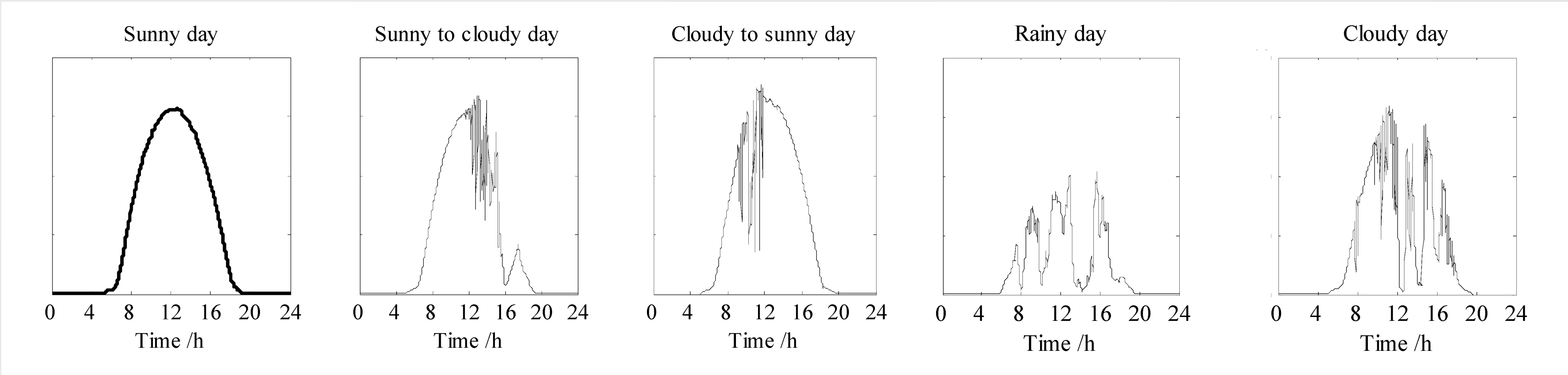


Standard Test Conditions

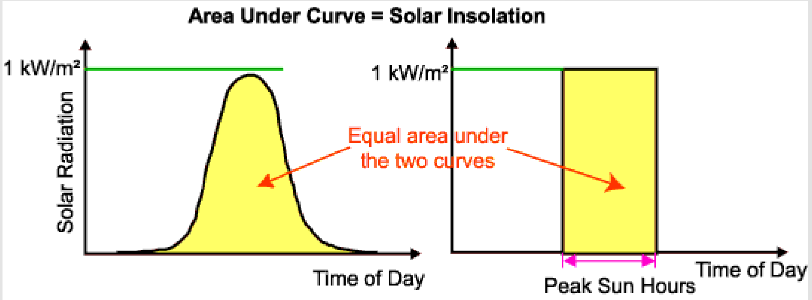
- Irradiance 1,000 W/m²
- Vertical (right angle) sun-angle
- Cell temperature 25°C
- AM1.5

Sizing & Optimization

Understanding solar insolation



In Thailand, the average daily solar insolation is equivalent to **~3.8 hrs/day (at 1,000 W/m²)** (depends on the climate of the site location)



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PV module sizing: Pre-Sizing

740 Wh/day

$$Total\ Wp\ needed\ for\ PV\ modules = \frac{Total\ energy\ per\ day\ used\ by\ appliances}{Average\ daily\ solar\ potential} \times \left(1 + \sum system\ losses\right)$$

Assumptions

Average daily solar potential ≈ 4,750 Wh/kWp/day

PV to Battery losses = 25% (inc. temp losses, cable losses, CC efficiency...etc.)

Battery round trip losses = 15%

Inverter losses = 5%

Total Wp needed for PV modules = 226 W_p

$$No.of\ PV\ modules\ needed\ = \frac{Total\ Wp\ needed\ for\ PV\ modules}{Wp\ of\ a\ PV\ module}$$

Example

Selected PV module = 250 Wp

No. of PV modules = 1 modules

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Battery

- Storage of energy

Lead-acid / Lead gel

- Bulky
- Frequent inspection
- Cheaper

Lithium-ion

- Light weight
- Higher roundtrip efficiency
- High Depth of Discharge (DOD)
- Longer lifetime
- More expensive

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Battery sizing: Pre-Sizing

740 Wh/day

$$Battery\ Capacity\ (Ah) = \frac{Energy\ required\ x\ (1 + \sum system\ losses\ )}{(0.6 \times nominal\ battery\ voltage)} \times Days\ of\ autonomy$$

Depth of discharge of the battery

the number of days that you need the system to operate when there is no power produced by PV panels

Example

Nominal battery voltage = 24 V

Days of autonomy = 2 days

$$Battery\ Capacity = \frac{1{,}073}{(0.6 \times 24)} \times 2 = 149\ Ah$$

Charge controller sizing: Pre-Sizing

- The sizing of controller depends on the **total PV input current** which is delivered to the controller and also depends on PV panel configuration (series or parallel configuration).
- According to standard practice, the sizing of solar charge controller is to take the short circuit current (Isc) of the PV array, and multiply it by **1.1**

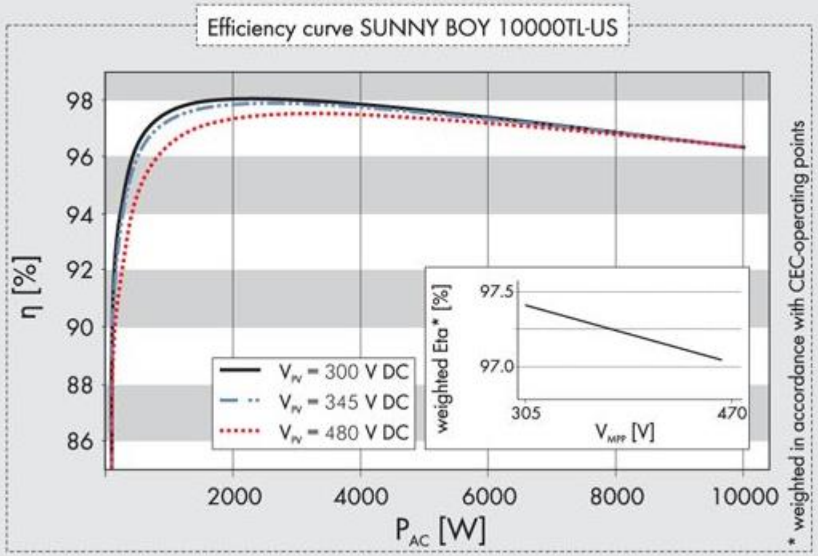
Example

PV module configuration:	Single module		Charge Controller Specification
PV module specification:	Pm =	250 Wp	Nominal PV power, 24V = 290 W
	Voc =	37.2 V	Max. PV open circuit voltage = 75V
	Isc =	8.87A	Max. PV short circuit current = 12A

Sizing & Optimization

Inverter

- Convert DC to AC



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Inverter sizing: Pre-Sizing

- The inverter must be large enough to handle the total amount of Power you will be using at one time.
- The inverter size should be **25-30% bigger** than total Power of appliances.
- In case of appliance type is motor or compressor then inverter size should be **minimum 3 times** the capacity of those appliances and must be added to the inverter capacity to handle surge current during starting

Example

Total Power of all appliances = 25 + (3 × 10) + 70 = 125 W

The inverter size should be about **160 W** (25-30% bigger).

Sizing & Optimization

AC bus system

- https://www.sma.de/en/sunbelt.html

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EXAMPLE: HYBRIDIZATION OF AN ISLAND

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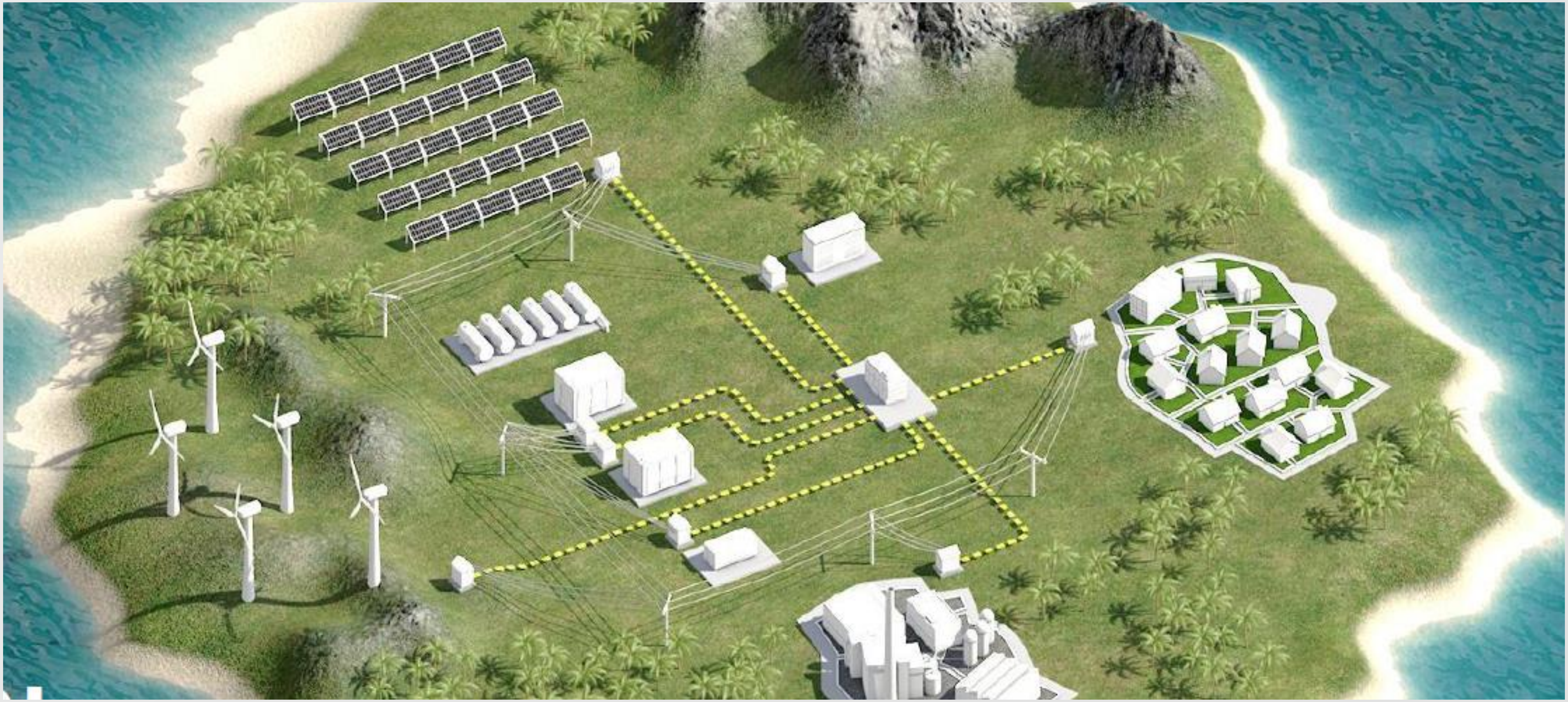
■ Hybrid Islands / Mini Grids - Introduction



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Design process (Mini-grid) – Project introduction

Island overview	
Location	Central Philippines
Population	1,500 households (6,000 inhabitants)
3 electricity customer groups	Residential Commercial others (public building, street light)
Number of customer connections	1,500 households (100% energized)
Main income source	Fishery Coconut farming
Average income	3,040 THB/month
Typical appliances	Fan, Water boiler, Freezer, Lighting, Mobile phone

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Design process (Mini-grid) – Project methodology

1. Prior to site visit
   - Current situation review
   - Available data and Socio-Economic background review
2. Site visit
   - Data gathering
   - Suitable areas for hybrid system
3. Data acquisition and analysis
4. Load Profile forecasting
5. Hybrid system simulation

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Design process (Mini-grid) – Project methodology

1. Prior to site visit

Current situation

8 hrs/day electricity available

3 diesel generators

Available data and Socio-Economic background review

Data	Unit	2010	2011	2012	2013	2014	2015
Residential	No.	1,195	1,247	1,299	1,351	1,331	1,380
	MWh	203.74	201.08	193.42	179.61	166.55	172.54
Commercial	No.	19	19	18	17	42	44
	MWh	12.39	12.23	11.76	10.92	28.98	30.02
Others (Public buildings and street light)	No.	0	0	0	0	47	49
	MWh	0	0	0	0	14.44	14.96
Total number of customers connections	No.	1,214	1,266	1,317	1,368	1,420	1,473
Total energy sales (EC to customers)	MWh	216.13	213.31	205.18	190.53	209.97	217.52
Total distribution losses	%	n. a.	n. a.	n. a.	18.48%	15.62%	13.38%

■ Design process (Mini-grid) – Project methodology

2. Site visit, Data gathering, Suitable areas

Site visit






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■ Design process (Mini-grid) – Project methodology

2. Site visit, Data gathering, Suitable areas

Data gathering

1hr Hourly power output
very important

Socio-economic data
very important
- Population growth potential
- Typical energy consumption per household
- etc.

other
- Actual load measurement
- Total energy measurement
- Daily fuel consumption
- Actual generation costs per kWh
- Possible areas for the hybrid system
- Collection of the SLD of the island distribution system
- Information of meter specifications

Suitable areas for hybrid system

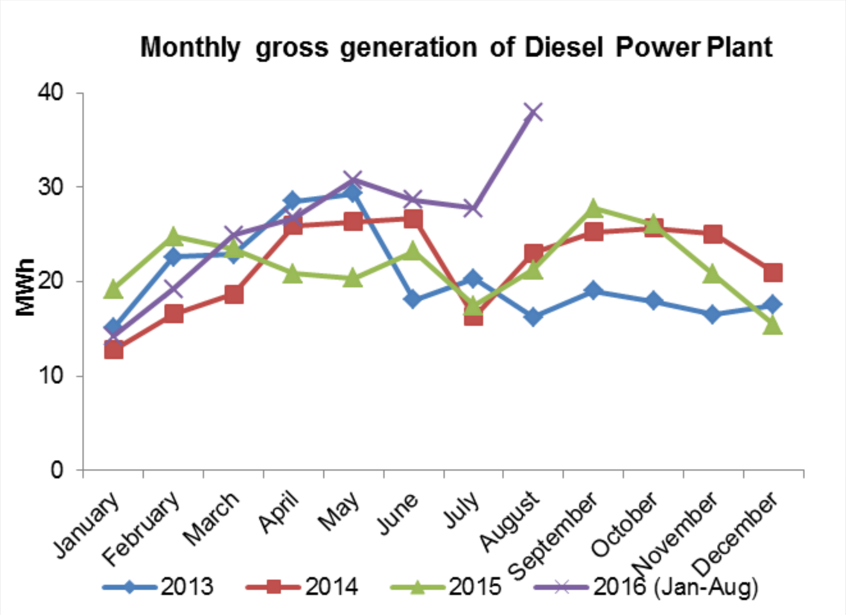
Design process (Mini-grid) – Project methodology

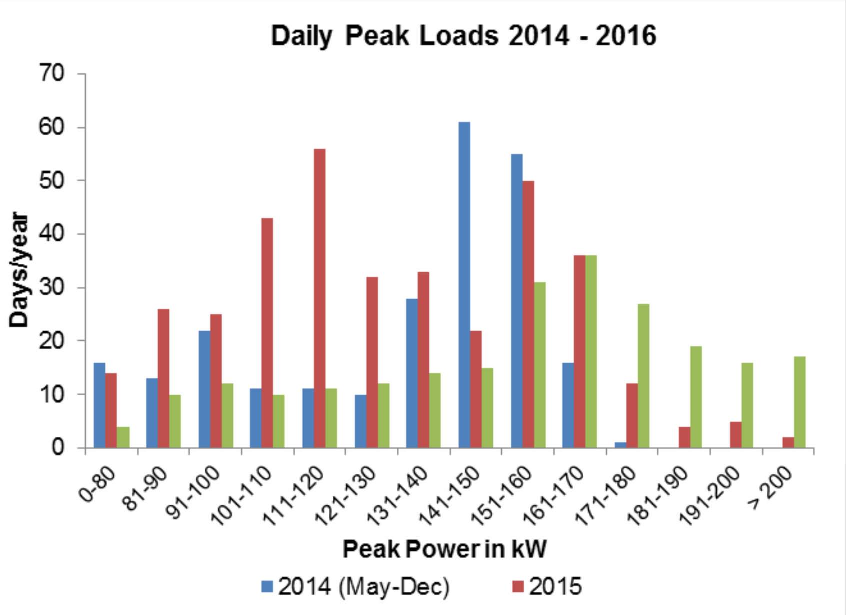
- Where should we put the hybrid system?
  - ✓ Not too far from the village
  - ✓ PV/battery/diesel generator shall be in the same area
  - ✓ No flood area
  - ✓ Flat area

Design process (Mini-grid) – Project methodology

3. Data acquisition and analysis

Data analysis





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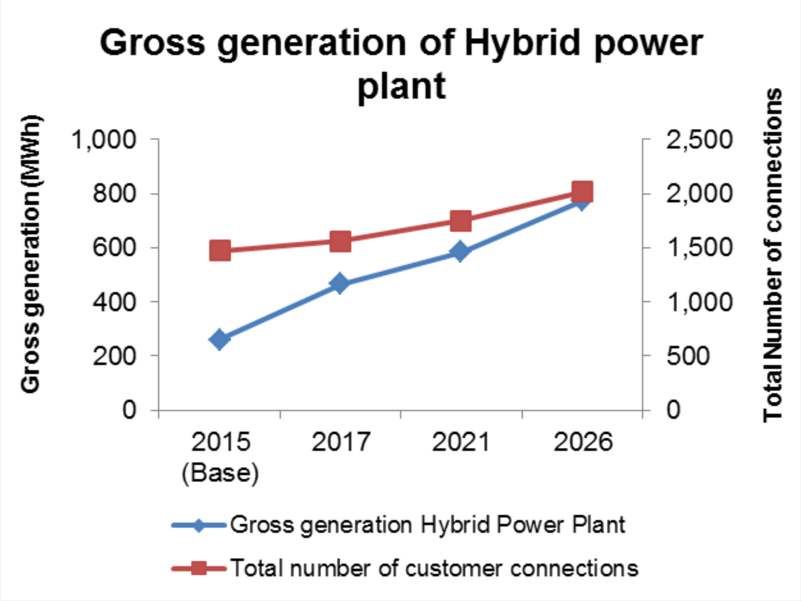
Design process (Mini-grid) – Project methodology

3. Data acquisition and analysis

Residentials were categorized according to the socio-economics into:
- Low, middle and high incomers
- For each of them with assumptions for
  - spendings on electricity
  - Additional appliances (for power and energy forecast)
  - Potential growth (population and energy consumption)

Data analysis

Data	Unit	2015 (BASE)	2017	2021	2026
Residential	No.	1,380	1,464	1,648	1,910
	MWh	172.54	325.13	411.86	553.51
Commercial	No.	44	46	50	55
	MWh	30.02	54.67	67.92	89.09
Others (Public buildings and street light)	No.	49	49	50	52
	MWh	14.96	25.78	27.92	30.83
Total number of customer connections	No.	**1,473**	**1,559**	**1,748**	**2,017**
Gross generation Hybrid Power Plant (including distribution loss)	MWh	**260.69**	**466.19**	**583.57**	**774.06**



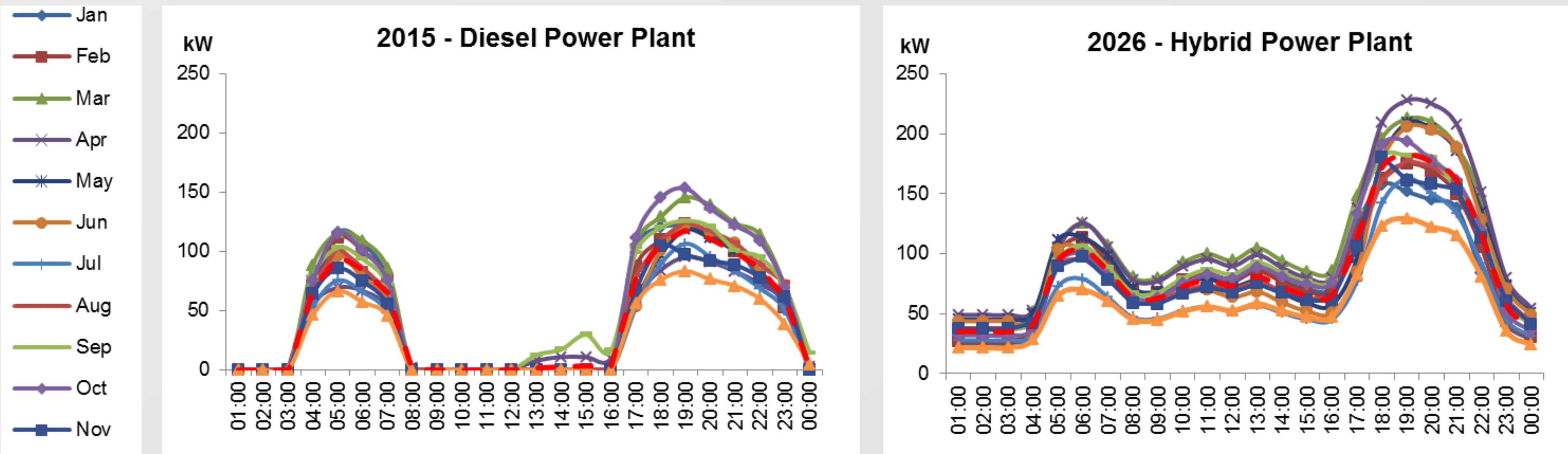
The customer can be categorized by 3 types: 1) Residential, 2) Commercial, 3) Others
(**based on the electricity consumption behavior or load profile shape**)

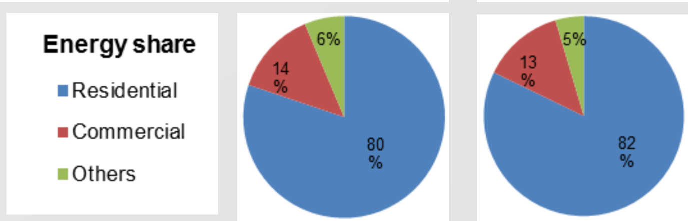
Design process (Mini-grid) – Project methodology

4. Load Profile forecasting

Load profile forecast (5 – 10 years)

“The better and accurate the input data, the better the results”





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■ Design process (Mini-grid) – Project methodology

5. Hybrid system simulation

General input in the simulation consisted of:

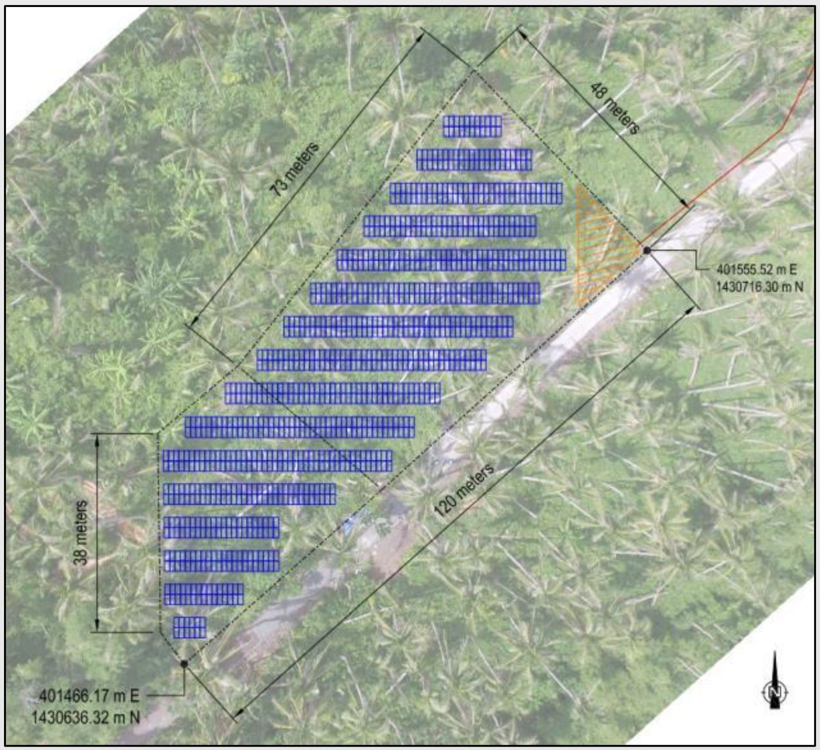
1. Load profile (hourly resolution)
2. Selected technologies and their technical parameters
3. Weather data (hourly resolution)
4. Consumption curves of the generator
5. Costs of each component
6. Financial parameters of each technology (CAPEX, OPEX, etc.)

The overall target of the simulation:

1. Provides electricity sustainable over 24 hrs / 7 days
2. Has a high renewable energy share
3. Ensures reliable and sustainable energy supply
4. Is capable to be expanded
5. Is optimized technically and economically (acc. to LCOE)
6. Is capable and sized sufficiently for at least 10 years

Design process (Mini-grid) – Project result

PV power plant layout



Solar-PV

- Total capacity: 300 kWp
- Module type: polycrystalline
- Inverter type: string inverter

Battery

- Technology: Li-ion
- Total capacity: 700 kWh
- Usable total battery capacity (SOC_{min} 10%): 630 kWh

Diesel generator

- Total capacity: 3x150 kW

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Design process (Mini-grid) – Project result

Simulation Output

Diesel / PV / Battery Hybrid System	Unit	2017	2021	2026
Total energy production/demand	kWh/a	457,097	572,186	758,964
Total diesel consumption	l/a	49,322	72,845	117,641
Reduction diesel consumption (compared to diesel reference scenario)	l/a	109,422	110,287	109,930
Renewable fraction (PV and battery)	%	62	56	46
Excess PV energy	%	32	23	15
Diesel operating hours	h/a	1,890	2,839	4,529
CO_2 emission	t/a	130	192	311
Reduction of CO_2 emission	t/a	289	291	290

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Design process (Mini-grid) – Financial

Initial CAPEX	
Diesel	4,233,330 THB
PV	12,234,300 THB
Battery	19,763,100 THB
Total	**36,232,350** THB

OPEX - PV	
Replacement costs string inverters	3,770 THB/kWp
Number of inverter replacements over lifetime	1
Resulting inverter replacement costs linear over project lifetime (year 6 - 30)	47,055 THB/a
General O&M costs	313 THB/kWp/a
Resulting general O&M costs linear over project lifetime	94,110 THB/a

OPEX - Diesel	
Replacement costs (30% of initial CAPEX)	3,140 THB/kW
Number of replacements over project lifetime	2
Resulting replacement costs linear over project lifetime	94,110 THB/a
O&M costs (labor costs and lube oil) Basis: average 2013-2016 on the Island	3.33 THB/kWh

OPEX – Battery Storage System	
Replacement costs battery cells and battery inverter(s) in year 2032 (based on future estimated Li-ion cell price in year 2030 according Bloomberg New Energy Finance: ~250 USD/kWh)	7,058,250 THB
General O&M costs (annual inspections)	125,480 THB/a

Parameter	LCOE [THB/kWh]	Reduction (reference scenario: 100% Diesel)
Reference scenario: 100% Diesel	22.15	reference
Diesel/PV/Battery hybrid system	**18.07**	**-18.35%**

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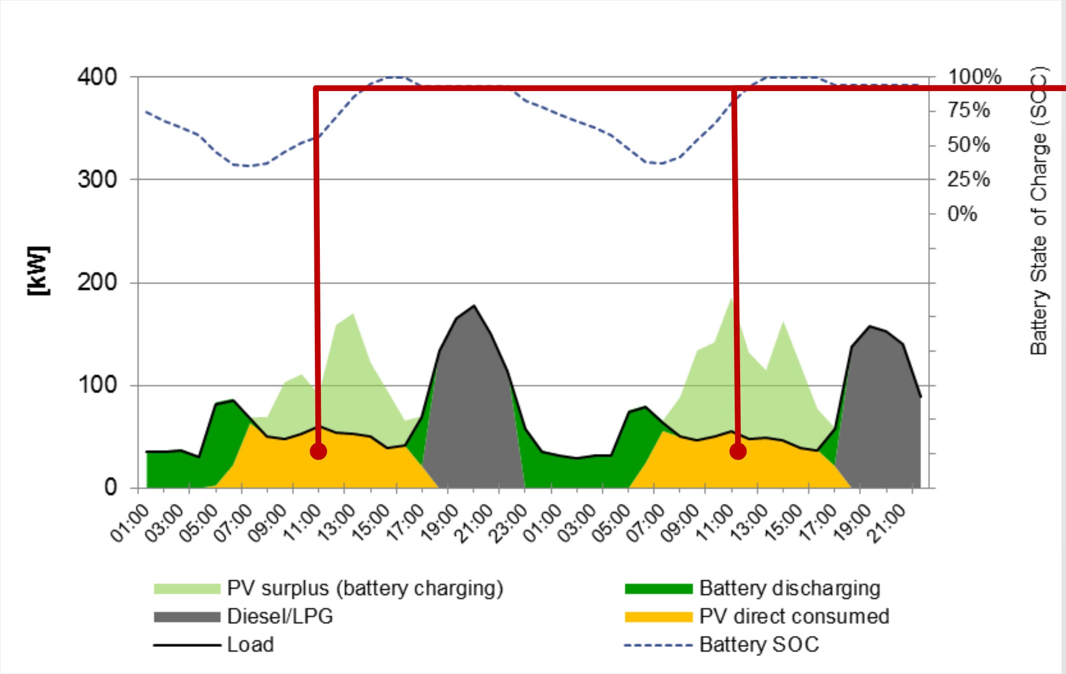
OPERATION & MAINTENANCE

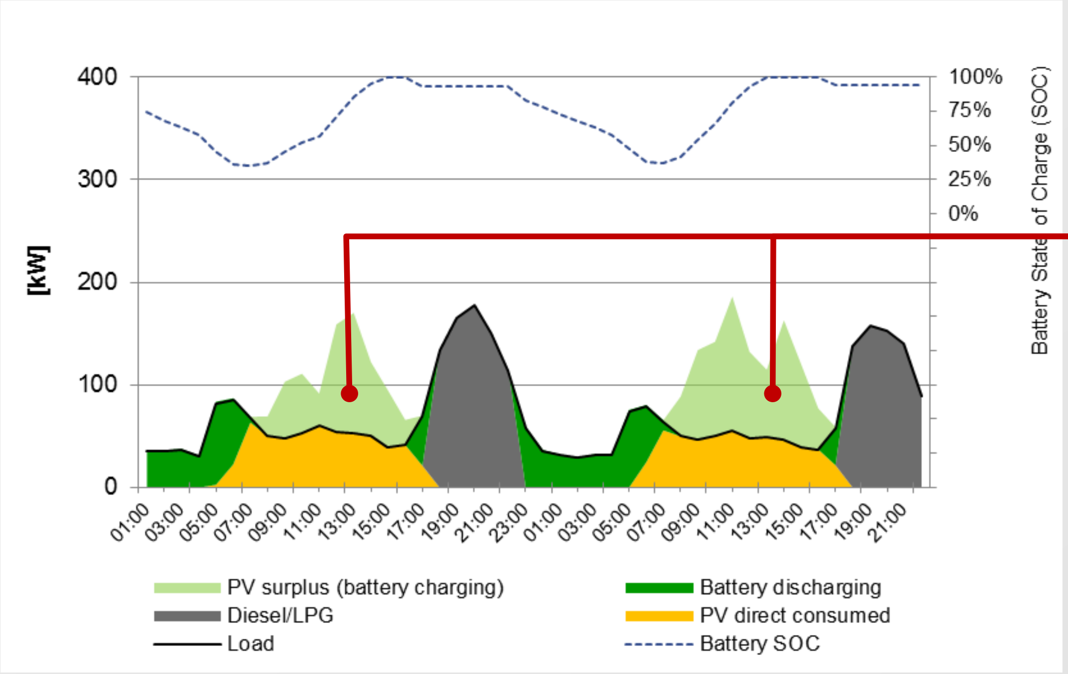
Operation modes



Daytime

- PV modules supply electricity to the loads.

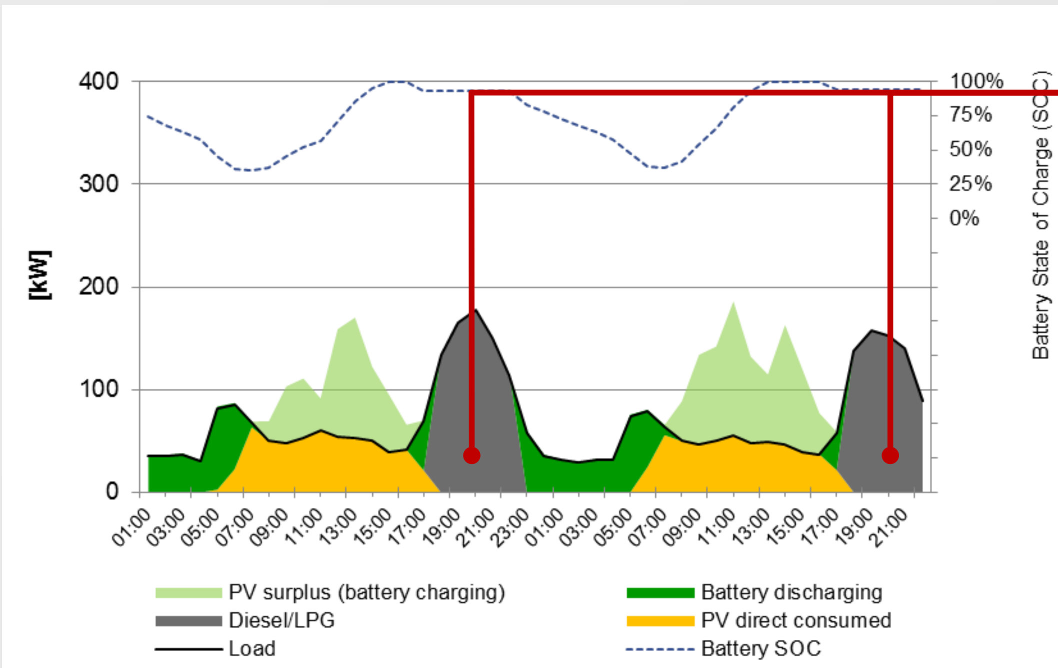
Operation modes



Daytime

- PV modules supply electricity to the loads.
- Moreover, Surplus energy will be stored in the battery.

Operation modes



Night time

- Peak load:

  Diesel generator will start supplying electricity to the loads.

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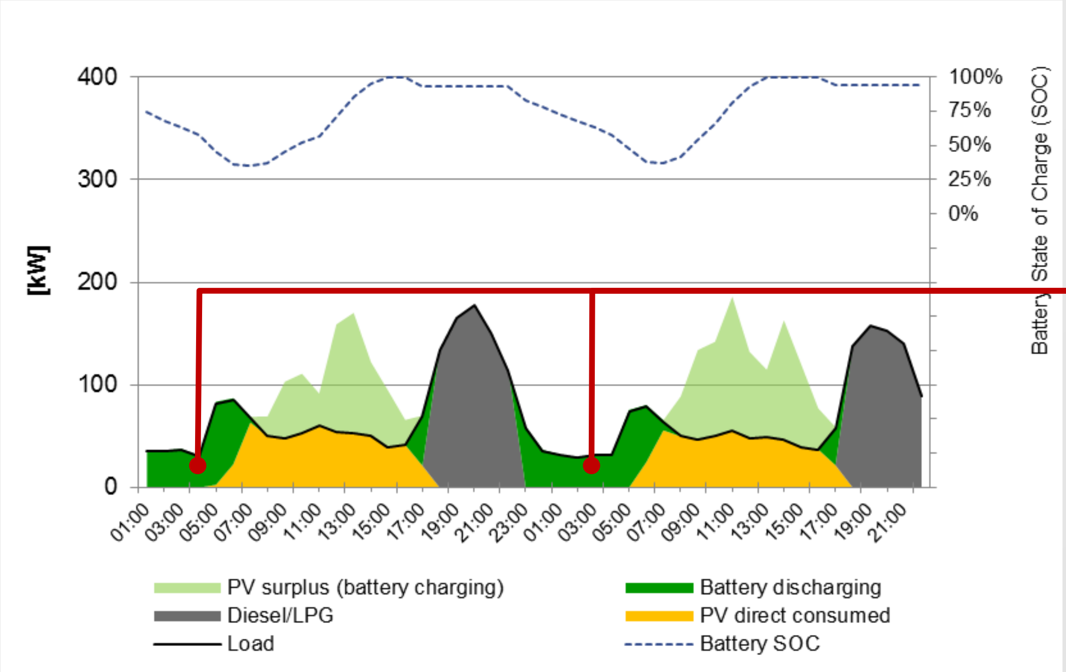
Operation modes



Night time

- Peak hours:
  Diesel generator will start supplying electricity to the loads.
- Non-peak hours:
  Battery will supply electricity to the loads.

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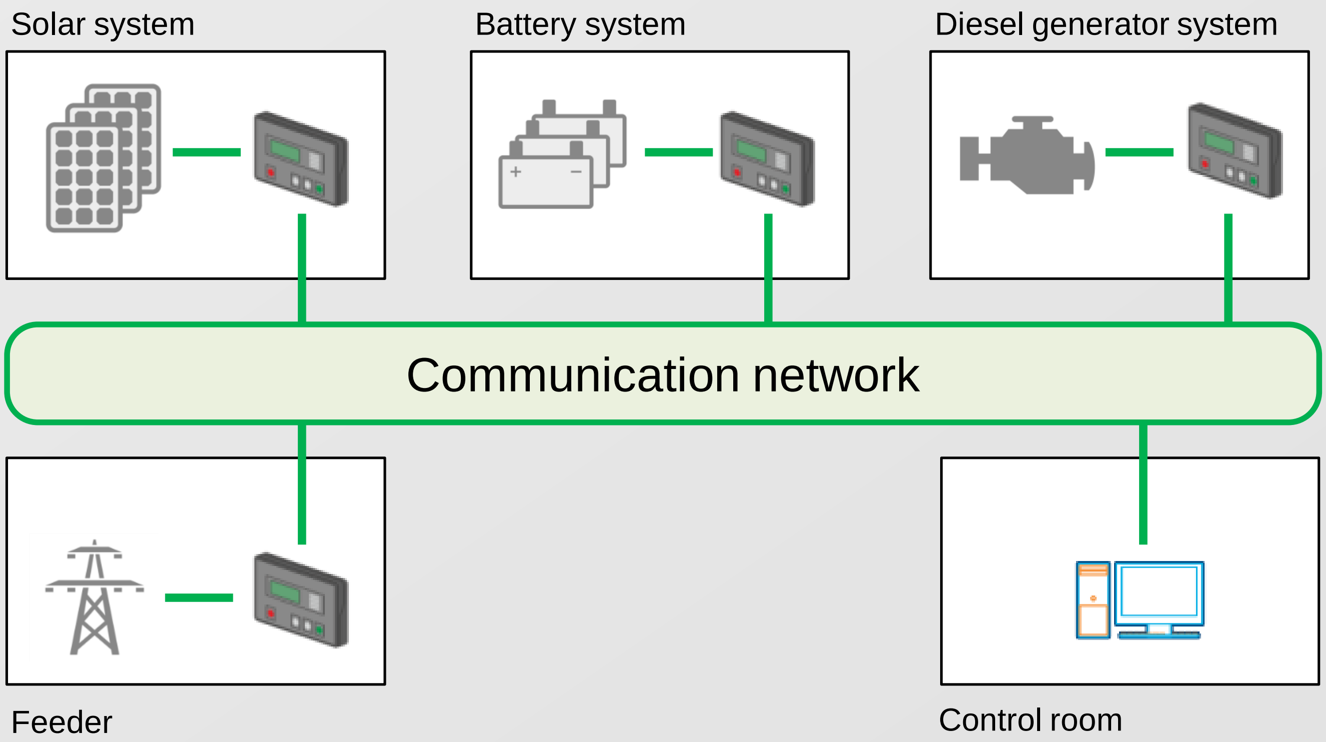
Interaction/communication of system components

- Each component need to communicate



Electricity meter functions and payment systems

Post-paid meter

- Cheaper system
- Not complicated system
- Do not need to spare a card in case of broken card or new customer

Pre-paid meter

- Customers pay for their electricity before they use
- Customers can monitor their usage and control against their budget
- Operator do not need to collect the money themselves

■ System maintenance – PV module

- To maintain the PV modules, the followings shall be done:
  - PV modules shall be cleaned
  - No grass / trees
  - No debris / bird droppings / leaves on the PV modules
  - Screws / terminals / connections inspection

Bad practices

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System maintenance – Battery

- To maintain the battery, the followings shall be done:

  Lead-acid battery

  - Maintain a proper fluid level between “maximum” and “minimum” by using distilled water
  - The top of the battery and connections should be clean
  - Leakage inspection

  Lithium-ion battery

  - Keep the battery at room temperature (25°C)
  - 100% DOD shall be avoided

Bad practices

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System maintenance – Inverter

- To maintain the inverter, the followings shall be done:
  - Electrical characteristic inspection
  - Corrosion of terminals and connections inspection
  - Clean / replace the filter (if any)

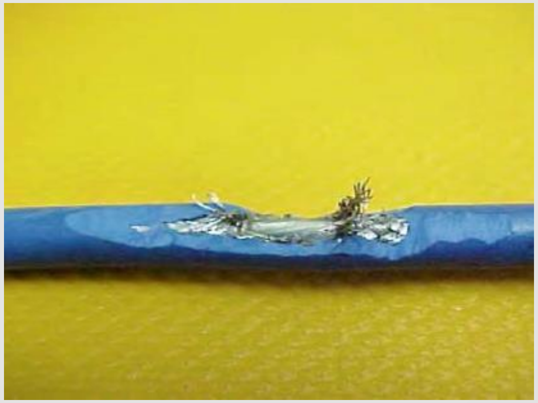
Bad practices

System maintenance – Cable

- To maintain the cables, the followings shall be done:
  - Regularly, measure the current (I) and the grounding
  - Damaged wire inspection

Bad practices





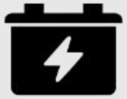
Lifetime and replacement of components


PV modules

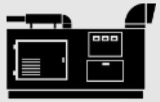
- Lifetime could be up to 30 years


Inverter

- Estimated: 15 years


Battery

- Depends on the environmental condition, e.g. temperature
- Estimated: average 10 years (at 25°C)


Diesel generator

- Depends on engine type / the operating hours
- Estimated: 20,000 – 80,000 hours

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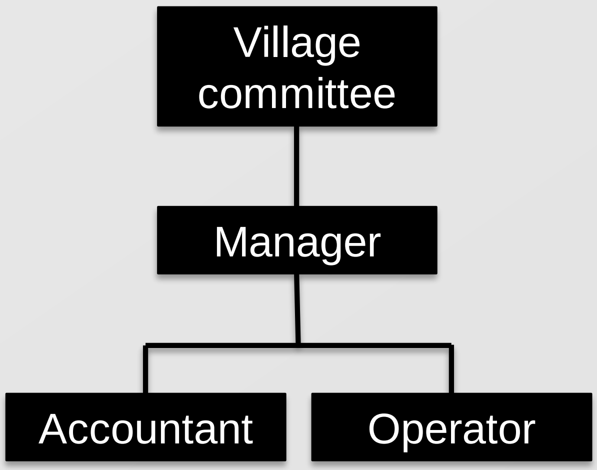
How community gets involved in hybrid system

- During the takeover period, the community shall be trained
- This can create the full-time job for local people

Example



3rd Thai-German Community-based Renewable Energy Conference, Bangkok 2018

MONITORING & UPSCALING

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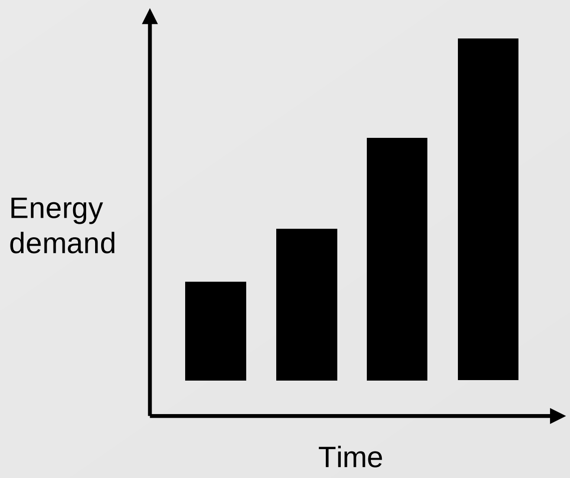
■ Upscaling possibilities

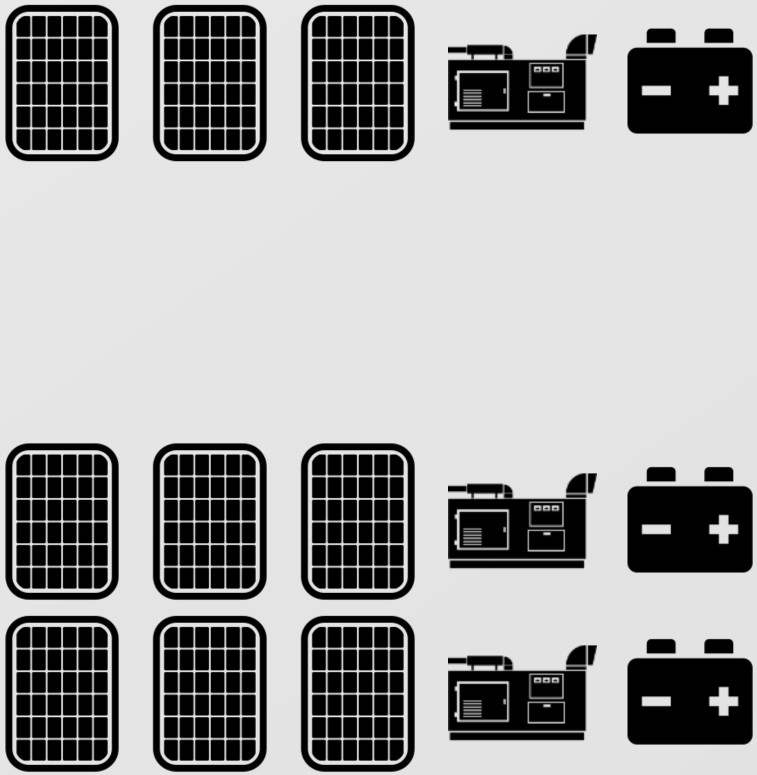
What if the hotels are constructed on the island (2x energy demand)

What can we do?

Monitoring & Upscaling

Upscaling possibilities





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Q&A

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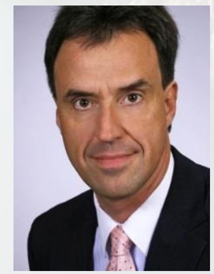
Thank you for your attention !

When your Vision becomes a Mission –

Your Business will become a Movement.

Frank Zimmermann



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