Facility Planning Method

(Exercise)

Text

Exercise [System planning for mega-solar]

1. Procedures of a mega-solar system planning in the exercise

In this exercise, the system planning for a mega-solar at 1MW is implemented. In the implementation of the mega-solar system planning, the data in your country shall be used for the natural conditions such as solar radiation and temperature. Also, environmental conditions such as snow in your country shall be considered.

Figure 1-1 shows procedures of PV system planning in this exercise. In the exercise, the system planning of mega-solar at 1MW (AC terminal of PCS) is implemented, and calculate annual energy production. Study of the PV array rack and foundation are not included. Also, study of system configuration for connecting to the electric power system is performed.

In the real system planning, it is necessary to calculate the approximate cost after determination of system configuration, and perform an economical evaluation. However, we perform up to system configuration study in this exercise.

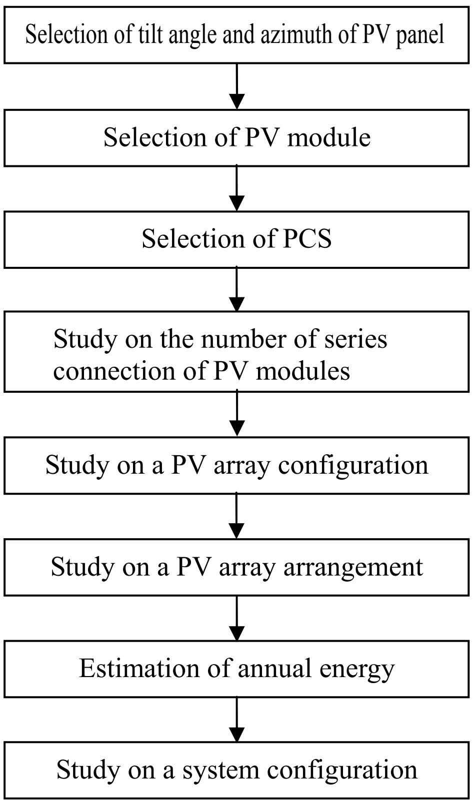


Figure 1-1 Procedure of system planning for mega-solar

2. Exercise (system planning for mega-solar)

①Selection of tilt angle and azimuth of PV panel

The optimal tilt angle and azimuth of PV panel in each country is determined using HOMER (https://users.homerenergy.com/) or RETScreen (http://www.retscreen.net/) . The solar radiation of the daily average in each month at selected optimal tilt angle and azimuth is recorded. Also, the average temperature in each month is recorded.

②Selection of PV module

Select PV module from the table 2-1 “PV module list”.

Table 2-1 PV module list

	PV module A	PV module B	PV module C	PV module D
Type	Monocrystalline silicon (HIT Power 240S)	Polycrystalline silicon (KD250GX-LFB2)	Multi-junction Hybrid (F-NJ150)	CIS (SF160-S)
Nominal Max. Output (P_{max})	240W	240W	150W	160W
PV module conversion efficiency	19.0	14.6	9.60	12.6
Nominal Max. Output Working Voltage (V_{pm})	43.7V	29.8V	125.8V	84.0V
Nominal Max. Output Working Current (I_{pm})	5.51A	8.06A	1.20A	1.91A
Nominal Open Circuit Voltage (V_{oc})	52.4V	36.9V	158.1V	110V
Nominal Short Circuit Current (I_{sc})	5.85A	8.59A	1.45A	2.2A
External Dimensions (mm) W×L×D	1,580×798×35	1,662×990×46	1,500×1,100×50	1,257×977×35
Temperature coefficient of short circuit current(I_{sc})	+0.03%/K	+0.060%/K	+0.055%/K	+0.01%/K
Temperature coefficient of open circuit voltage(V_{oc})	−0.24%/K	−0.36%/K	−0.39%/K	−0.30%/K
Temperature coefficient of Max. output(P_{max})	−0.30%/K	−0.46%/K	−0.35%/K	−0.31%/K

※The temperature coefficient of output working voltage shall be the same as the temperature coefficient of open circuit voltage.

③Selection of Power Conditioning System

Selecting Power Conditioning System from the table 2-2 “Power Conditioning System list”.

Table 2-2 Power Conditioning System list

		PCS-A	PCS-B	PCS-C	PCS-D
Output capacity		10kW	100kW	250kW	500kW
DC input	Rated voltage	400V	345V	350	350
	DC voltage range	0～600V	0～650V	0～600V	0～600V
	Range of MPPT	200～550V	315～600V	320～550V	320～550V
	Number of phase	Three-phase three-wire	Three-phase three-wire	Three-phase three-wire	Three-phase three-wire
AC input	Rated voltage	202V	202V	415V	210V
	Rated frequency	50 or 60Hz	50 or 60Hz	50 or 60Hz	50 or 60Hz
	Power conversion efficiency	94.5%	95.3%	95.7%	96.8%

*You can confirm specifications for each solar module and power conditioner at the following site to assist you in making your selection. (http://www.enfsolar.com/)

④Study on the number of series connection of PV modules

The number of series connection of PV modules is considered from the specification of the selected PV module and a Power Conditioning System. The number of series connection of PV modules is: 110% of rated voltage (on DC side) of a selected PCS is divided by the maximum working voltage of the PV module, as a reference value. Also, the number of series connection of PV modules is determined in consideration of following points eventually.

- Is the variation by the temperature characteristics of a PV string's open circuit voltage within a the DC voltage range (below the upper limit of the DC voltage range) of a power conditioning system?
- Is the variation by the temperature characteristics of a PV string's output working voltage within MPPT (maximum power point tracking) range of a power conditioning system?

The highest and the lowest PV module temperatures are calculated by the following formulas:

The highest PV module temperature=Annual highest temperature in each country + weighted average PV module temperature rise⊿T

The lowest PV module temperature=Annual lowest temperature in each country + weighted average PV module temperature rise⊿T

* Installation type is a back open type (rack-mount type), the weighted average PV module temperature rise ⊿T is at 18.4 (℃). (JIS C 8907 Estimation method of generating electric energy by PV power system)

⑤Study of the PV array configuration

In consideration of the PV array configuration, the number of parallel connections of the PV strings in the PV array is determined, and then the number of lines and rows of PV modules is determined. If the size of the PV array is specified, it is necessary to consider the PV array to fit its size as specified. The PV array consists of the number of PV modules of the integral multiple of the determined PV modules connected in series.

[Conditions of PV array arrangement]

Condition 1: The width of a PV array shall be 25m and below.
（Consideration given for efficiency during inspection）

Condition 2: Maximum height of a PV array is 2.0m and below from GL.
（Consideration given for reach）
The bottom of a PV panel shall be 0.5m from GL.
（To minimize the impact of insects, small animals, and grass）

Condition 3: The spaces between PV modules and the edge of PV modules shall be kept at 50mm.
（Space is created with mounting brackets. In cases where the mounting brackets are specified, 10 mm brackets are sometimes used.）

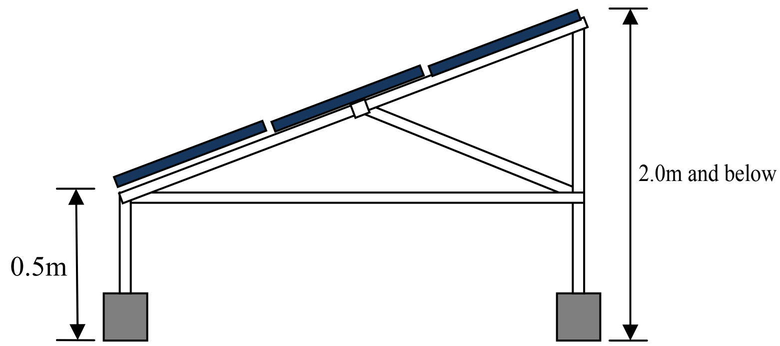


Figure 2-1 Conditions of PV array arrangement 2

⑥Study of the PV array arrangement

The number of the PV array is determined to be set at 1MW (AC terminal of PCS) and work out the PV array arrangement. The conversion efficiency of PCS and DC loss (2%) should consider when determining the number of the PV array. It assumes that the site for the PV array arrangement is a flat land, and the arrangement should be formed as a square shape as much as possible.

[Conditions of PV array arrangement]

Condition 1: The space at 10m x 10m for installing a collecting box, PCS, a transformer board, and an interconnection board is secured.

Condition 2: The distance of PV arrays facing to the north-south is set in consideration of shade impact by a front PV array. Please refer to figure 2-2.

Condition 3: The distance of PV arrays facing to the east-west should be more than 1.5m. Please refer to figure 2-3.

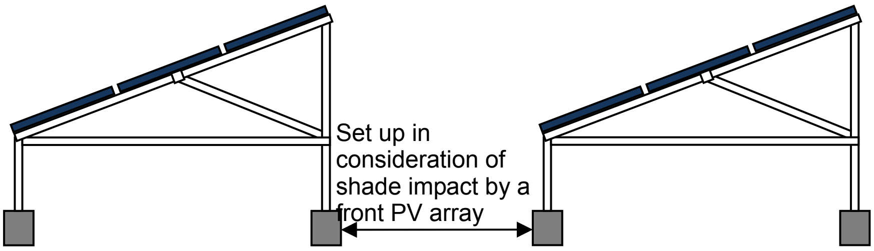


Figure 2-2　Conditions of PV array arrangement 2

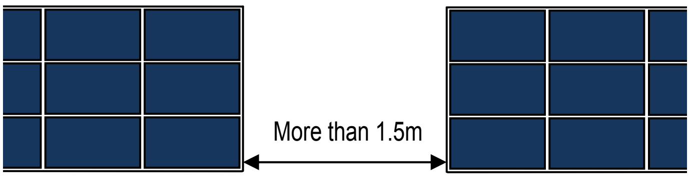


Figure 2-3　Conditions of PV array arrangement 3

⑦Estimation of annual energy production

Annual energy production is calculated from the capacity of the PV array

Expected annual energy Ep can be represented by the following equation:

$Ep = \Sigma H_A / Gs \times K \times P_{AS}$

- Ep = Expected annual energy (kWh/year)
- H_A = Average daily irradiation on a monthly basis ($kWh/m^2/day$)
- Gs = Irradiance under standard condition = 1 (kW/m^2)
- K = Total design factor (= $Kd \times Kt \times \eta_{INV}$)
  - * DC correction factor Kd:
    Corrects change in solar irradiance due to stains on the PV cell surface and characteristic difference in PV cell. Kd is about 0.9.
  - * Temperature correction factor Kt:
    Corrects temperature rise of PV cell and change in conversion efficiency due to sunlight.
    $Kt = 1 + \alpha (Tm - 25) / 100$
    α: Temperature coefficient at max. output (%／℃)
    Tm: Module temperature (℃) = $Tav + \Delta T$

Tav: Monthly mean temperature (℃)
ΔT: Module's temperature rise (℃) = 18.4 (℃)

* PCS efficiency η_{INV}: AC/DC conversion efficiency of the inverter.

・P_{AS} = PV array output under standard condition (kW)

AM = 1.5*; Irradiance = 1 kW/m^2; PC cell temperature = 25ºC

⑧Study of the PV system configuration

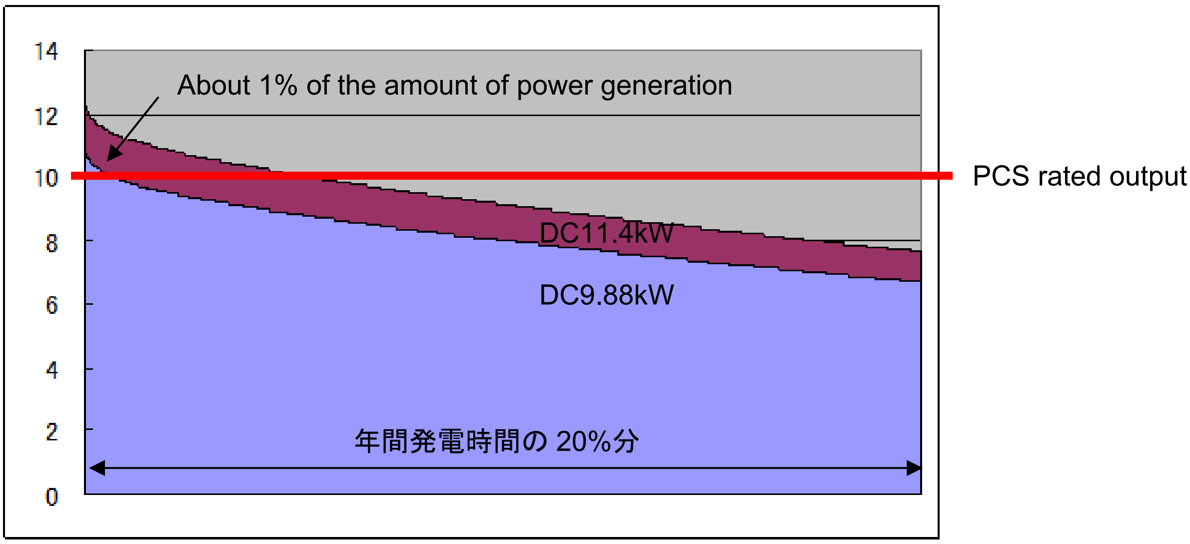
As shown in the figure below, solar power generation reaches 90% or more only a few % of the hours per year. Therefore, the PCS rated output or more power cannot be generated, but to effectively increase the annual power generation output, extra PV modules should be installed such that their output total is approximately 10% of PCS rated output.

＜Example＞

PCS output = PV module output DC9.88kW × DC loss 98% (-2%)
×PCS conversion efficiency 95% ＝ AC9.20kW

PCS output ＝ PV module output DC11.4kW × DC loss 98%（-2%）
×PCS conversion efficiency 95% ＝ AC10.61kW
→PCS rated output, but actually AC10kW

DC9.88kW-AC10kW	DC11.4kW-AC10kW
11,251kWh/year (9.88kW*8760h*0.13)	12,852kWh/ year (11.4kW*8760h*0.13*0.99)



Dilation curve of solar power output（1 second measurement）

Others. In the consideration of the PV system configuration, the specification of each equipment except PV array and PCS is worked out. Also, the number of circuits and the necessary number of units of the junction box and the collection box are worked out. A junction box is selected from four, eight, ten, twelve or sixteen circuits, and calculates the required number of units. A collection box is set per PCS, and calculates required number of circuits. In addition, it is necessary to configure the PV system for connecting to the electric power system in each country. (Installation of the step-up transformer to the system voltage, etc.)

Exercise[The facility planning sheet for Mega Solar]

Mega Solar planned installation site:[Country]   [Area]

① Tilt angle of PV panel ________°

Azimuth __________

Solar irradiation in the above-mentioned tilt angle and azimuth

Month	Solar irradiation per day ($kWh/m^2/day$)	Ambient temperature (℃)
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
Annual		

② Specification of selected PV module

Type	
Nominal Max. Output (P_{max})	
PV module conversion efficiency	
Nominal Max. Output Working Voltage (V_{pm})	
Nominal Max. Output Working Current (I_{pm})	
Nominal Open Circuit Voltage(V_{oc})	
Nominal Short Circuit Current (I_{sc})	
External Dimensions (mm) W×L×D	
Temperature coefficient of short circuit current	
Temperature coefficient of open circuit voltage	
Temperature coefficient of Max. output	

③ Specification of selected PCS

Output capacity		
DC output	Rated voltage	
	DC voltage range	
	Range of MPPT	
	Number of phase	
AC output	Rated voltage	
	Rated frequency	
	Power conversion efficiency	

④ Number of series connection of PV modules ________ in series

PV string open circuit voltage (PV module temperature 25℃) :________ V

(Max. PV module temperature ℃):________ V

(Min. PV module temperature ℃):________ V

PV string output working voltage (PV module temperature 25℃) :________ V

(Max. PV module temperature ℃):________ V

(Min. PV module temperature ℃):________ V

⑤ PV array configuration _____ lines _____ rows（PV module _____ pieces）

_____ in series _____ in parallel

PV array output ________ kW

PV array size (W) ________ m×(L) ________ m (projected area in the horizontal surface)

PV array max. height ________ m

⑥ PV array arrangement ________________

Number of PV array ________ unit

Total output of PV array ________ kW

⑦ Annual energy production

Month	Generated energy (kWh)
January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	
December	
Annual	

⑧ System configuration

- Gernation scale ________ kW（AC）
- Number of arrays ______
- Array output ________ kW（DC）
- Number of PCS ______
- System voltage ________ kV
- Step-up transformer ________ kVA
  Primary voltage/Secondary voltage ________ kV/ ________ V
- Power transformer for substation ________ kVA
  Primary voltage/Secondary voltage ________ kV/ ________ V

Exercise [System planning sheet for mega-solar] (Suggested answer)

Mega solar planned installation site: [Country] Japan [Area] Naha

① Tilt angle of PV panel 18 °

Azimuth South

Solar irradiation in the above-mentioned tilt angle and azimuth

Month	Solar irradiation per day ($kWh/m^2/day$)	Ambient Temperature (℃)
January	2.89	17.4
February	3.13	17.4
March	3.79	19.1
April	4.54	21.7
May	4.99	24.3
June	5.46	26.9
July	6.57	29.1
August	6.22	28.9
September	5.66	27.8
October	4.79	25.5
November	3.70	22.6
December	3.11	19.2
Annual	**4.58**	**17.4**

② Specification of selected PV module

	PV module B
Type	Polycrystalline Silicon
Nominal Max. Output(P_{max})	240W
PV module conversion efficiency	14.6
Nominal Max. Output Working Voltage (V_{pm})	29.8V
Nominal Max. Output Working Current (I_{pm})	8.06A
Nominal Open Circuit Voltage (V_{oc})	36.9V
Nominal Short Circuit Current (I_{sc})	8.59A
External Dimensions (mm) W×L×D	1,662×990×46
Temperature coefficient of short circuit current	+0.060%/K
Temperature coefficient of open circuit voltage	−0.36%/K
Temperature coefficient of Max. output	−0.46%/K

③ Specification of selected power conditioning system

		PCS-A
Output capacity		10kW
DC input	Rated voltage	400V
	DC voltage range	0～600V
	Range of MPPT	200～550V
	Number of phase	三相 3 線
AC output	Rated voltage	202V
	Rated frequency	50 or 60Hz
	Power conversion efficiency	94.5%

④ Number of series connection of PV modules <u>16 in series</u>

PV string open circuit voltage(PV module temperature 25℃) : <u>475.52 V</u>

(Max. PV module temperature 54.0℃) : <u>427.25 V</u>

(Min. PV module temperature 25.0℃) : <u>475.52 V</u>

PV string output working voltage (PV module temperature 25℃) : <u>388.80 V</u>

(Max. PV module temperature 54.0℃) : <u>349.34 V</u>

(Min. PV module temperature 25.0℃) : <u>388.80 V</u>

（Calculation）

1) Calculation of the number of series connection of the PV module from the rated voltage of a power conditioning system and the nominal maximum output voltage of a PV module.

Rated voltage of power conditioning system: 400V, Nominal max. output voltage of PV module: 29.3V

400V× 1.1 = 440V 440V / 29.3V≒15.02≒<u>16 in series</u>

2) Calculation of maximum and minimum PV module temperature

Maximum temperature in Naha: 35.6℃, Minimum temperature in Naha: 6.6℃

Max. PV module temperature = 35.6 + 18.4 = <u>54.0℃</u>

Min. PV module temperature = 6.6 + 18.4 = <u>25.0℃</u>

3) Calculation of the PV string open circuit voltage at the highest and the lowest PV module temperature

Temperature coefficient of the PV module open circuit voltage: -0.36% / ℃

PV string open circuit voltage at PV module temperature of 25℃

36.9V × 16 = <u>590.4V</u>

PV string open circuit voltage at the maximum PV module temperature (54.0℃)

590.4V × {1 - 0.0036× (54.0 - 25)} ≒ <u>528.76V</u>

PV string open circuit voltage at the minimum PV module temperature (25.0℃)

590.4V× {1 - 0.0036× (25.0 - 25)} = <u>590.40V</u>

4) Calculation of PV string output working voltage at the maximum and the minimum PV module temperature

Temperature coefficient of PV module output working voltage: -0.36% / ℃ (Same as the temperature coefficient of open circuit voltage)

PV string output working voltage at PV module temperature of 25℃

29.3V × 16 = <u>468.8V</u>

PV string output working voltage at the maximum PV module temperature (54.0℃)

468.8V× {1 - 0.0036 × (54.0 - 25)} = 349.336 ≒ <u>419.86V</u>

PV string output working voltage at the minimum PV module temperature (25.0℃)

468.8V × {1 - 0.0036 × (25.0 - 25)} = <u>468.80V</u>

(Check on DC voltage range and MPPT range)

DC voltage range

The PV string open circuit voltage operates in the range of 528.76 to 590.40V to the DC voltage range of a power conditioning system at 0 to 600V. Hence, there is no problem.

MPPT range

The PV string output working voltage operates in the range of 419.86V to 468.80V to the maximum power point tracking range of a power conditioning system in 200V to 550V. Hence, there is no problem.

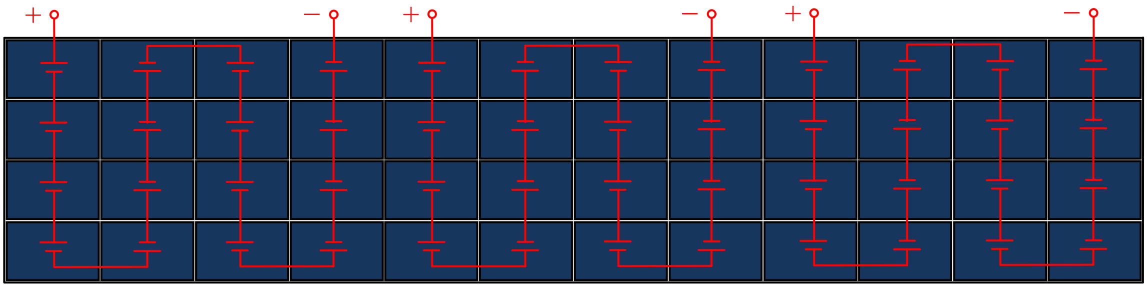
⑤PV array configuration 4 lines 12 rows (PV modules: 48 pieces)
16 in series 3 in parallel

PV array output 11.52 kW

PV array size (W) 20.594 m × (L) 4.004 m (projection of horizontal surface)

The maximum height of PV array 1.801 m

Wiring diagram of the PV array



（Calculation）

1) Calculation of the maximum number of lines and rows of the PV array

The maximum number of lines of the PV array: a

The maximum height of PV array: 2.0m and below from GL (The bottom of the PV panel is 0.5m from GL), Tilt angle of the PV panel: 18°

Depth of PV module: 990mm

(2.0m - 0.5m) = 1.5m

1.5m ≧ X × sin18° ⇒ 4.854m ≧ X

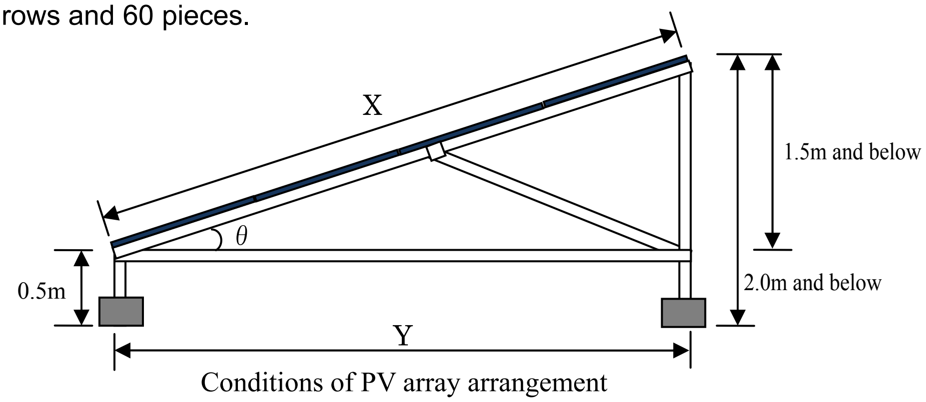
4.854 / 0.99 ≒ 4.9 a = 4 lines

The maximum number of rows of the PV array: b

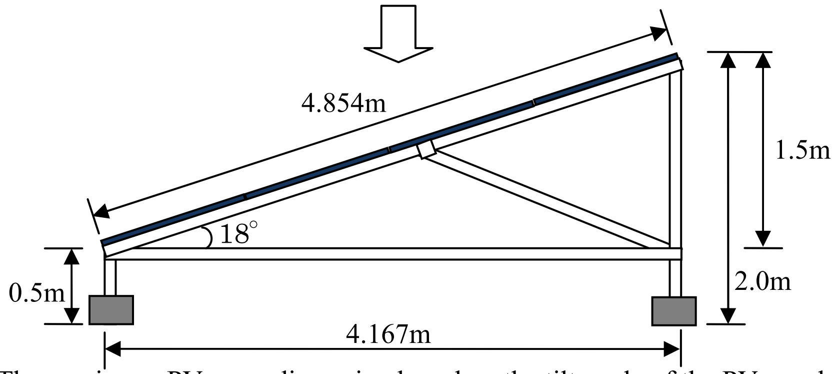
The maximum width of PV array: 25m and below, width of the PV module: 1,662mm

25 / 1.662 ≒ 15.1 b = 15 rows

The maximum number of the PV module piece only on the conditions of PV array arrangement is 4 lines, 15 rows and 60 pieces.



Conditions of PV array arrangement



The maximum PV array dimension based on the tilt angle of the PV panel

2) Calculation of the maximum number of parallel connection and the number of the PV module pieces from the number of series connection of the PV module

The maximum number of PV module piece only on the conditions of PV array arrangement: 60 pieces

The number of series connection of the PV module: 16 in series

60 / 16≒3.75　　<u>3 in parallel</u>

16 in series × 3 in parallel = <u>48 pieces</u>

3) Calculation of the PV array output from the number of PV module pieces

Nominal maximum output of the PV module: 240W

240W × 48 = 11,520W　⇒　<u>11.52kW</u>

4) Calculation of the number of PV array rows from the number of PV module pieces

The number of PV module piece: 48 pieces, the maximum number of lines of PV array a: 4 lines

48 / 4 = 12　　<u>12 rows</u>

5) Calculation of the PV array size from the number of lines and rows of the PV array

Dimension of the PV panel

Depth of the PV module: 990mm, The space between PV modules and the edge of the PV modules: 50mm

(0.99 × 4) + {0.05 × (4 + 1)} = 4.21m

The maximum height of the PV array

Tilt angle of the PV panel: 18°Height of the bottom of the PV panel: 0.5m from GL

(4.21m × sin18°) + 0.5m = <u>1.801m</u>

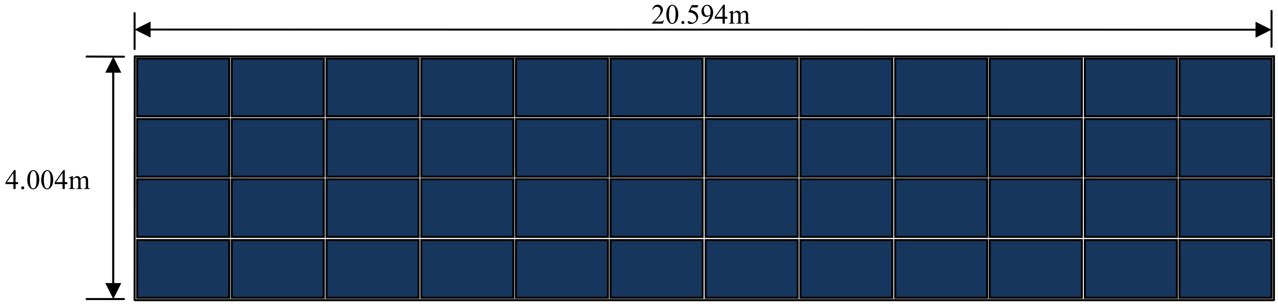
Length of the PV array　L (projection of horizontal surface)

4.21m × cos18°= <u>4.004m</u>

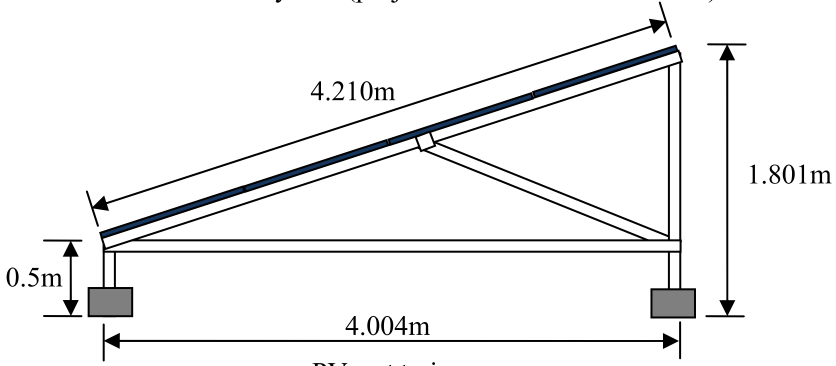
Width of the PV array　　W

Width of the PV module: 1,662mm

(1,662× 12) + {0.05 × (12 + 1)} = <u>20.594m</u>



PV array size (projection of horizontal surface)



PV array size

⑥PV array arrangement

Number of PV array 100 units

Total output of PV array 1,152 kW

(Calculation)

1) Calculation of the total output of the PV arrays

11.52kW × 100 = 1,152kW

2) Calculation of the shadow scale factor of north and south direction

The latitude and the longitude in Naha: North latitude 26.1312, East longitude 127.4048

Solar altitude h: 19.35° Azimuth: 50.11°

*The data is at 9am on the winter solstice (21st of December 2012), the azimuth is directly south at 0°

Scale factor of the shadow R

$R = L_S / L = \coth \times \cos \alpha = \cot(19.35°) \times \cos(50.11°) = 1.826$

(The length "Ls" of the shadow of north and south direction cast by the object of height "L".)

3) Calculation of the distance of PV arrays facing to the north-south

The maximum height of PV array: 1.801m

(1.801- 0.5) ×1.826 ≒ 2.375 m

4) PV array arrangement and total area

Install according to the location. Consider with SketchUp.

⑦ Annual Energy Production

Month	Generated energy (kWh)
January	80,025
February	78,283
March	104,033
April	118,981
May	133,295
June	139,198
July	171,031
August	162,096
September	143,598
October	127,138
November	96,510
December	85,323
Annual	**1,439,509**

*Annual energy production is the sum total of monthly expected energy production.

Annual power generation projections can be made using HOMER （https://users.homerenergy.com/） or RETScreen（http://www.retscreen.net/）.

The calculation method is as shown below.

(Calculation)

1) Calculation of expected monthly energy production [January](kWh / Month)

Average daily irradiation on monthly basis H_A: 2.89kWh/m^2/day, Irradiance under standard condition Gs: 1kW/m^2

PCS conversion efficiency η_{INV}: 94.5%, DC correction factor Kd: 0.9, Temperature coefficient at max. outputα: -0.46 % / K

Monthly mean temperature Tav: 17.4℃, Weighted average PV module temperature rise⊿T: 18.4℃

Module temperature Tm

Tm = Tav + ⊿T = 17.4 + 18.4 = 35.8℃

Temperature correction factor Kt

Kt = 1 + α (Tm-25) / 100 = 1 - 0.46 (35.8－25) / 100 = 0.95032

Total design factor K

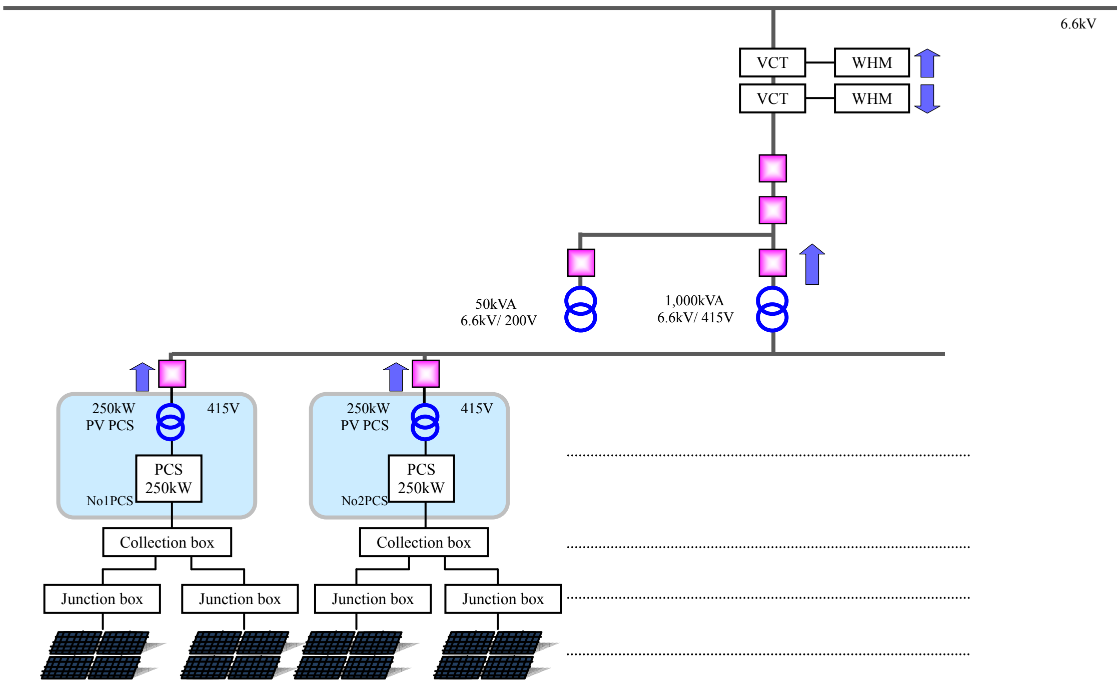
K = Kd × Kt × η_{INV} = 0.9 × 0.95032 × 0.945 = 0.808247

Expected monthly energy production Ep

Ep = ΣH_A / Gs × K × P_{AS} = 31 × 2.89 / 1 × 0.808247 × 1,152 ≒ 83,417kWh

⑧ System configuration

- Generation scale 1,000 kW（AC）
- Number of arrays 100
- Array output 1,152 kW（DC）
- Number of PCS 100
- System voltage 6.6 kV
- Step-up transformer 1,000 kVA
  Primary voltage / Secondary voltage 6.6 kV/ 415 V
- Power transformer for substation 50 kVA
  Primary voltage / Secondary voltage 6.6 kV/ 200 V



Republic of Seychelles Project
for formulation of Master Plan for Development of Micro Grid

Facility Planning Method (Skethup)

Text

Table of Contents

Chapter 1 Preparation

1. Download and installation of SketchUp

Access the following URL. **http://www.sketchup.com/intl/ja/index.html**

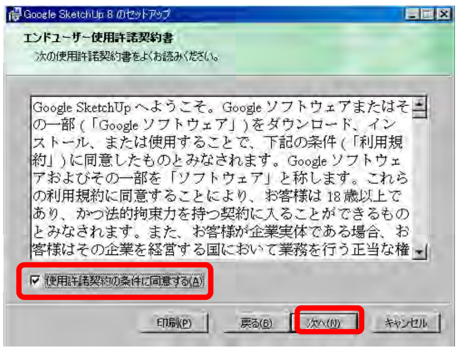
Click the download button and open the link.

Download "SketchUp8."

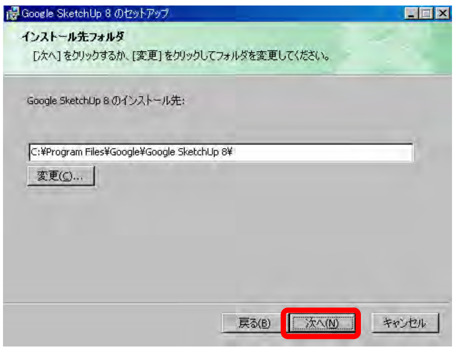
Click "Accept and download."

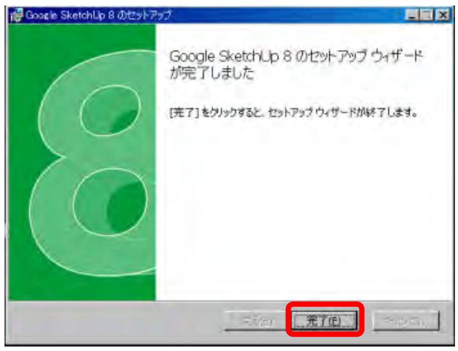
Double-click the downloaded file and install.

Click "I agree to the terms of the license agreement."



Proceed according to the instructions to complete the installation.

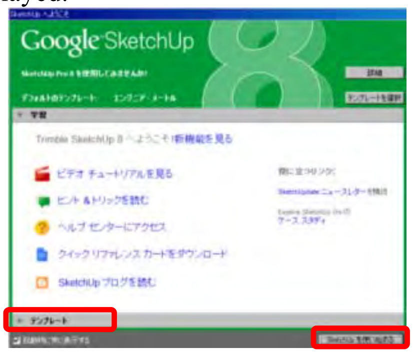




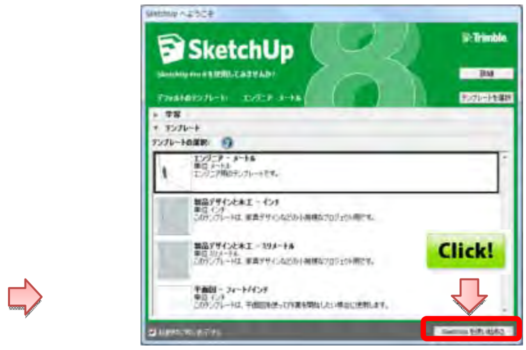
2. Launch and end

Double-click the icon to start [SketchUp].

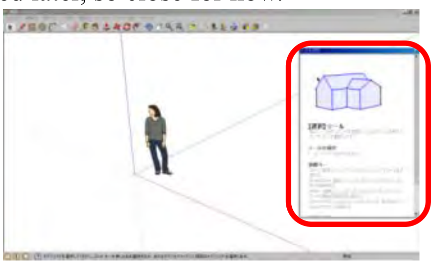
Usage instructions and the template selection screen are displayed.



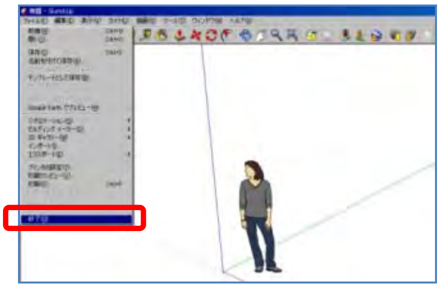
Select template per metric unit.



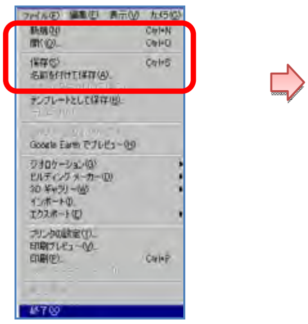
The template screen is displayed.
The "instructor" who explains how to operate can be displayed later, so close for now.



To end SketchUp
Select [File] -> [Exit].



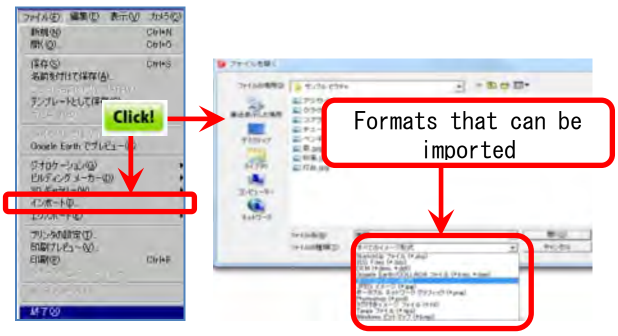
3. Loading and saving file

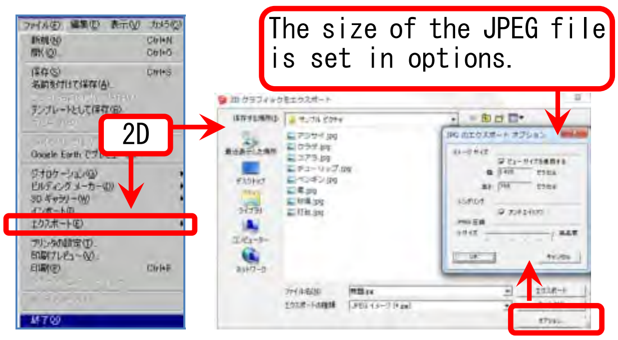


[File] menu

New	Create new file.
Open	Open an existing file
Save	Overwrite and save file
Save as	Save the new file

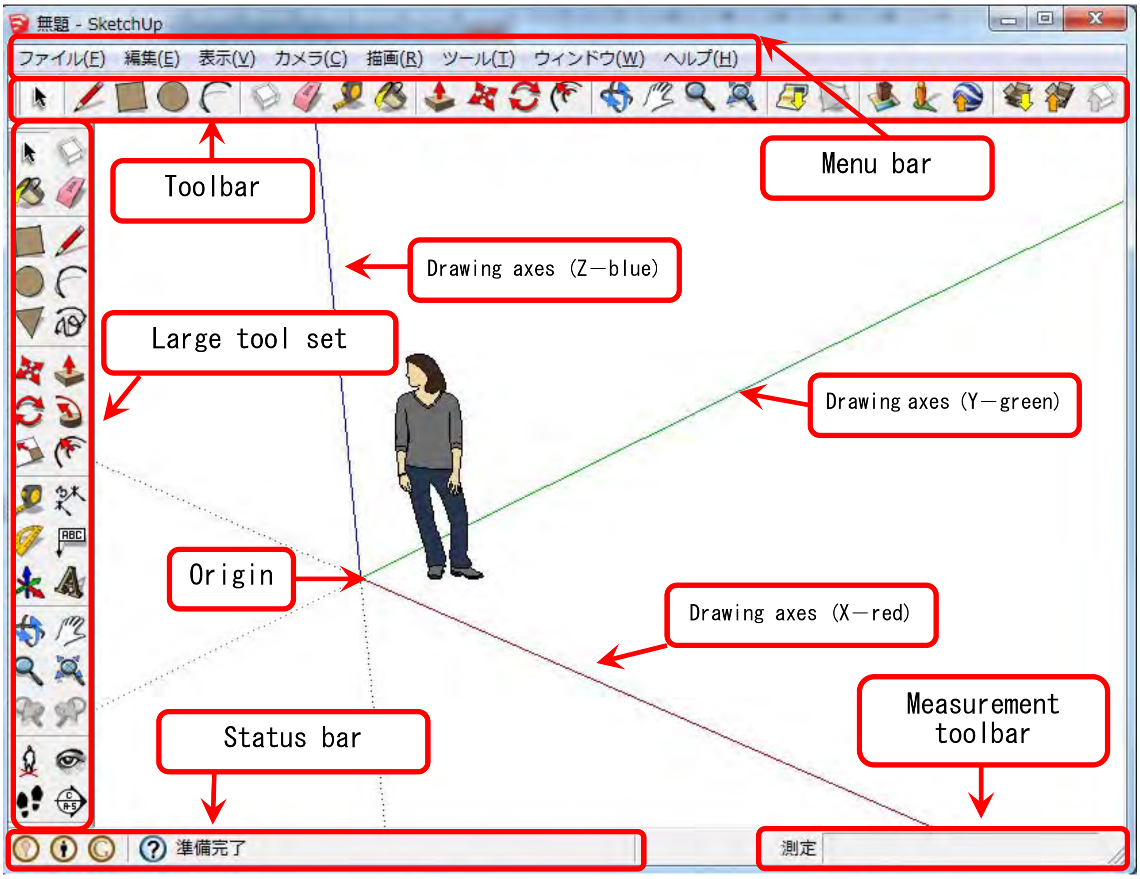
1-4. Import and export file





Chapter 2 Operation screen (interface) and tools

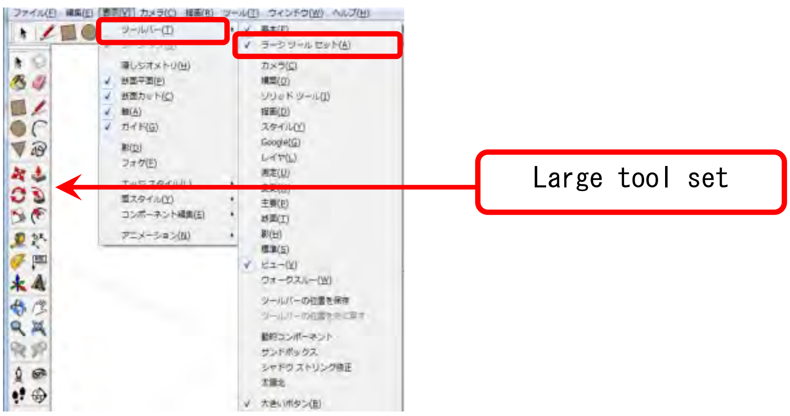
1. Names of the parts of the operation screen



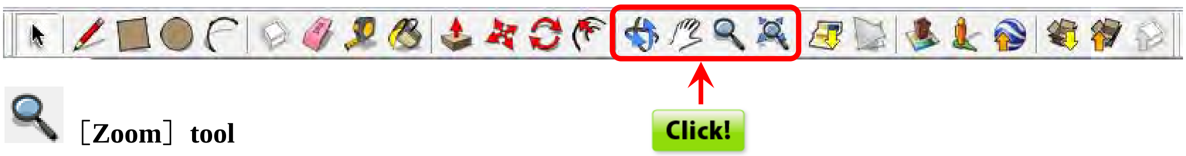
- **Menu bar** : Tools from the menu bar can be selected.
- **Toolbars** : Select a tool and operate.
- **Status bar** : Description of the operation is displayed.
  (The key is to effectively use the status bar at the bottom of the screen)
- **Measurement toolbar** : Value of the dimension is displayed.
  (The values for length and angles can be input to draw accurate shapes)

2. Display of the toolbar

The required tools can be displayed on screen with the [Toolbar] from the [View] menu.



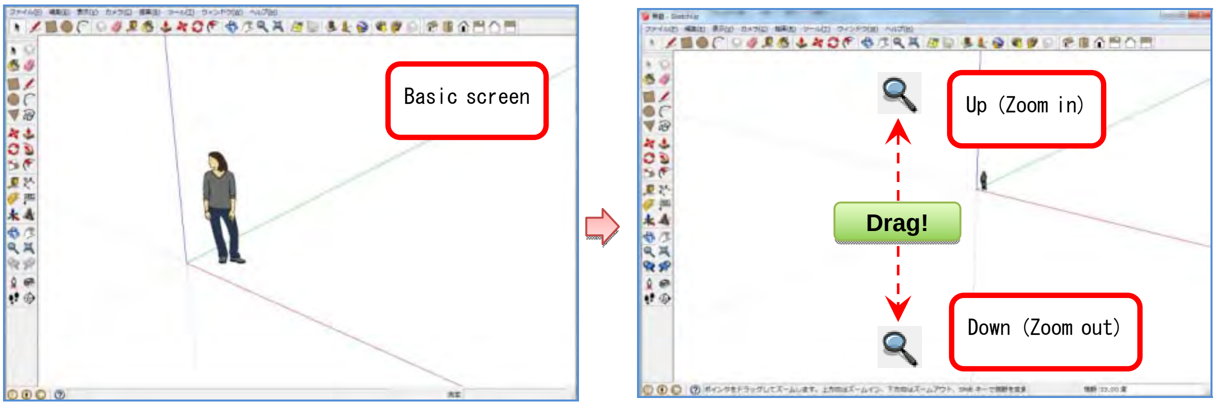
3. Screen operation



［Zoom］ tool

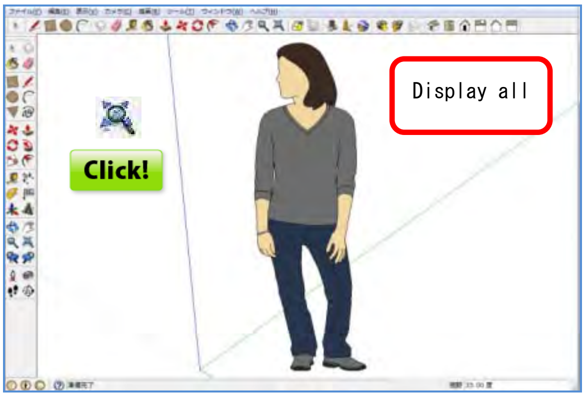
Can zoom in / out by dragging the screen up or down.

* This can also be done by using the scoll wheel.



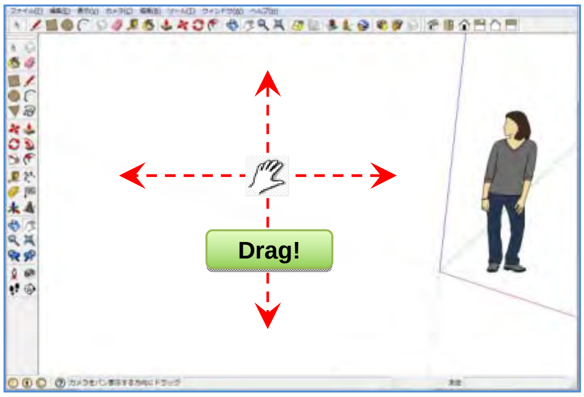
［Display all］ tool

Full screen display of the object.



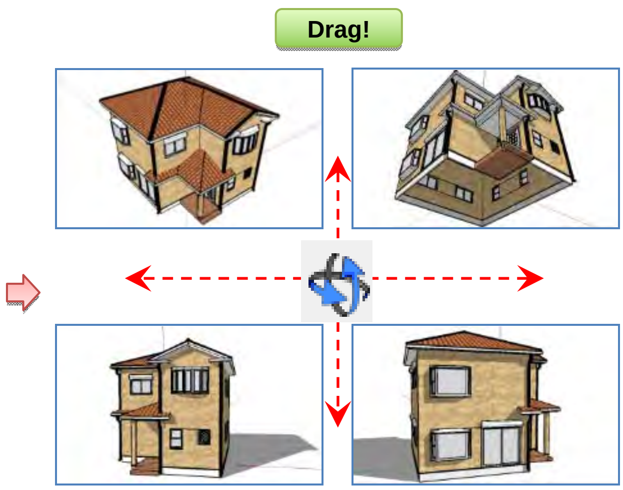
[Pan］ tool

Move the screen perpendicularly and parallel.



［Orbit］ tool

Change the angle of the screen.

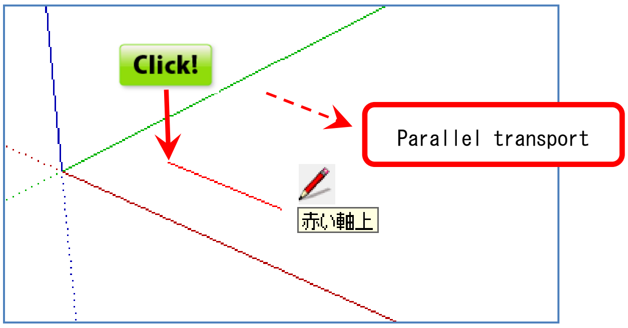


Chapter 3 Basic operations

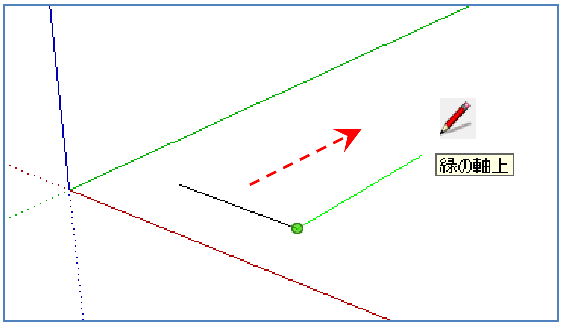
1. Draw a line

 **［Line］ tool**

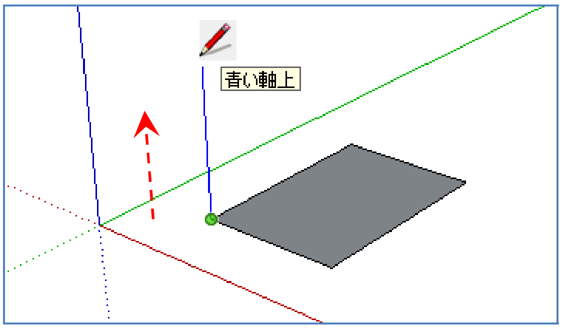
Draw lines parallel to each axis, and the color changes (red, green, blue).
Along the red axis (x-axis), the line is red.



Along the green axis (y-axis), the line is green.
 * Plane: Red (x-axis), green (y-axis)

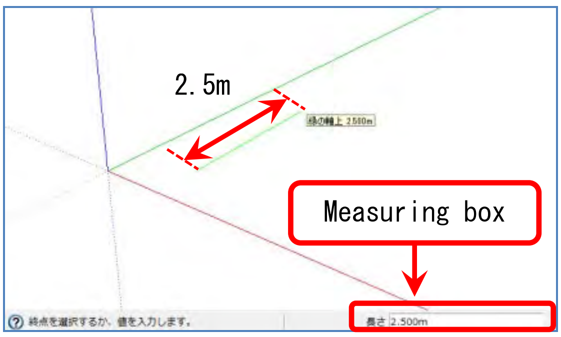


Along the blue axis (z-axis), the line is blue.
 * Height: Blue (z-axis)



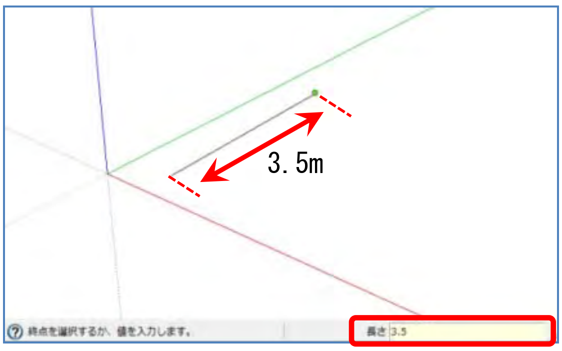
The values for length and angles can be input into the measuring box to draw accurate shapes.

Enter a length.   Press [**2.5**] + [**Enter**] key.



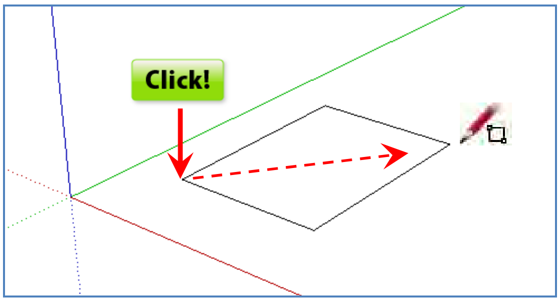
> Press the [Esc] key during an operation to cancel it, and the operation can be redone.

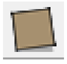
Even after finalizing, the size can be changed if it is done before the next operation.



> To restore the original for errors after finalizing,
> Undo [Ctrl] + [Z]

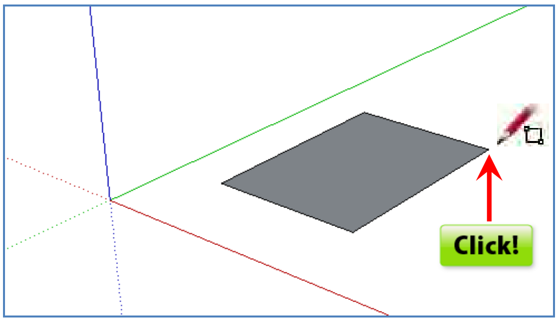
2. Create a rectangle and circle



［**Rectangle**］ **tool**

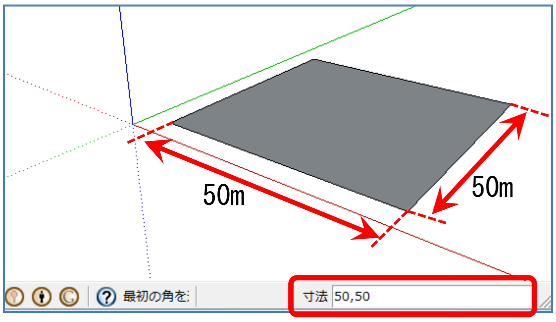
Click anywhere and move in a diagonal direction.

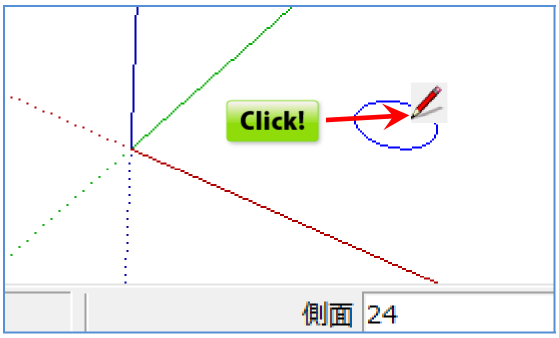
Clicking after moving the mouse creates a rectangle.



Enter the dimensions.

Press [**50,50**] + [**Enter**] key.

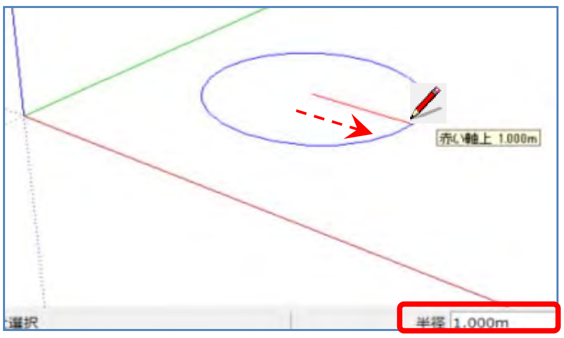




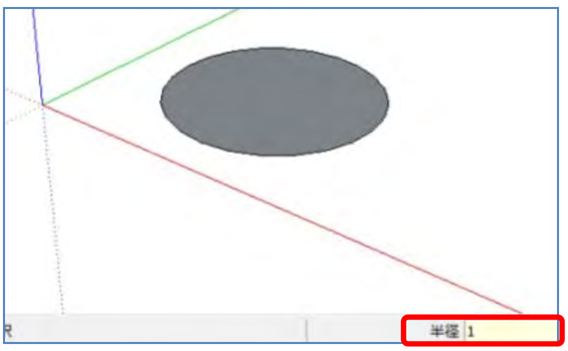
［**Circle**］ **tool**

Click the point where you want to center the circle.

Move the cursor to specify the RADIUS and press the [**Enter**] key.



Create a circle with a radius of 1m.

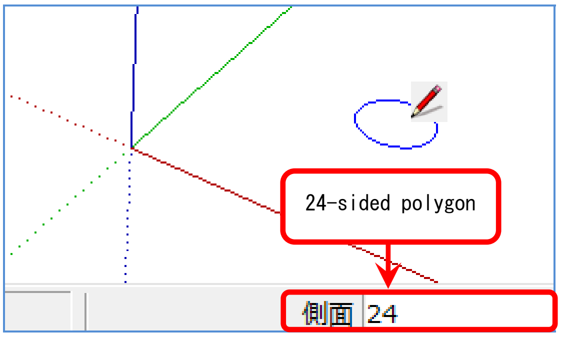


● **Specify the number of segments (number of lines).**

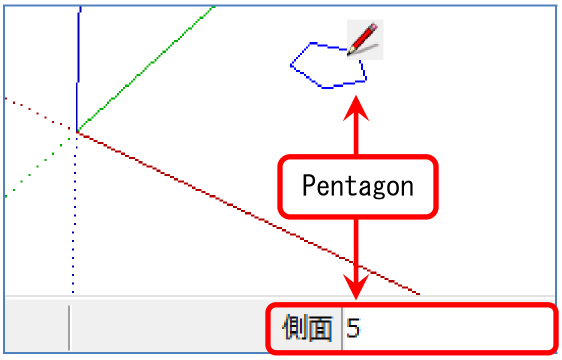
When the circle tool is selected, [**24**] is displayed in the value control box.

This means to draw a circle in the form of a 24-sided polygon, but the value can be changed.

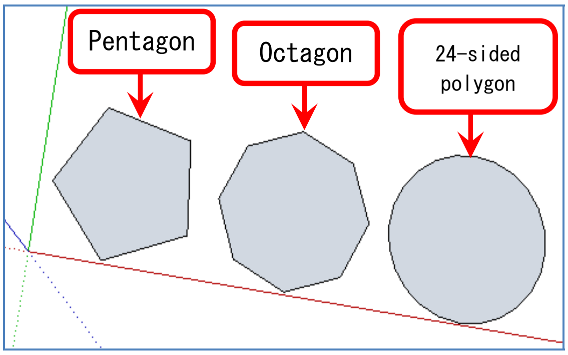
* Number of segments: 24 (default setting)



Press [**5**] + [**Enter**]
for a pentagon.

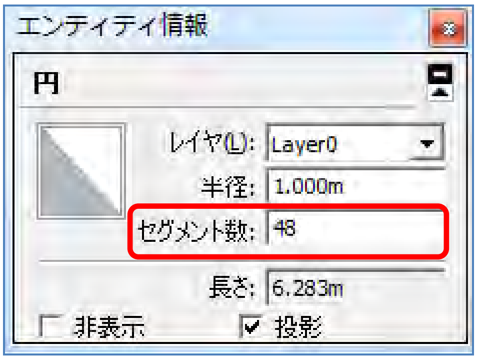


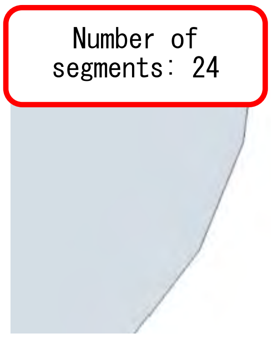
Polygons can be created.

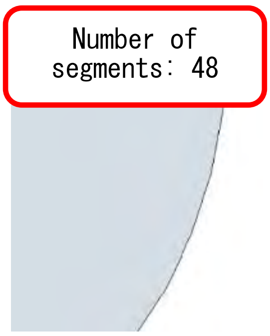


● **Specify the number of segments (number of lines).**
Right-click the circumference with the [Select] tool and select [Entity information].

Change the number of segments and press the [**Enter**] key.

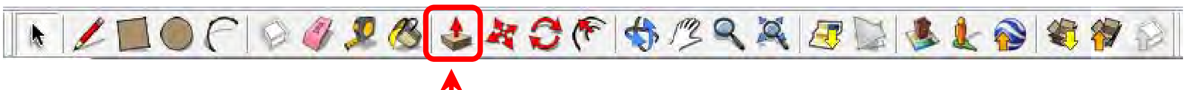






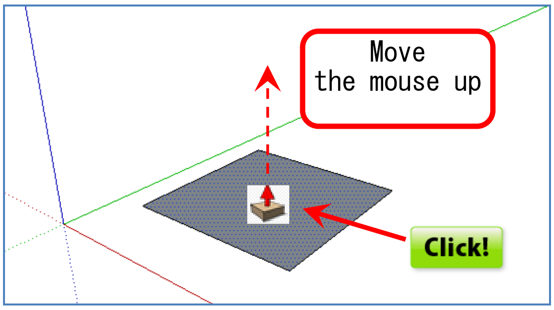
The number segments can be increased for a smoother circle, but the file size becomes larger causing operations to become slower.

3. Create a cube

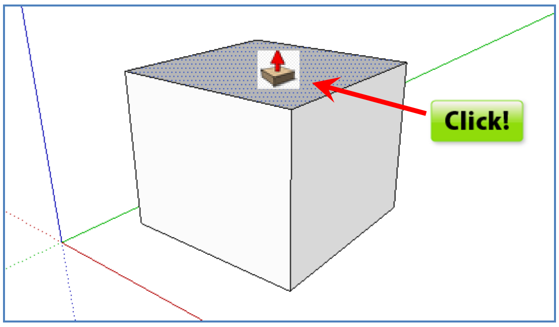


［**Push/pull**］ **tool**

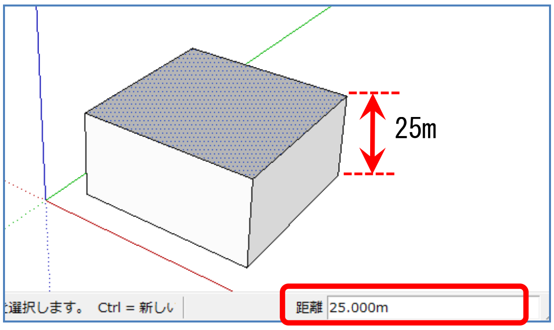
Click a side of the rectangle created.
Move the pointer to make the rectangle three-dimensional.



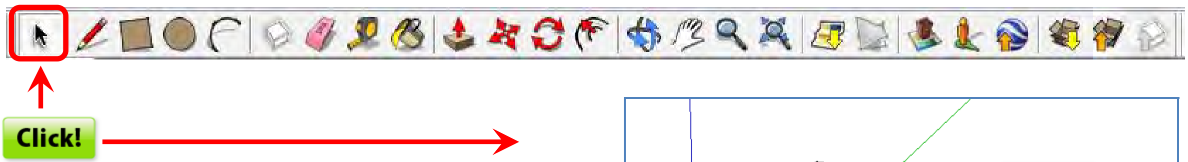
Click on the size you want.



Specify and enter the value. Press [**25**] + [**Enter**] key.

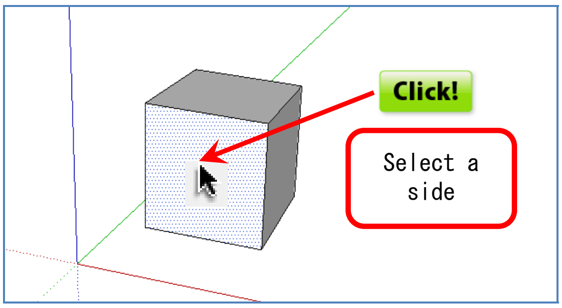


4. Selecting a shape

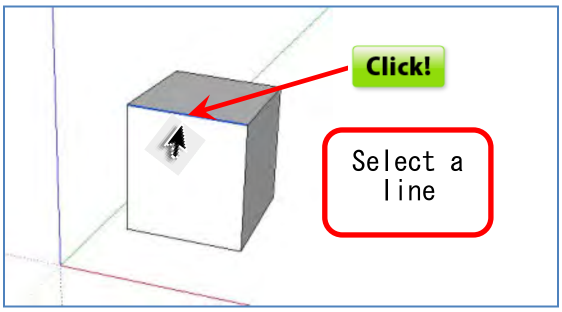


［**Select**］ **tool**

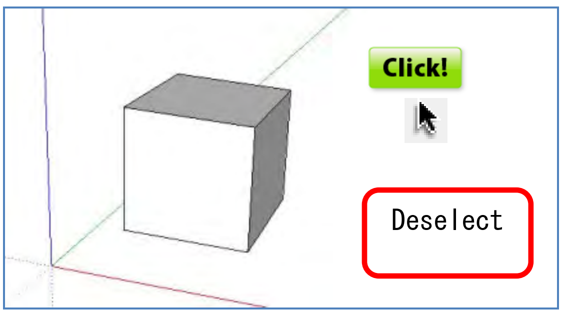
Click the [**side**] you want to select to change it to the selected state.



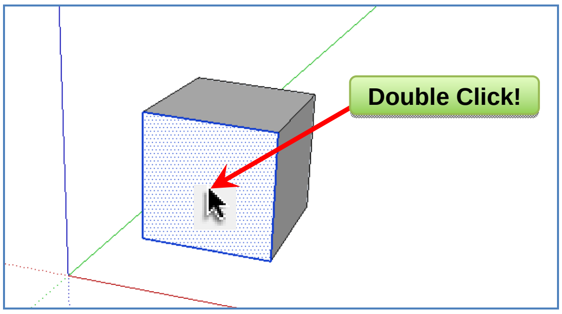
When a [**line**] is selected, it becomes a bold blue line.



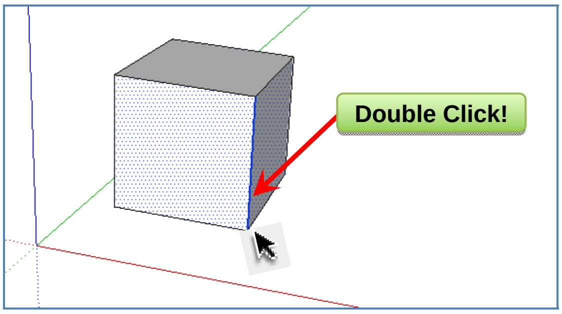
To deselect, click an area outside the shape.



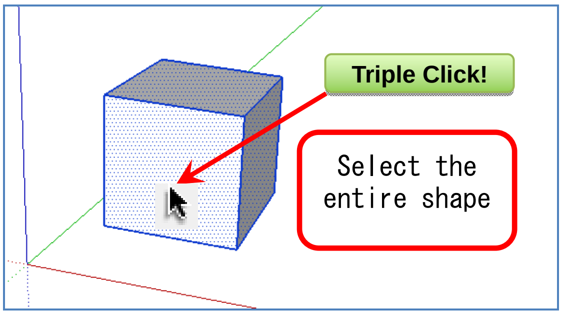
Double-click the [side]
The side and the surrounding lines are selected simultaneously.



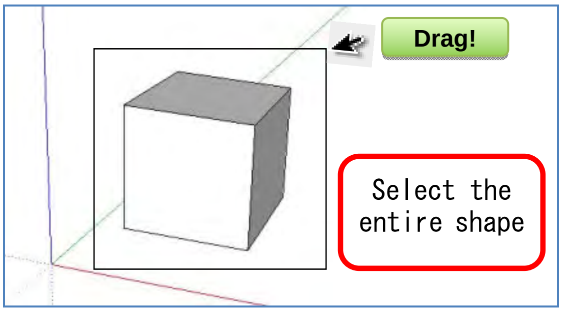
Double-click the [**line**]
The line and the sides adjacent to it are selected simultaneously.



Triple click a [**line**] or [**side**]. The entire shape including its lines and sides are selected.



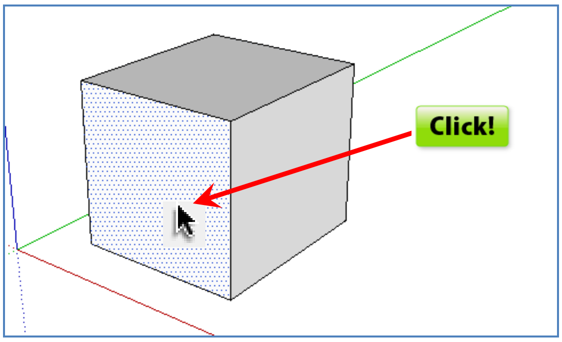
Drag the [**Select]** tool to select the entire shape.
Or, select the entire shape by pressing **Ctrl** + **A**.



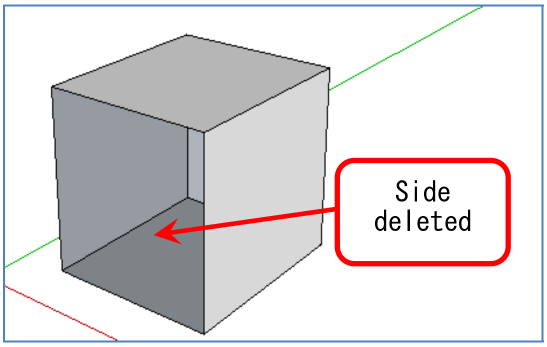
To select all of the shapes in the drawing area press Ctrl + A

● **Delete a line or side.**

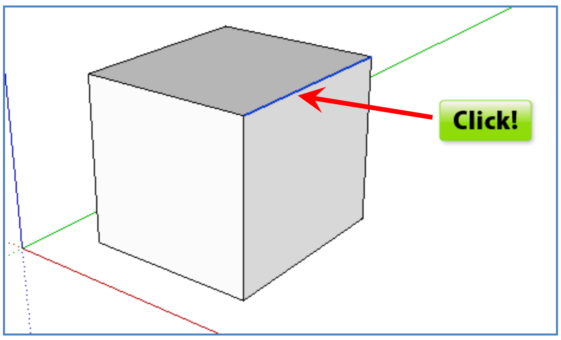
Select the side and press [**Delete**].



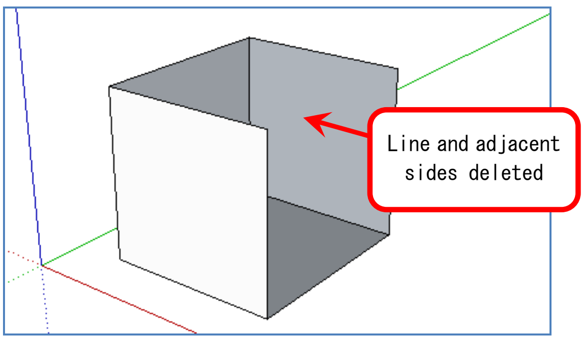
The side is deleted.



Select the line and press [**Delete**].



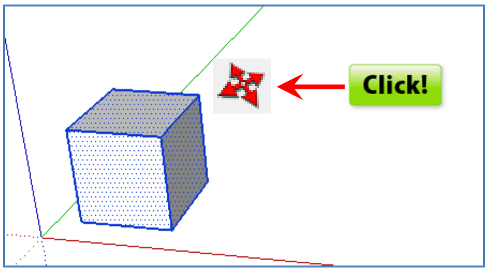
The line and adjacent sides are deleted.



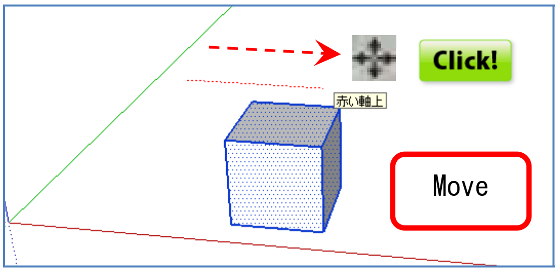
5. Move and copy

［Move］ tool

Select the entire shape and click any location with the [Move] tool.

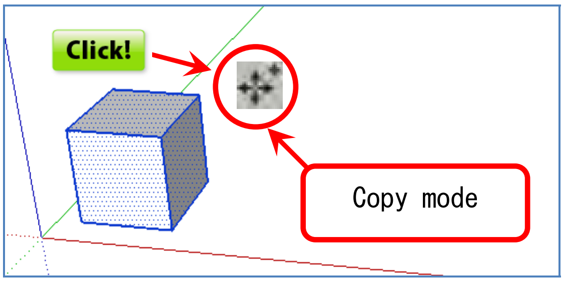


Move the cursor from the point clicked. The shape is moved the same distance.

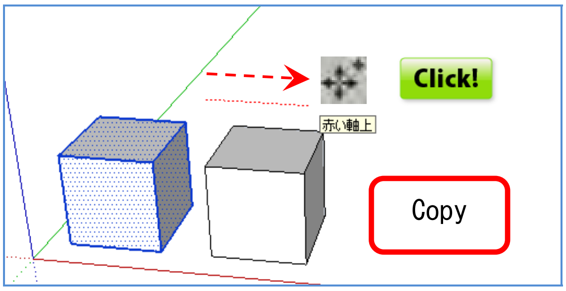


● **Copy the shape.**

Press the **CTRL** key and a [+] mark is displayed above and to the right of the cursor and changes to copy mode.

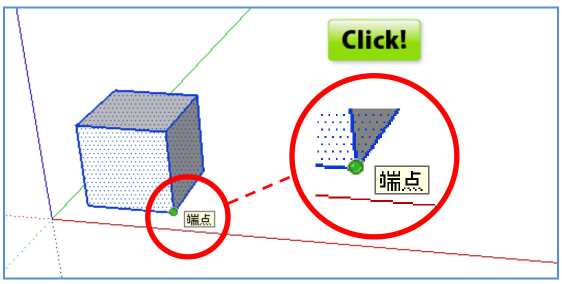


Move the cursor
Click to copy.

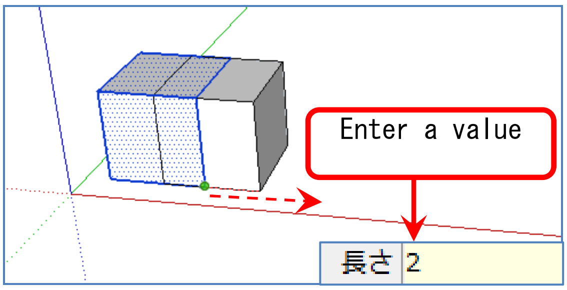


● **Create multiple copies at equal intervals.**

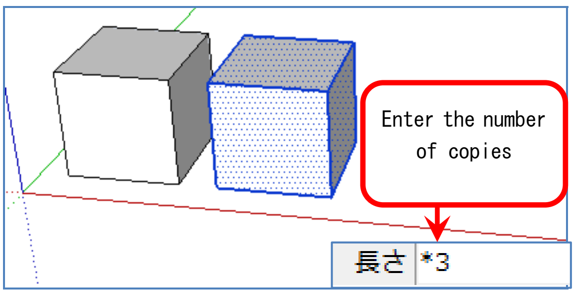
Select the entire shape and click an [end point].



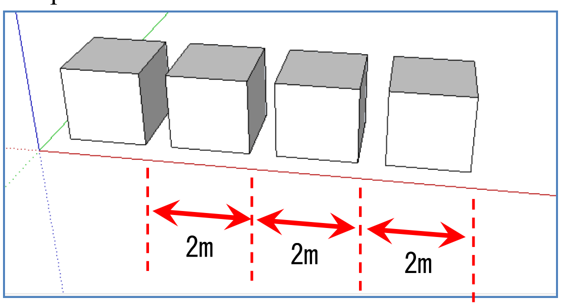
Specify and copy the value. [2] + [**Enter**]



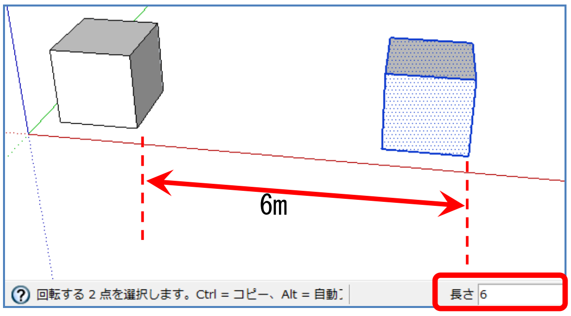
In the selected state
Press [*3] + [**Enter**].



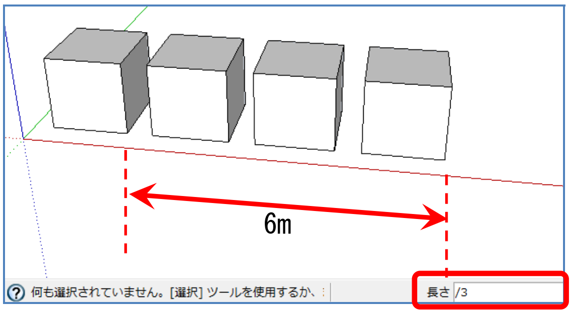
3 copies created at 2m intervals.



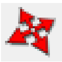
● **Create multiple copies placed equidistantly.**
One copy 6m away. [**6**] + [**Enter**]



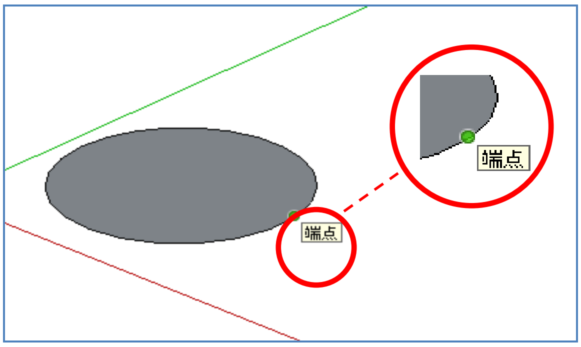
In the selected state, press [/**3**] + [**Enter**].
3 copies created within a 6m range.



● **Change the size of the circle.**

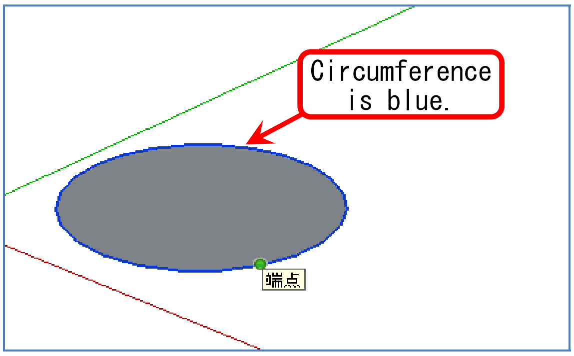
 Select the [Move] tool.

Click an [end point].

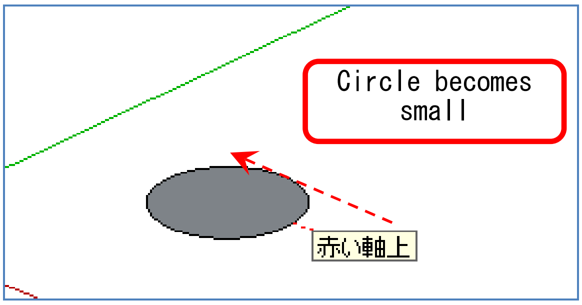


With an [end point] where the circumference has changed to the selected color (blue), the entire circle moves, and its size cannot be changed.

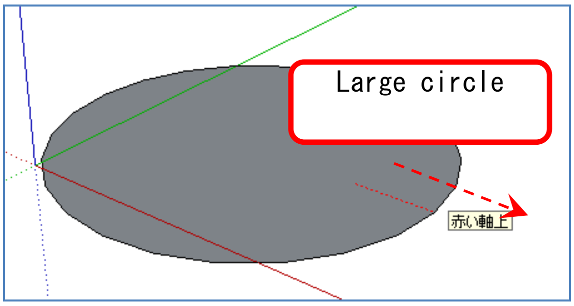
* Will result in move.



Move the cursor to the inside of the circle, and it becomes small.



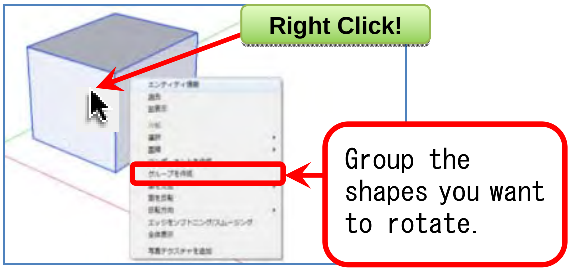
Move the cursor to the outside of the circle, and it becomes large.



6. Rotate

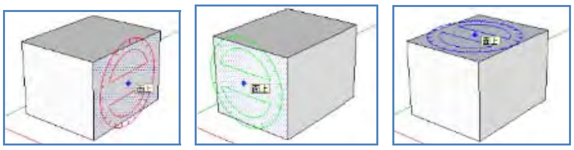
［Rotate］ tool

Select the entire shape, click the [Select] tool, Right click the drawing to group.

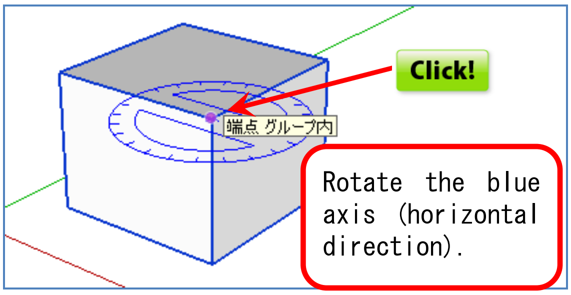


Select the [Rotate] tool, and a protractor mark appears.

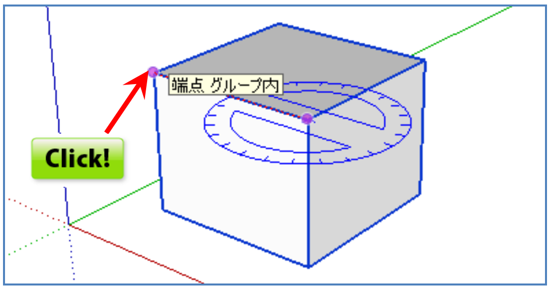
The color of the protractor changes according to the axis of rotation (red, green, blue).



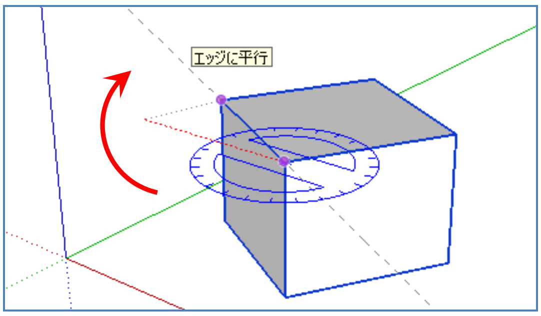
Click a corner. (It becomes the axis of rotation.)



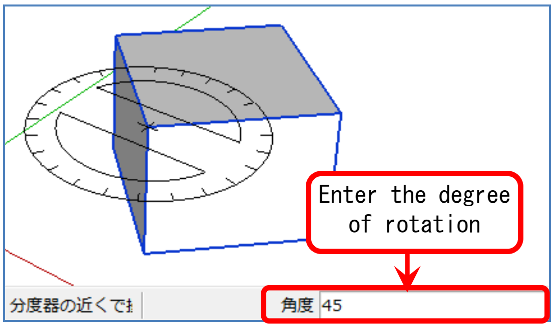
Click another corner. (It becomes the starting point of rotation.)



Rotate.

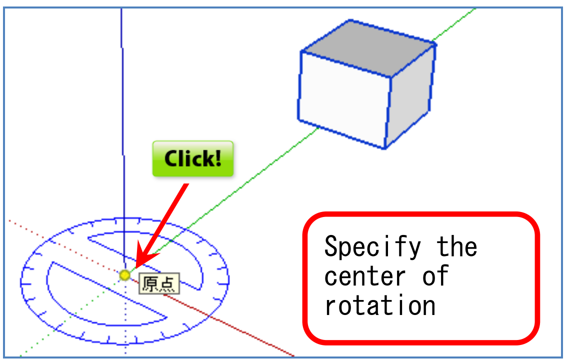


Specify the degree of rotation. [**45**] + [**Enter**]

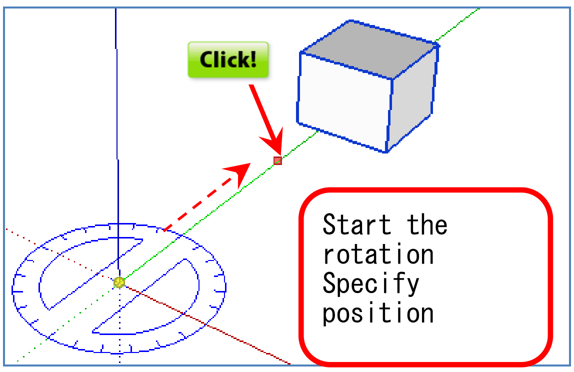


- **Copy rotation.**

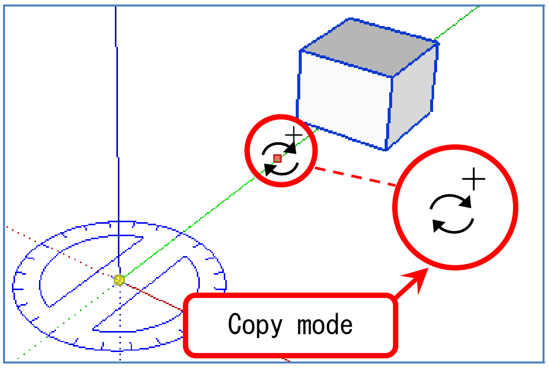
Click the center of the rotation.



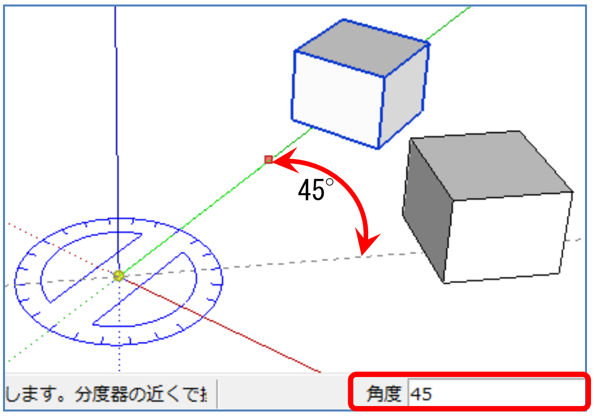
Move the cursor
and click the point to start rotation.



Press **CTRL** when executing with the [Rotate] tool, and a [+] is displayed above and to the right of the cursor and changes to copy mode.

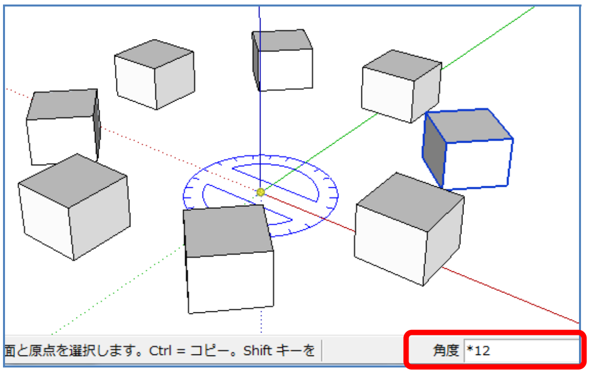


When entering [45] for the degree of rotation, a 45° rotation is copied. [**45**] + [**Enter**]



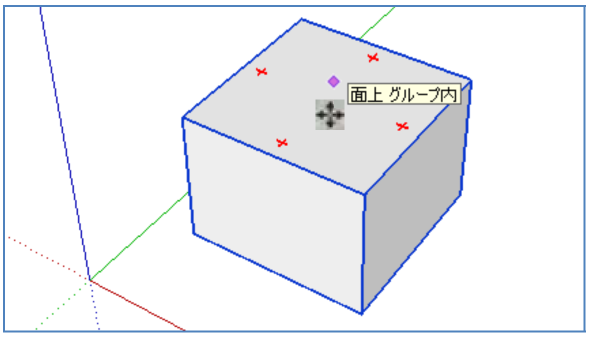
Subsequently, press [***12**]＋[**Enter**].

12 copies of the shape rotated 45° each are created.



● **Rotate with the [Move] tool.**

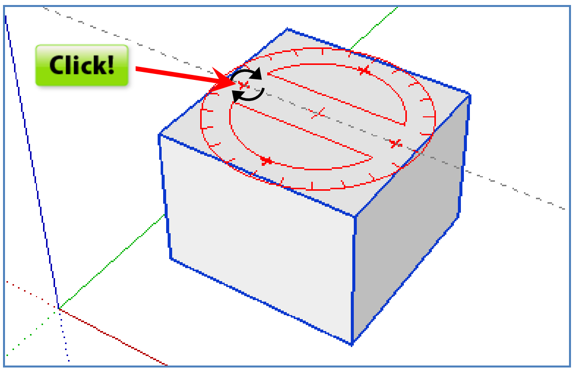
Group the shapes in advance.



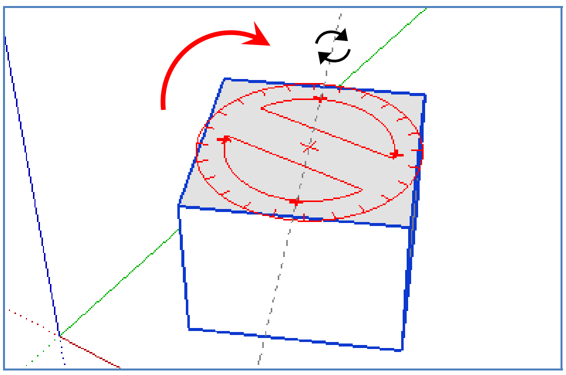
 Select the [Move] tool.

When you move the cursor to the surface you want to rotate, 4 [＋] marks are displayed.

When you move the cursor to a [＋] mark, a protractor is displayed. Click the [＋].

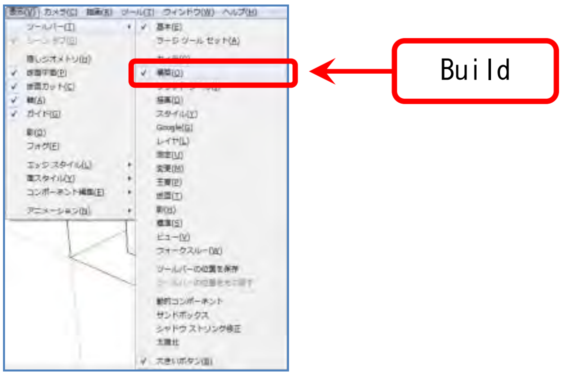


Move the cursor or enter the degree of rotation, and press [**Enter**].

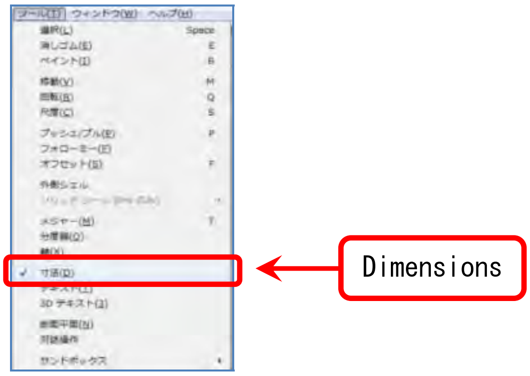


7. Enter dimensions and characters

Select the [Build] tool from the [View] menu.

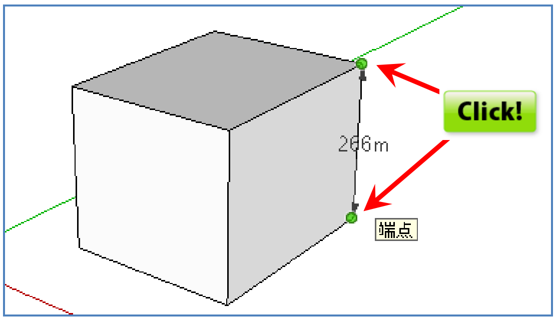


Or select [Dimensions] tool from the [Tools] menu.

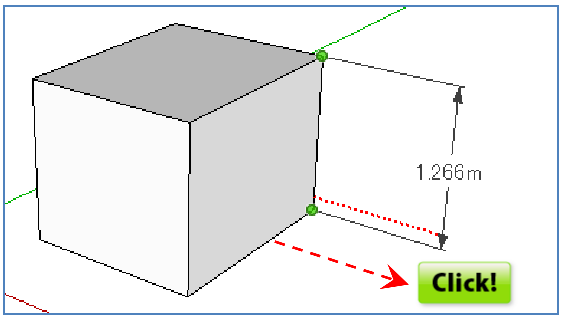


［Dimensions］ tool

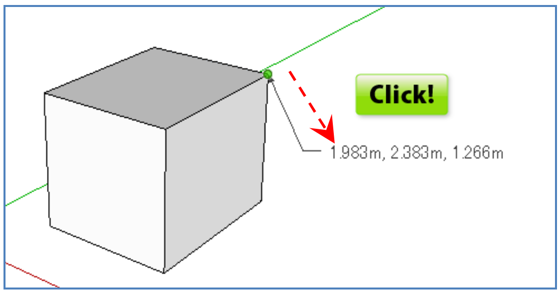
Select the [Dimensions] tool, and click two points.



Move the cursor and the dimensions are displayed.



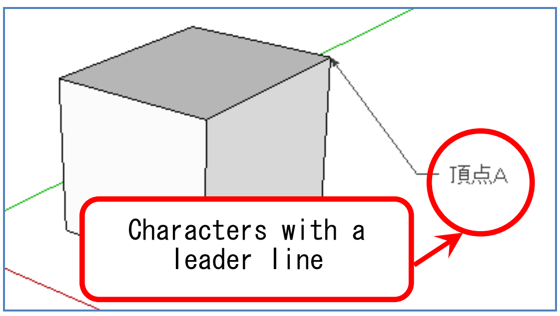
Click the vertex and move the cursor, and the coordinate values are temporarily displayed.



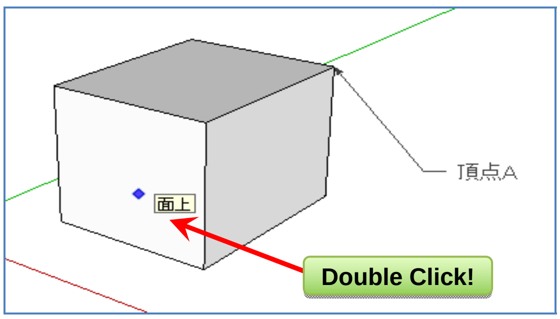
● **Enter characters.**

 **[Text] tool**

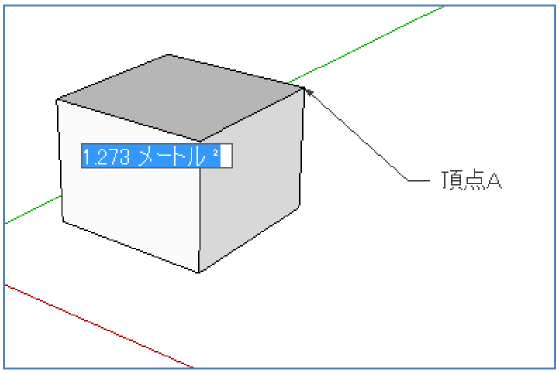
Enter the characters in the part where the coordinates are displayed.



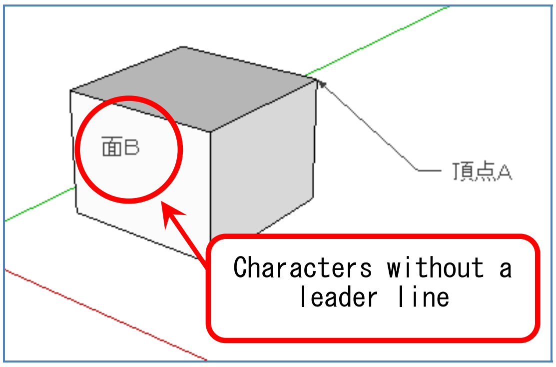
Double-click a side



The area is temporarily displayed, changes to a character input state.

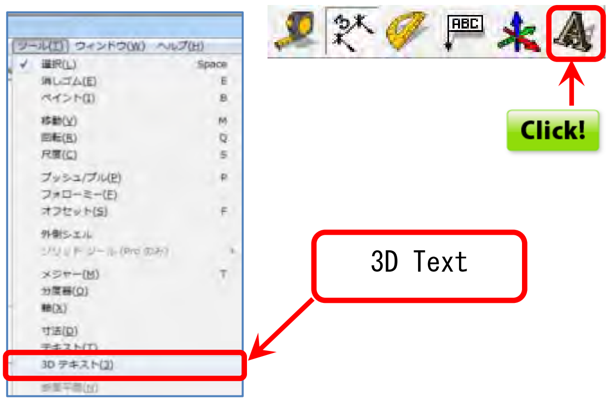


Characters without a leader line can be entered



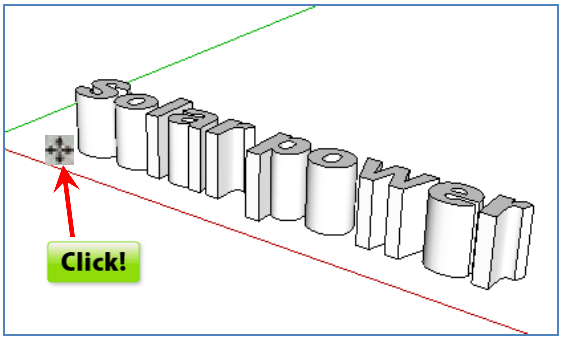
● **Create a three-dimensional character.**

Select [3D Text] from the [Tools] menu.

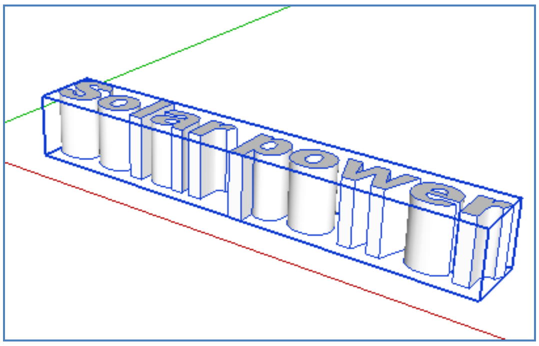


Enter the characters and click the [Align] button.

Click on any location.



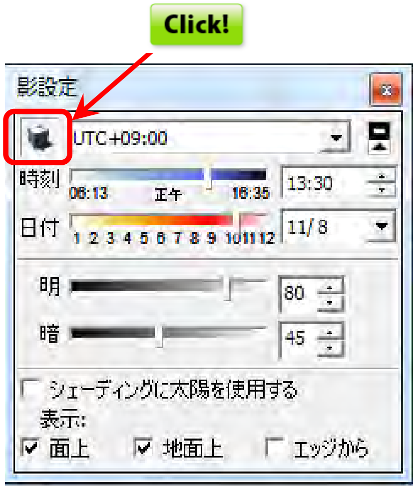
The 3D text is created.



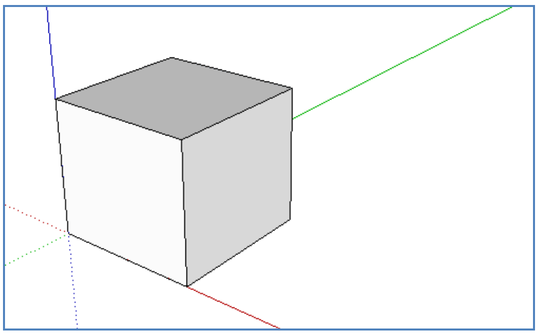
8. Shadow settings

From the [Windows] menu select the [Shadow] tool.

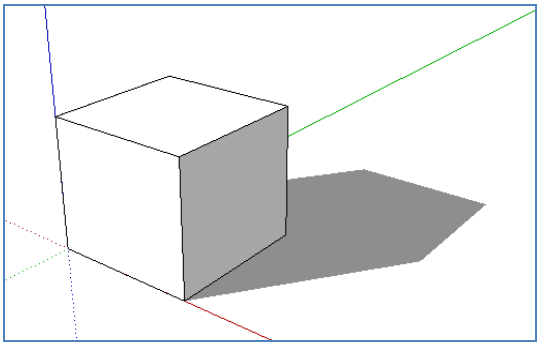
Click the [Show/hide shadow] button at the top left of the [Shadow settings] dialog box displayed.



Click the [Show/hide shadow] button, and the shadow disappears.

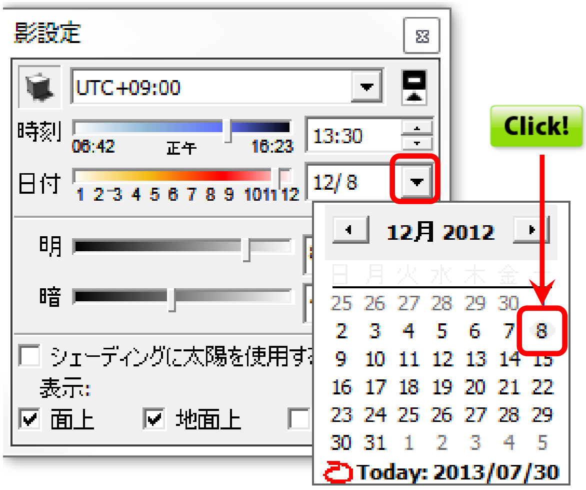


Shadows are displayed.

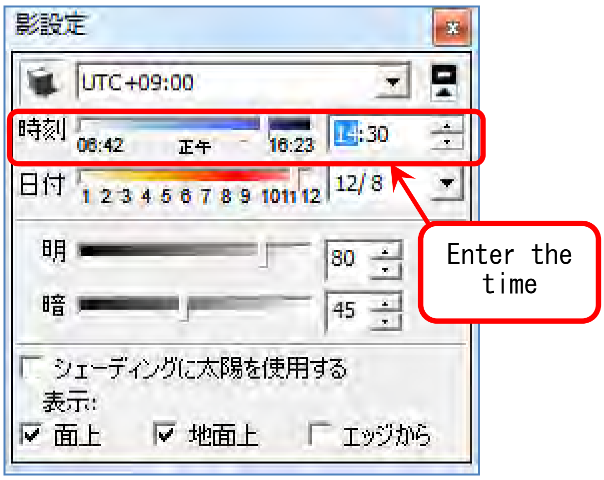


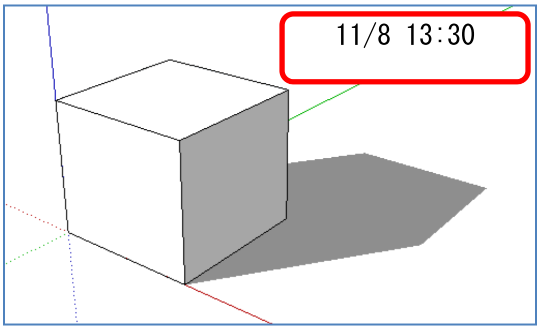
● Change the time and date.

Click the [▼] button on the far right of the [Date] slider to change the date.

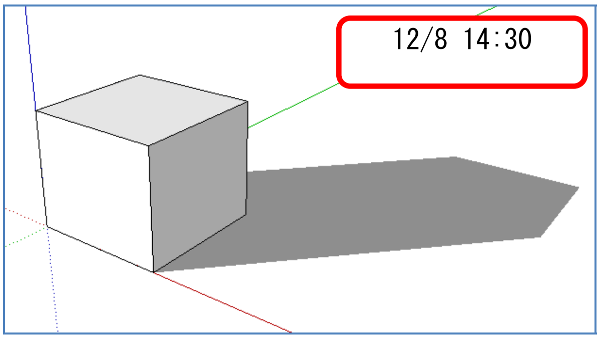


On the [Time] slider, move the slide bar or enter a value to change the time.





The shadow changes according to the time set; the shadow extends.



Chapter 4 PV array layout plan

1. PV module creation

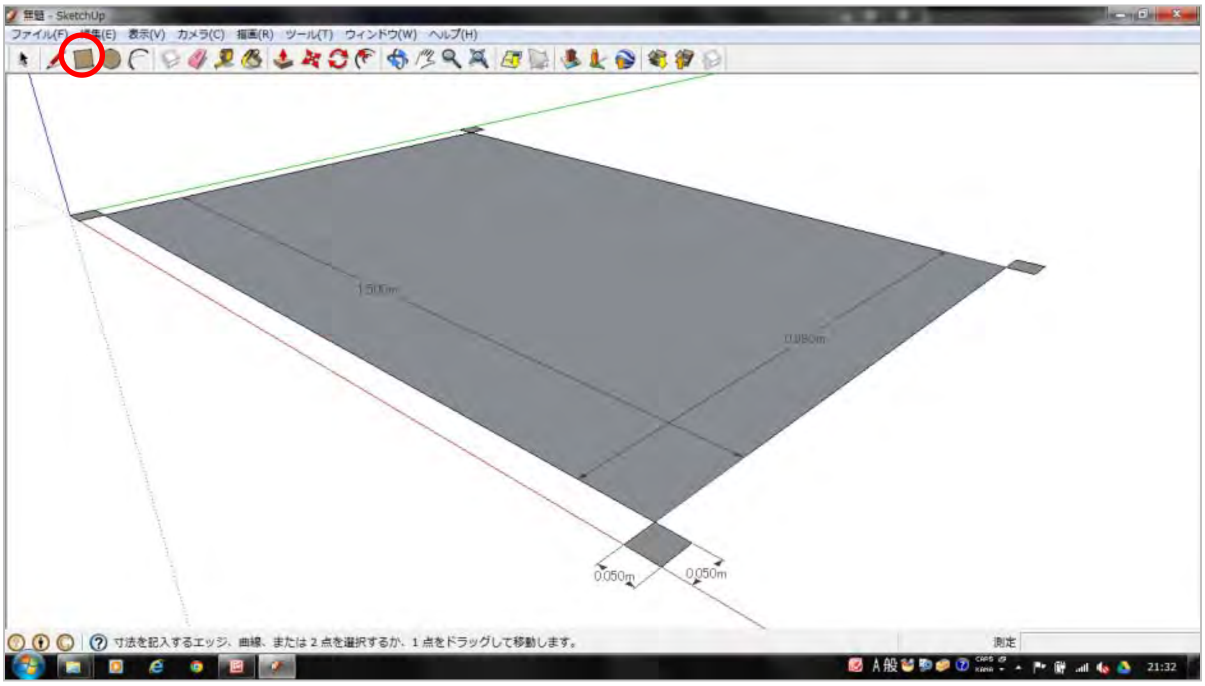
Create a 3D PV module.

Here, the dimensions of the PV module are as provided in the sample module.

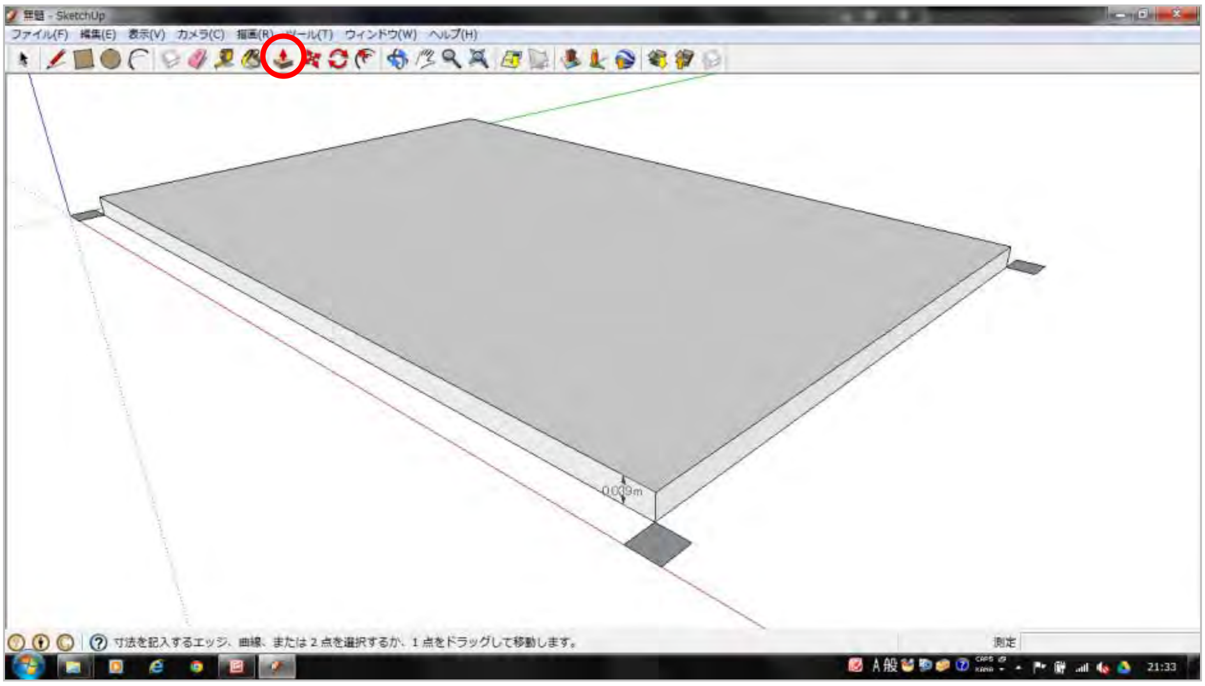
Sample module dimensions: 1,500mm x 990mm x 36mm

Module spacing: 50mm

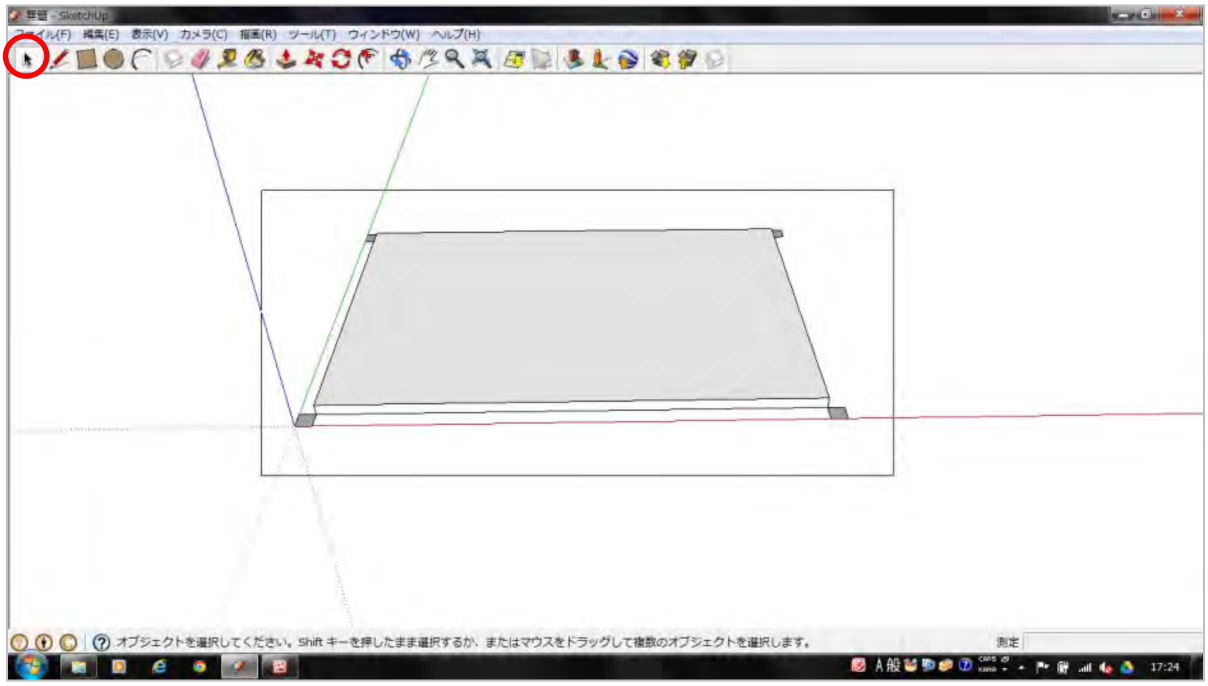
Draw a 0.05m x 0.05m and 1.5m x 0.99m rectangle on the x-y plane as shown below.



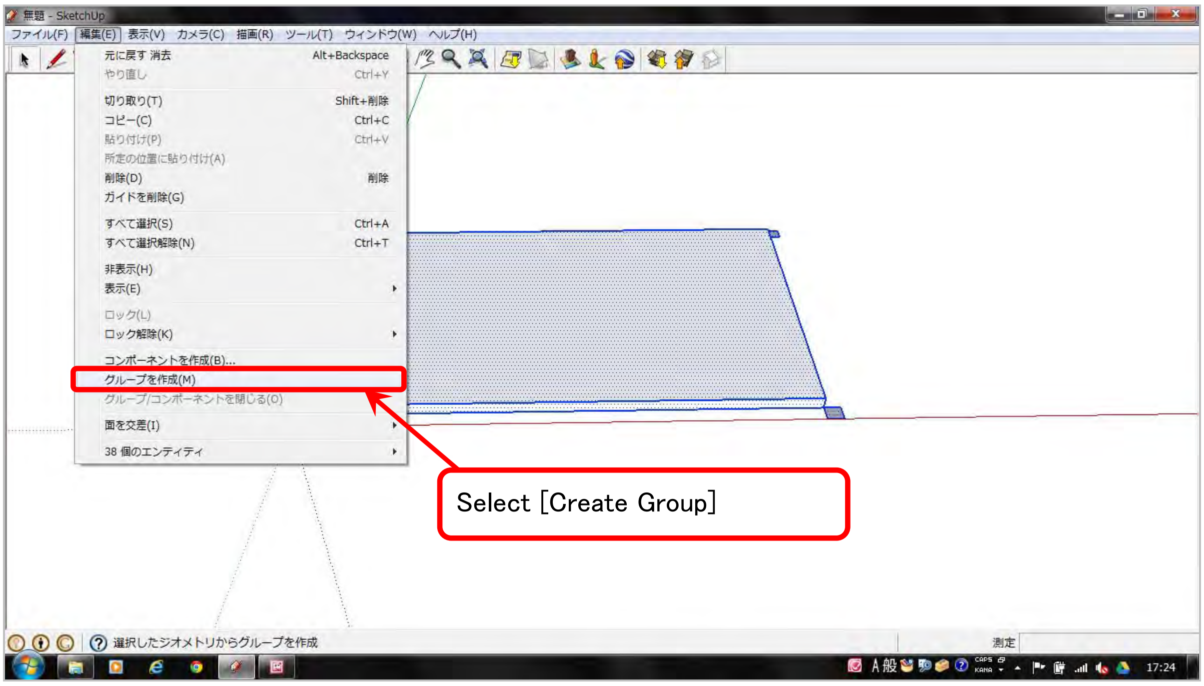
With the [Push/Pull] tool, raise only the module portion 0.039m to make it 3D.



Specify the entire range.



From the [Edit] menu, select [Create Group] and group as a PV module.



The PV module is completed.

The 0.05m x 0.05m squares at the corners serve as a guide for module spacing.

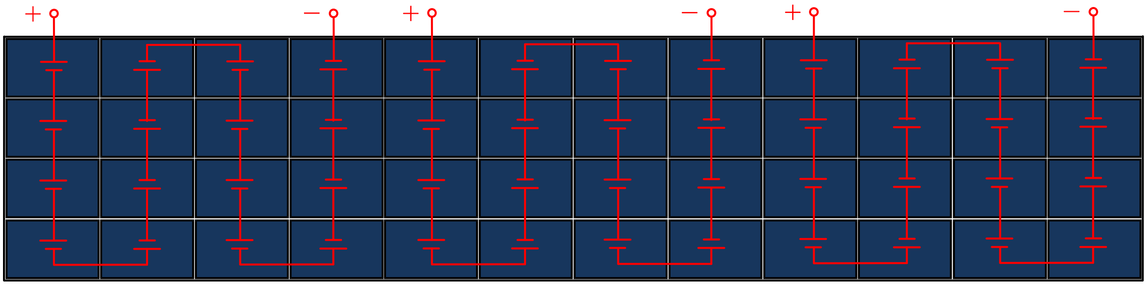
We continue without deleting these for now, but if they become an impediment in the finishing process, they may be deleted.

2. Create PV array

Create a 3D PV array.

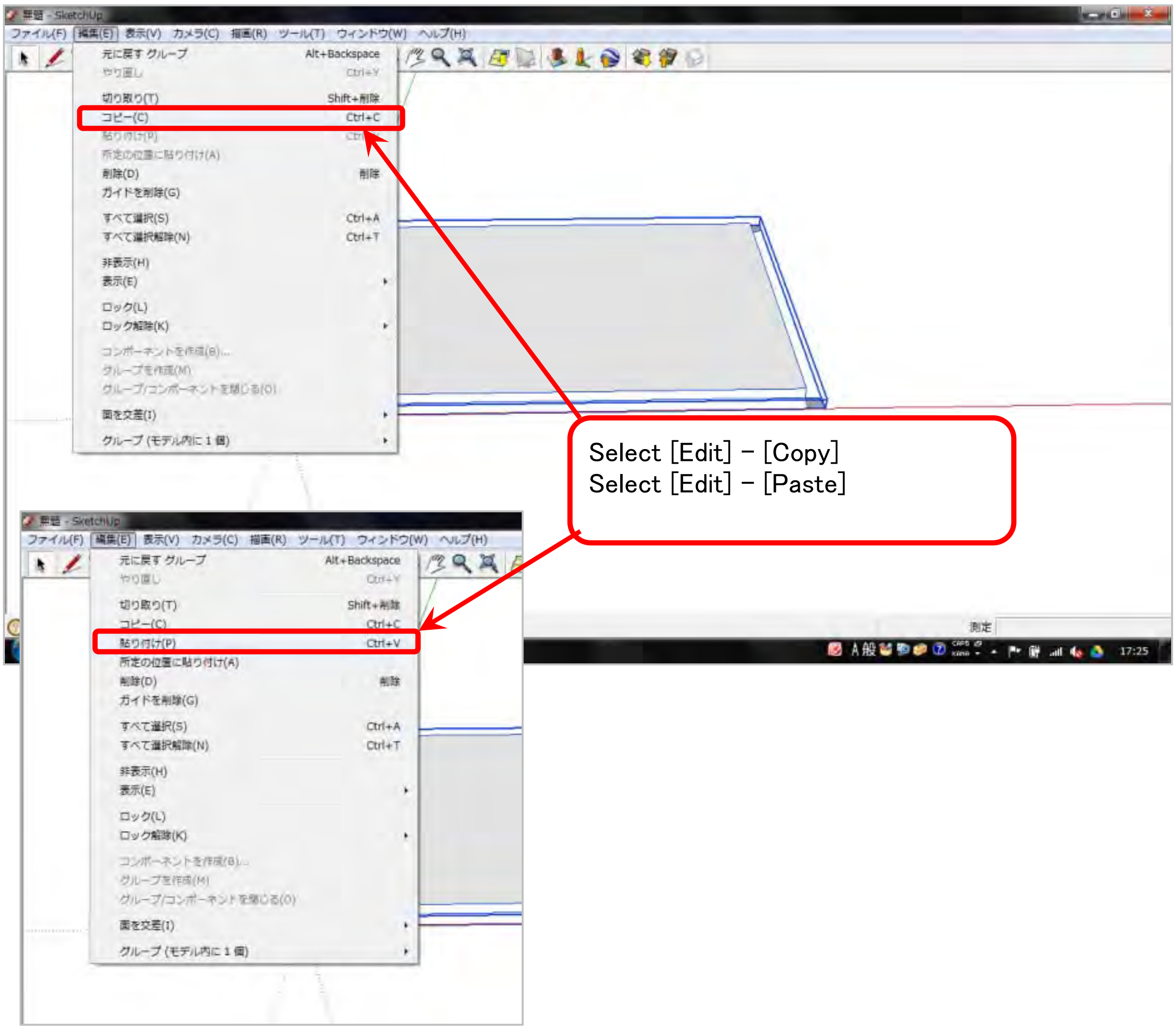
Here, the PV array is arranged as in the sample array.

Sample array 12 columns 4 rows

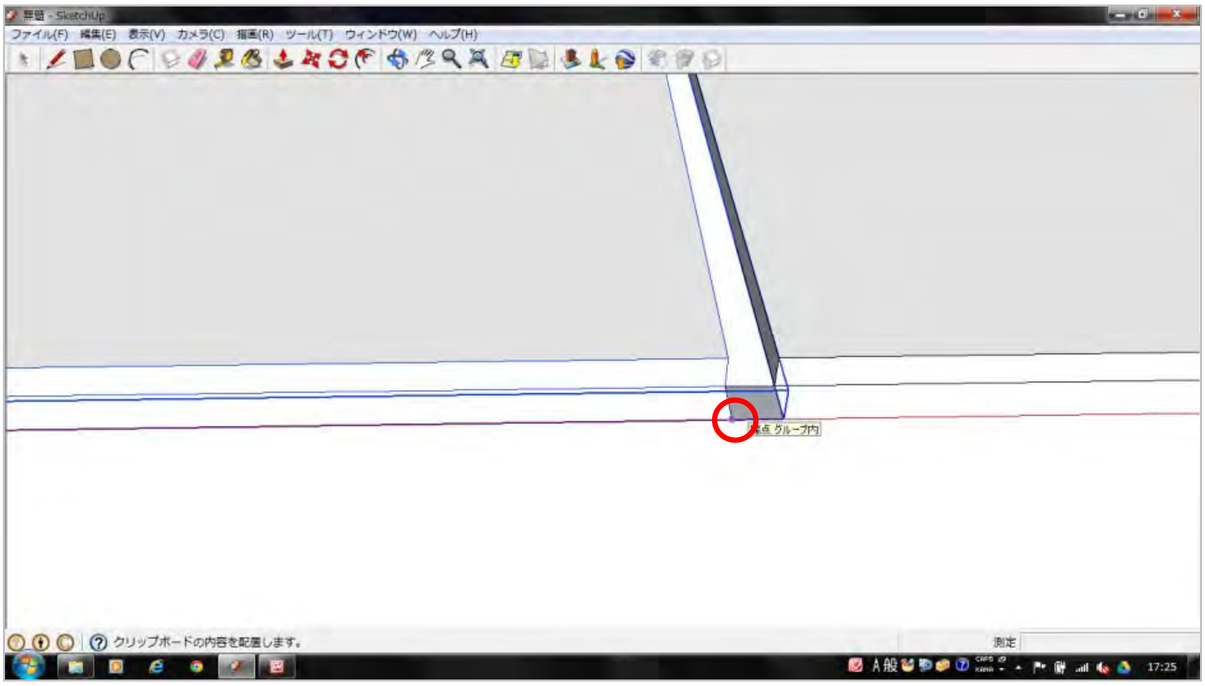


Select [Edit]-[Copy] on the PV module you created on the previous page and select [Edit]-[Paste], and a copy linked to the mouse cursor will appear on the screen.

* [Copy] can be executable with Ctrl + C. [Paste} is executable with Ctrl + V.

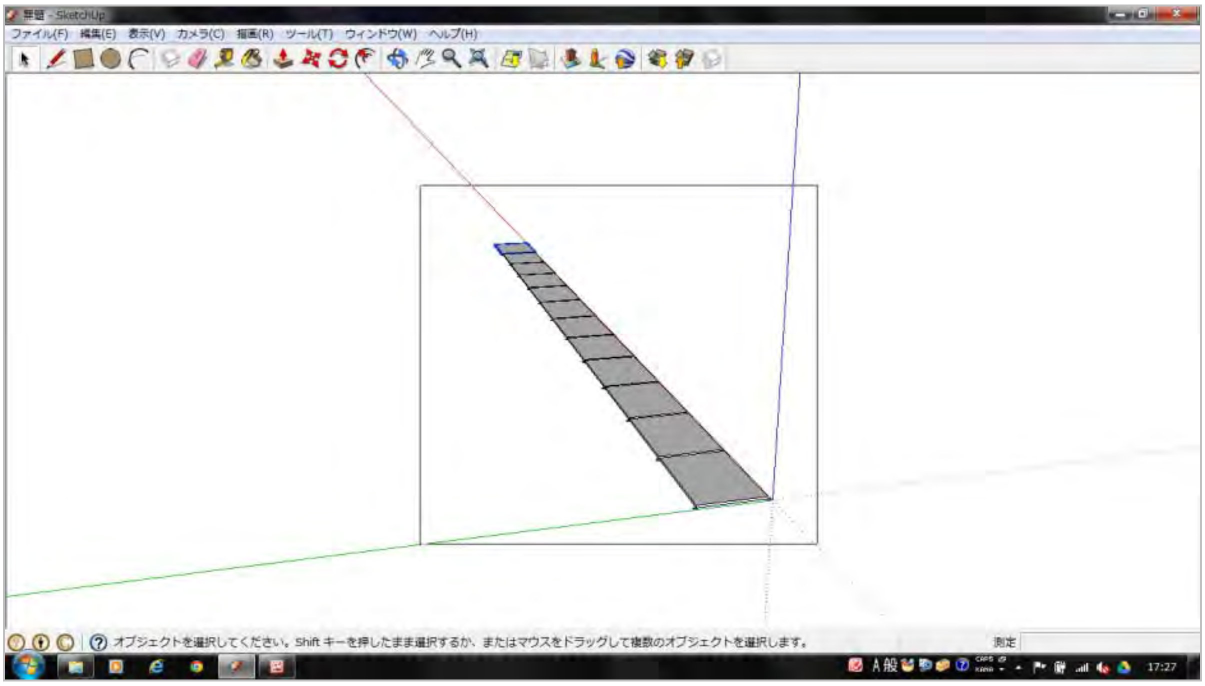


Verify that the mouse cursor reacts when placed at the end point of the shape and drag.

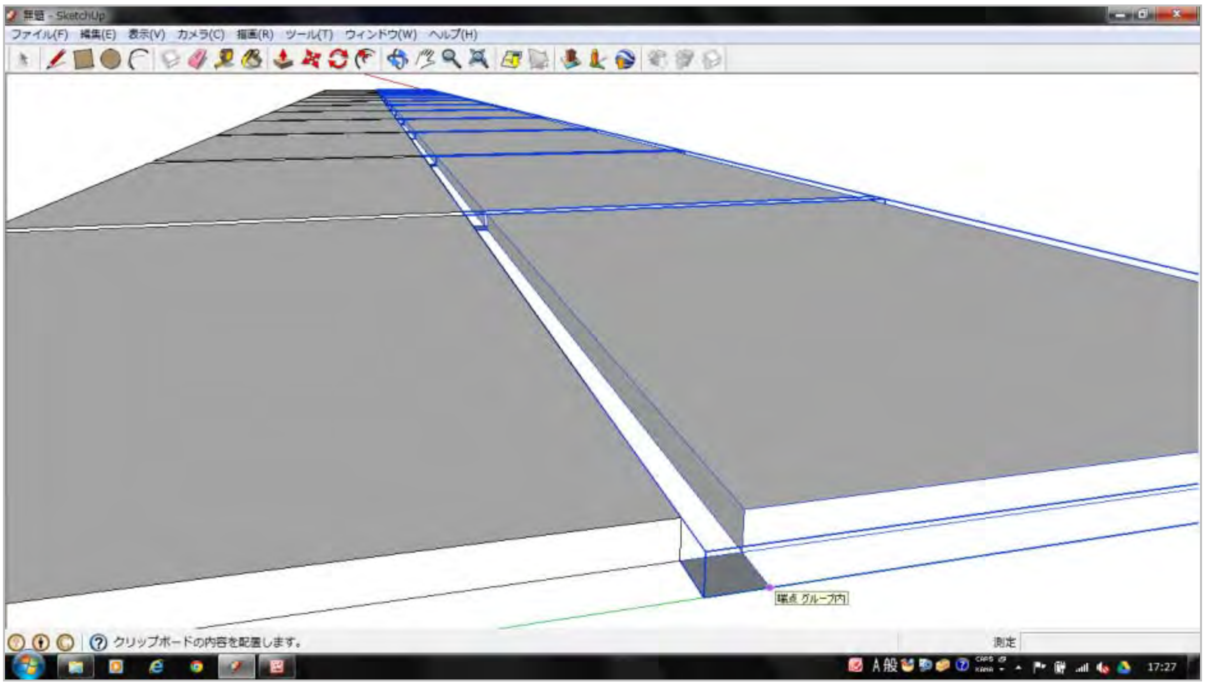


We continue so that the module has 12 columns as in the above.

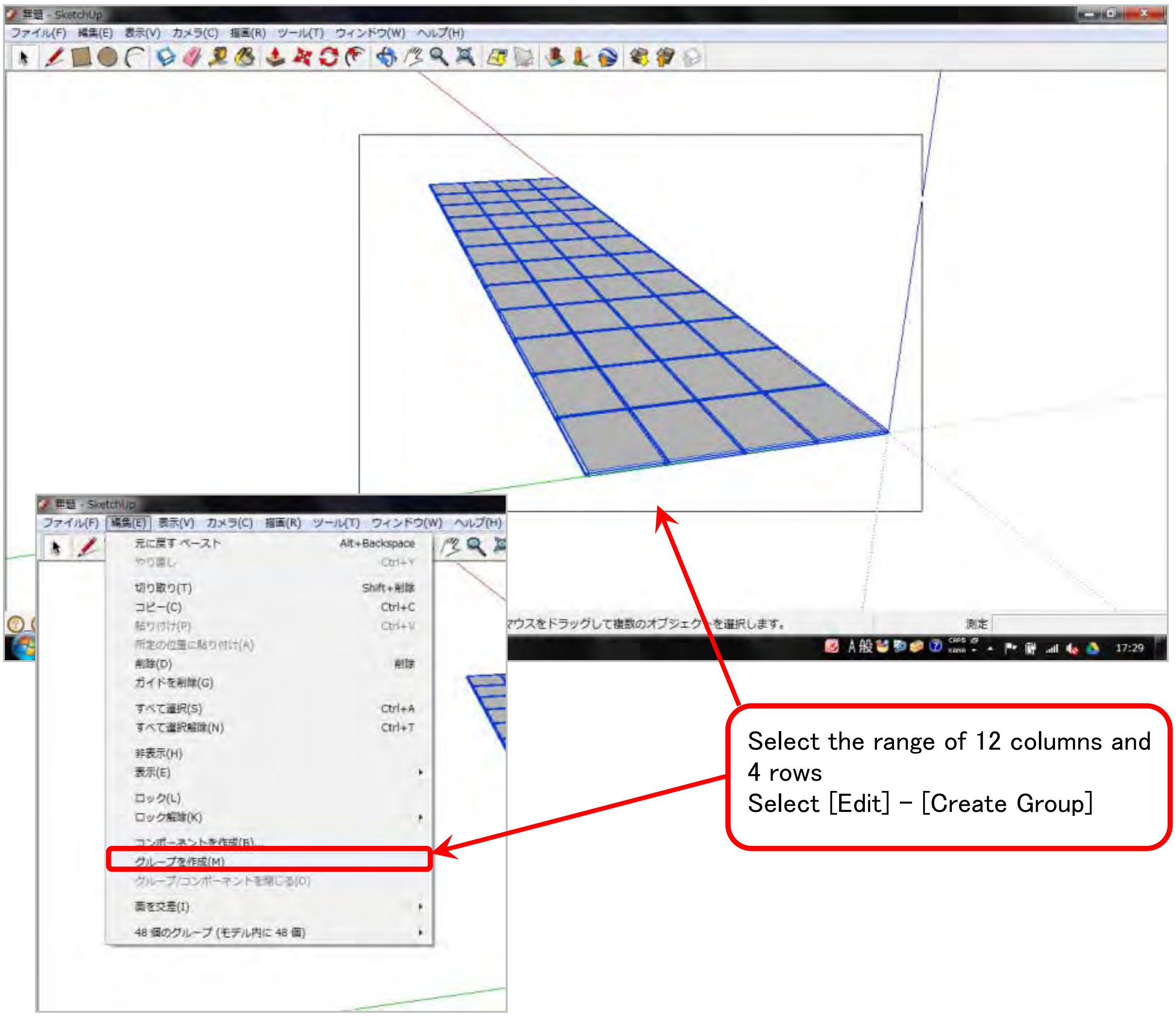
Select the module's 12 columns and select [Edit]-[Create Group] to group.



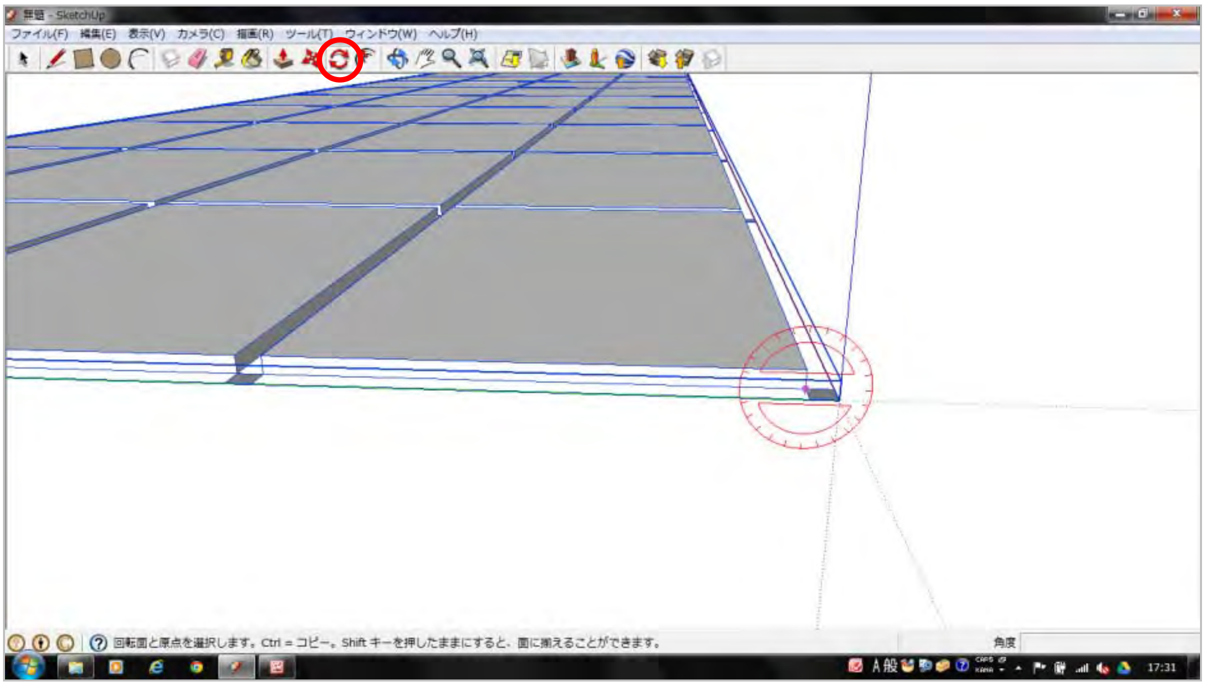
Also repeat [Copy] → [Paste] for each column.



When 12 columns and 4 rows have been created, group again.

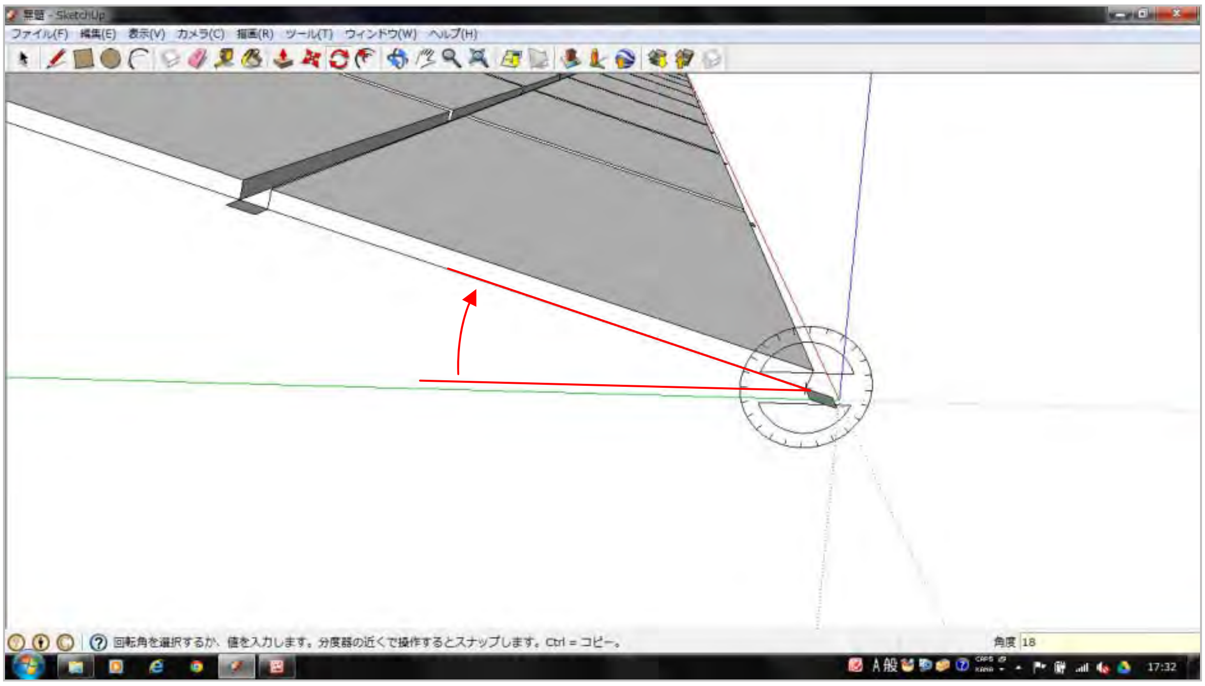


Select the Rotate tool and align the mouse cursor at the end point of the PV module near the origin. Verify that the protractor mark appears on the x-y plane.

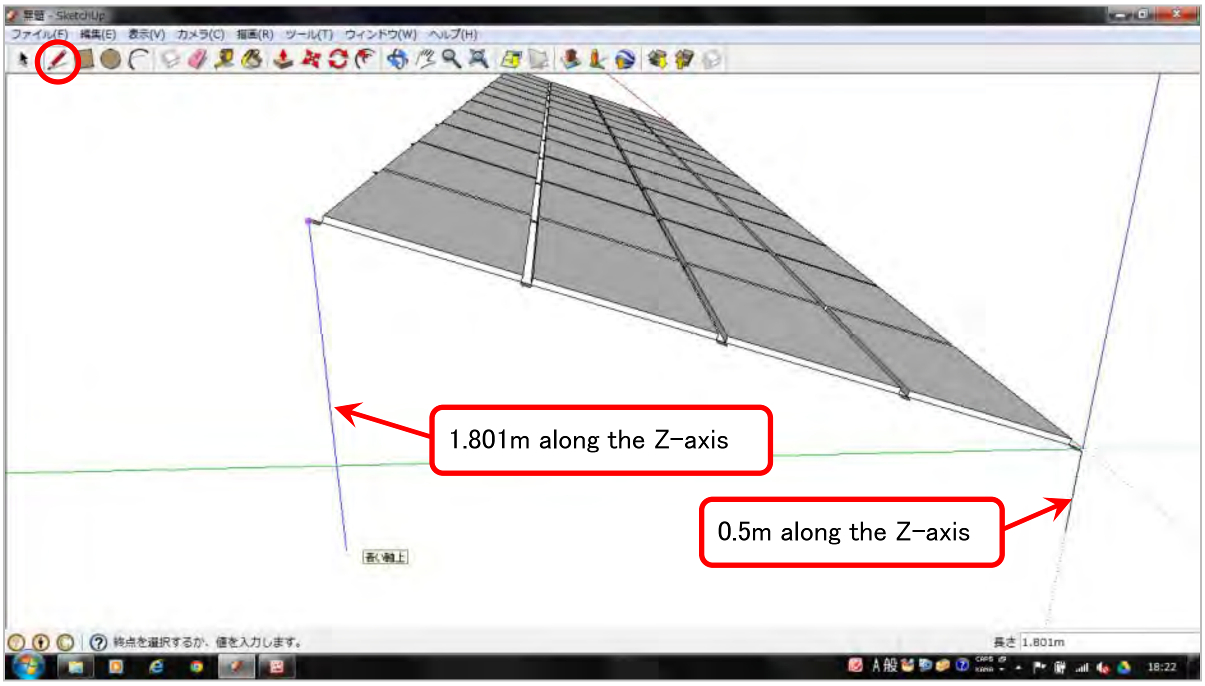


Click once on the horizontal position (along the y-axis from the end point) and move the mouse in the direction of rotation.

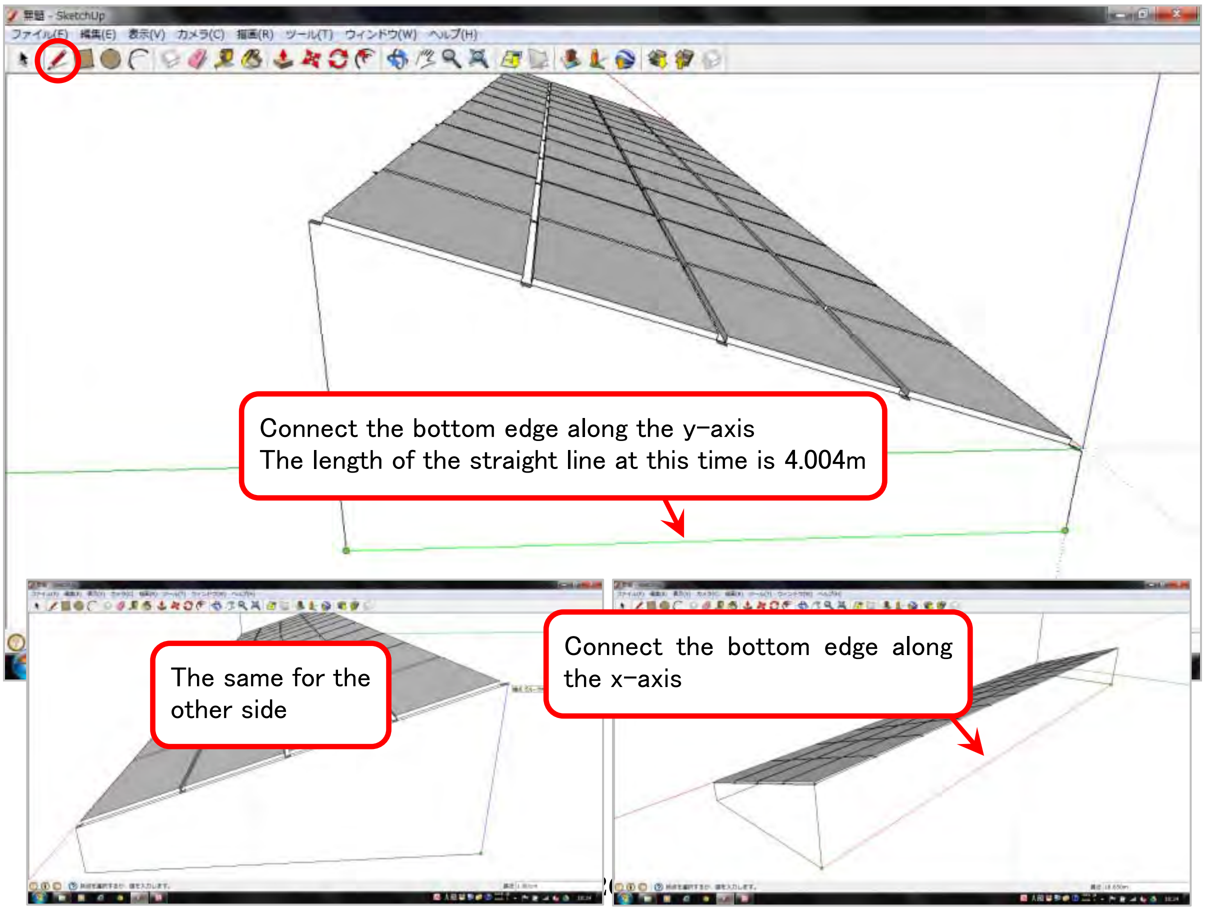
For the value input, enter [18] so that the array has an 18-degree angle.



Align the mouse cursor on an end point of the module's 0.05m × 0.05m spacing guide.
For the front side of the array, draw a 0.5m straight line along the Z-axis, and for the rear side, draw a 1.801m straight line along the Z-axis.

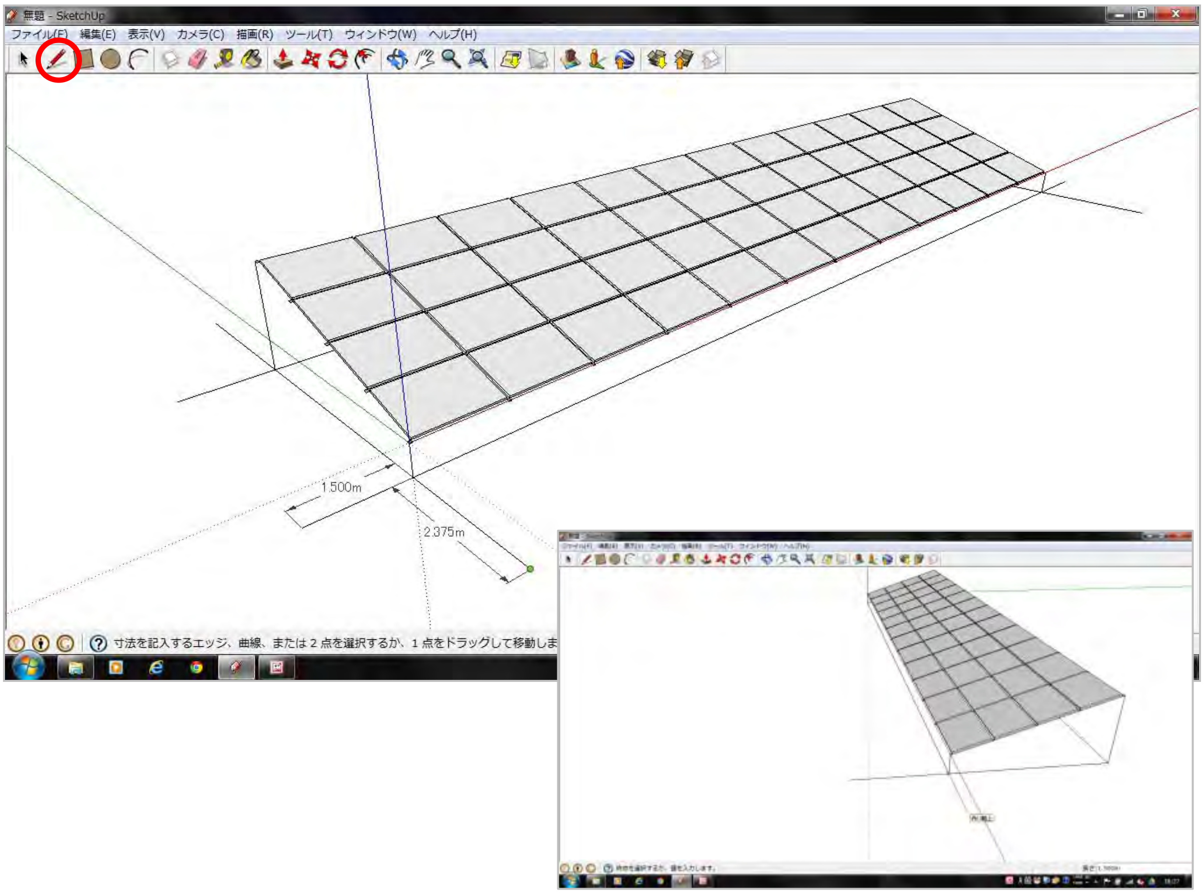


Connect the bottom of the straight lines drawn for the array's front and rear sides with a line along the y-axis.
This is the bottom of the array which will be in contact with the ground.
Draw the other side of the array in the same manner, connecting the entire perimeter of the array's bottom.

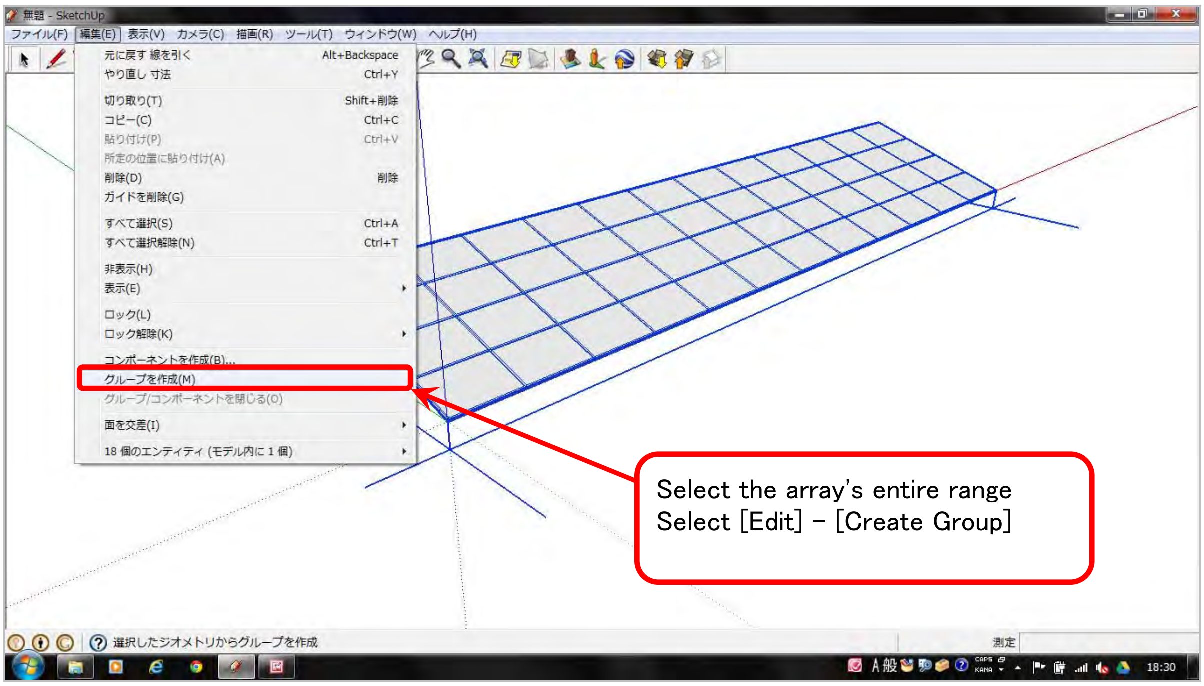


Draw a 1.5m straight line from the bottom edge of the array along the x-axis (the array's east-west separation).

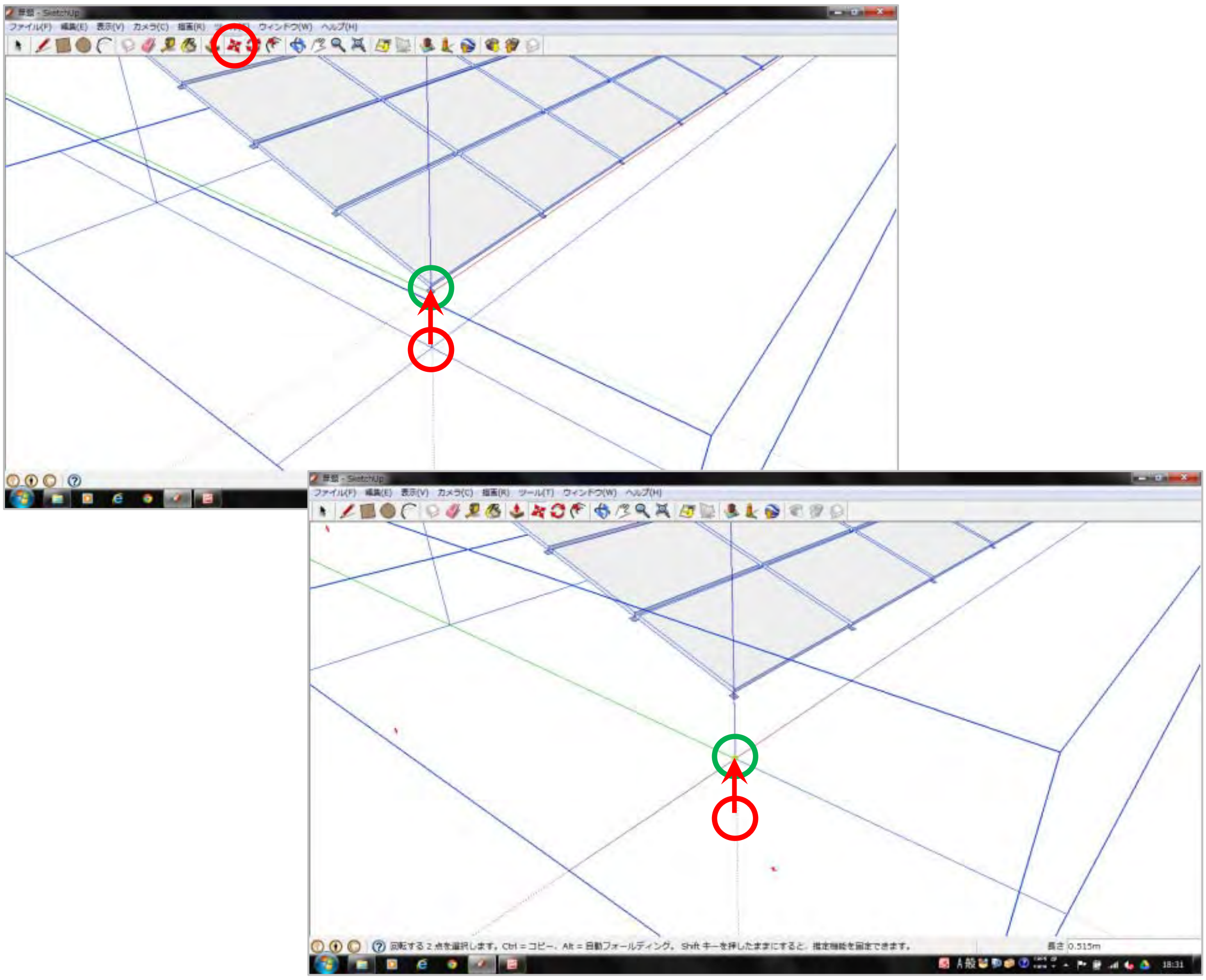
Draw a 2.375m straight line from the bottom edge of the array along the x-axis (the array's north-south separation).



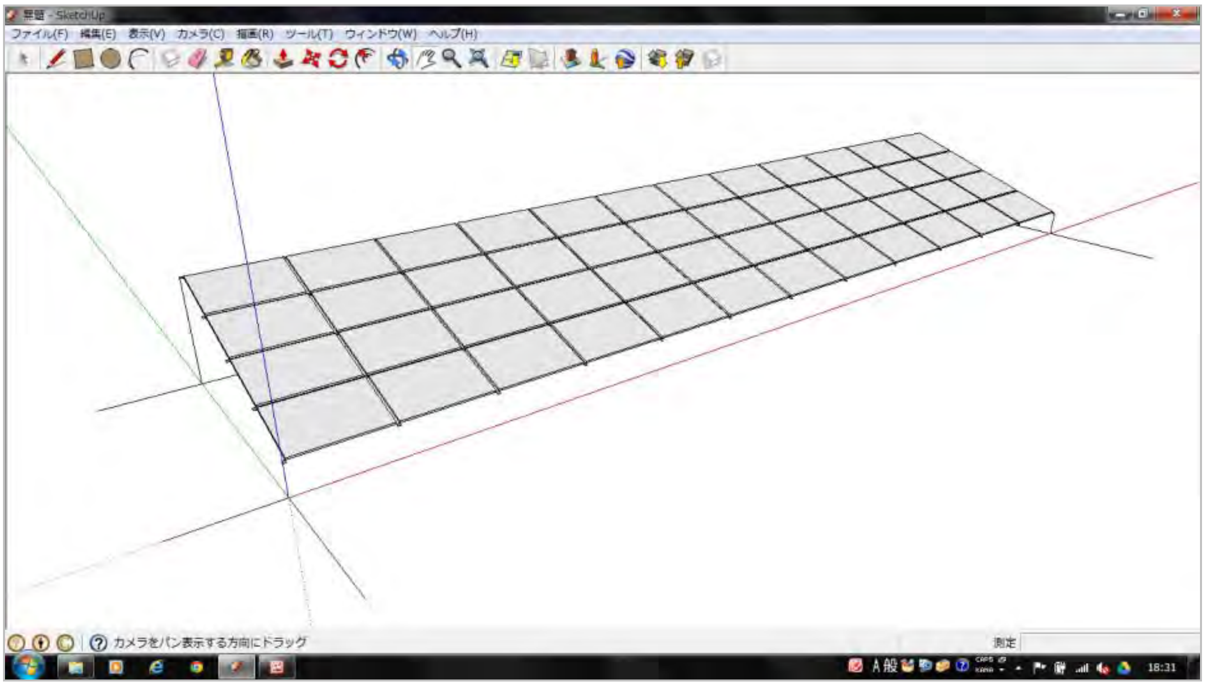
Select the entire range including the array's spacing guide straight lines and group them.



Align the mouse cursor on the bottom edge of the array near the origin and click to align with the origin.



This completes the PV array.

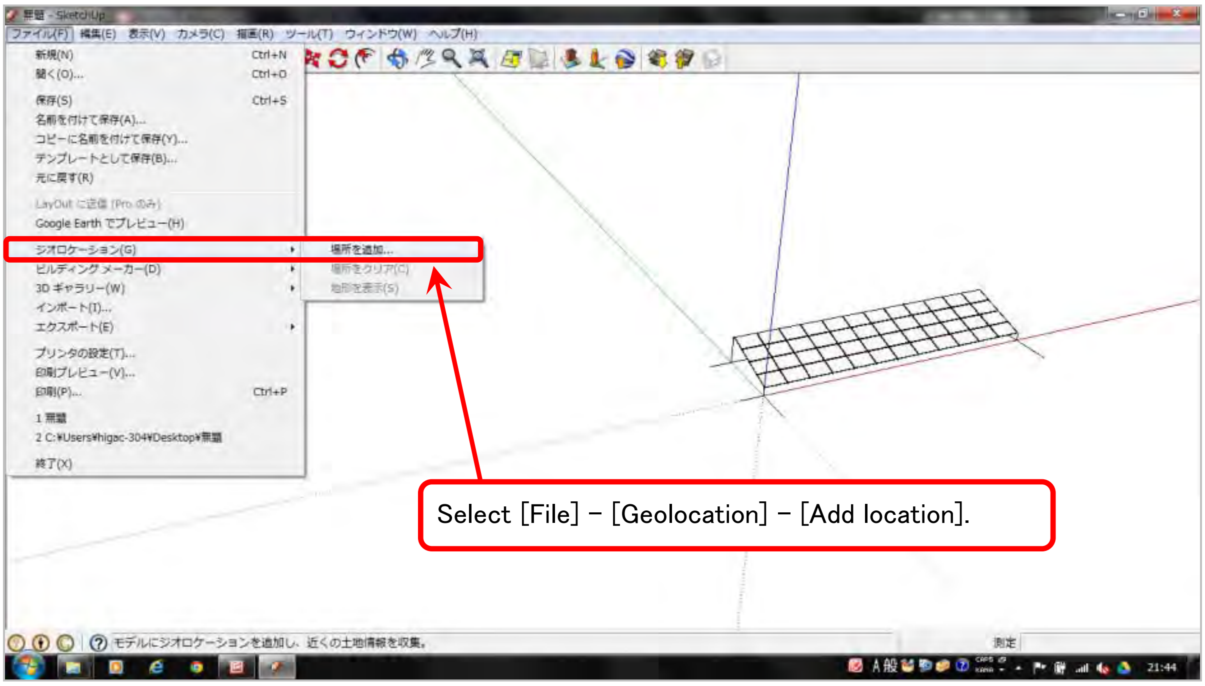


3. Layout plan for the PV array

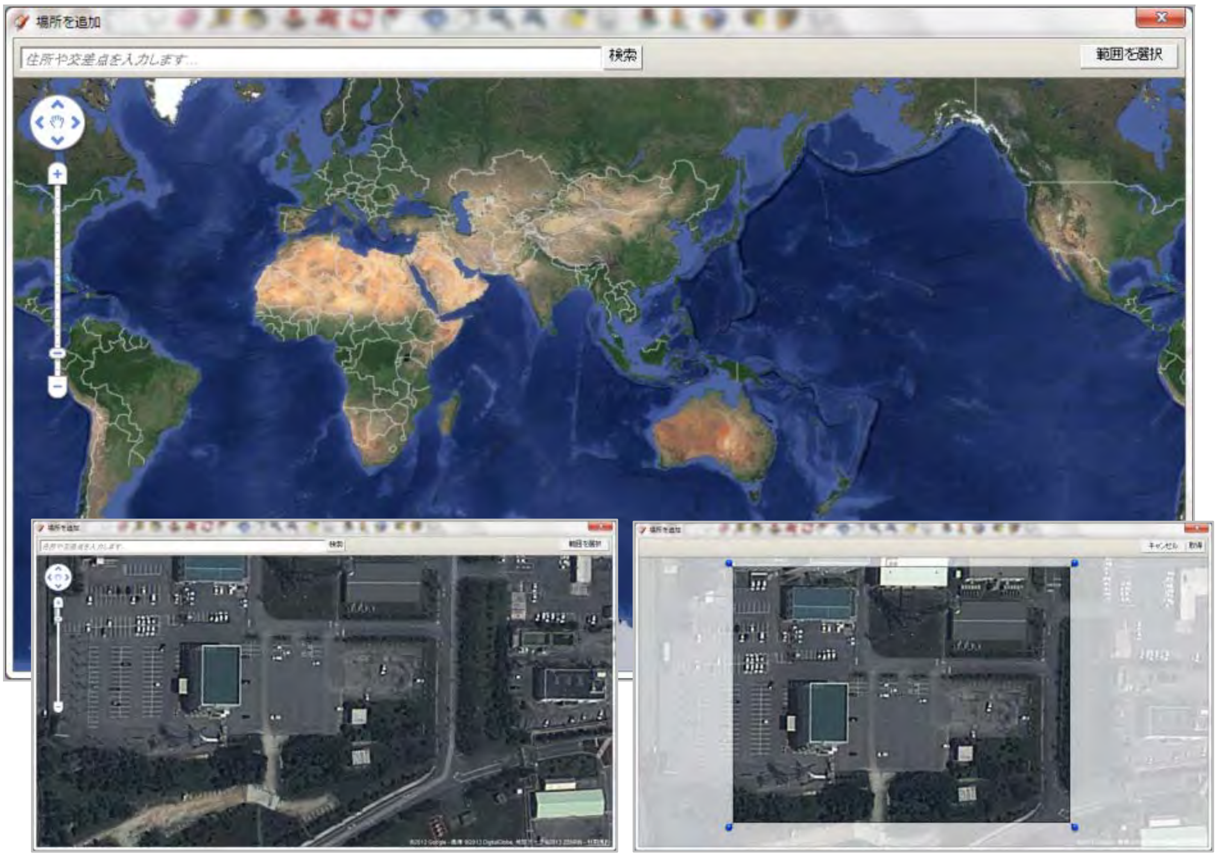
Place the created PV array on the planned site.

Here, we will place it on the parking lot in front of Okinawa Enetech's building as a sample site.

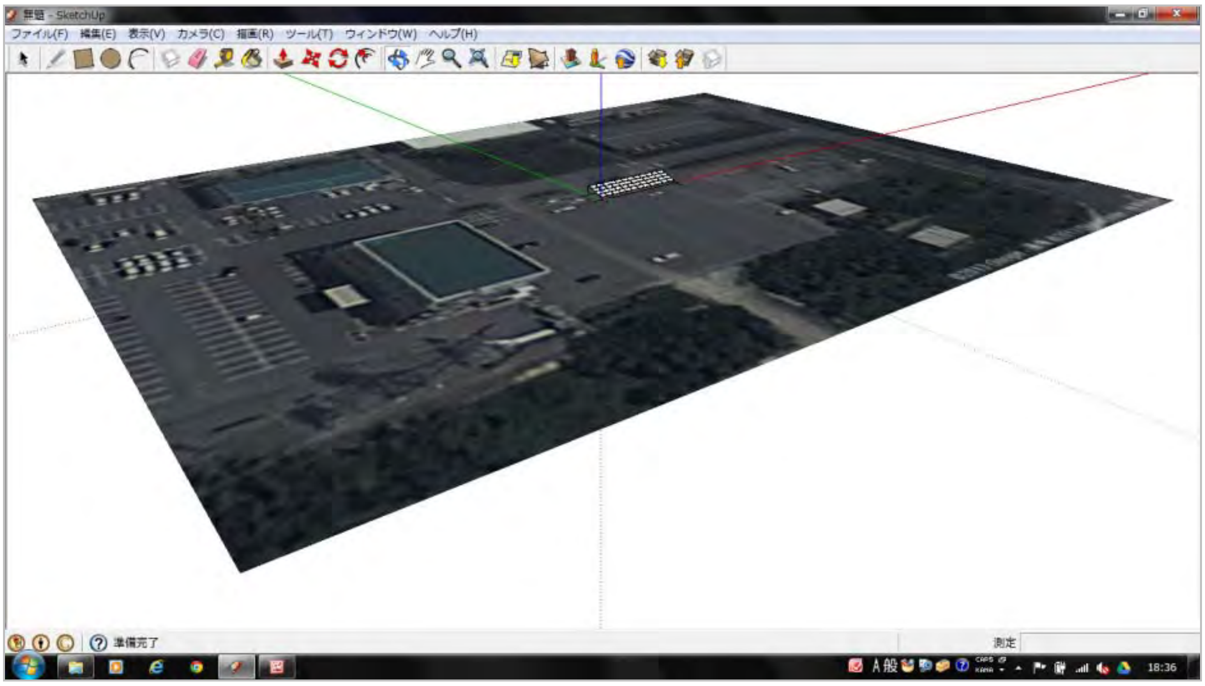
Select [File] - [Geolocation] - [Add location].



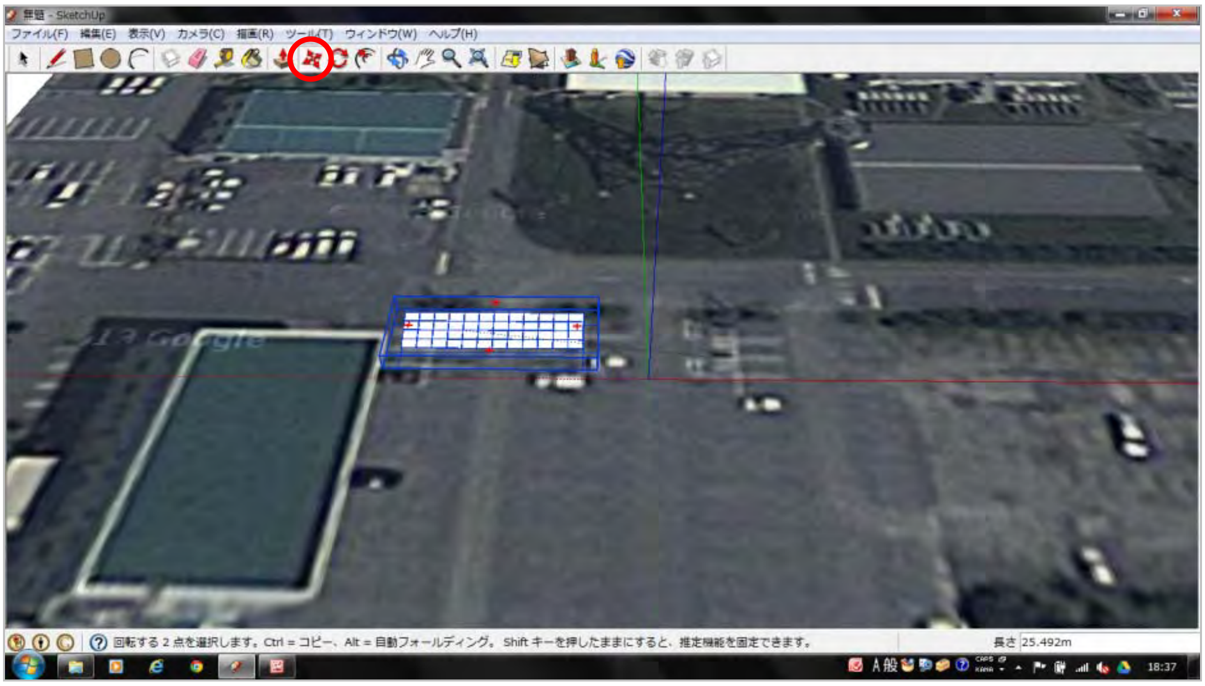
Search for the planned site on the map displayed in the pop-up window. Click the [Select range] button to switch to the range selection screen, and click [Get] to get the site location.



Once you get it, the range acquired is displayed on the screen in 3D as shown below.
This includes latitude and longitude.

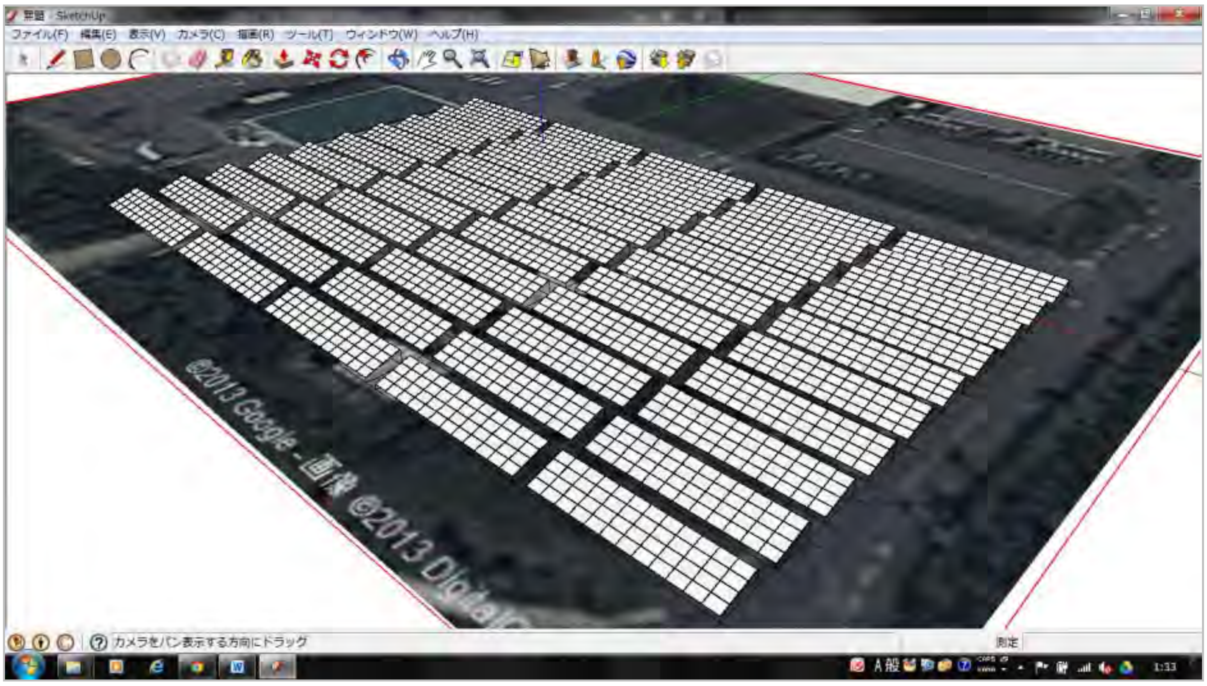


Place one array on the designated location.
The y-axis corresponds to North-South direction, and the x-axis corresponds to East-West direction.
If the site is in the Southern Hemisphere, at this point, use the [Rotate] tool to rotate the array 180 degrees.



While separating by 1.5m along the x-axis (array East-West direction) and 2.375m along the y-axis (array North-South direction), place the arrays using [Copy]→[Paste].

Place the planned arrays below on the planned site.
This completes the layout plan.

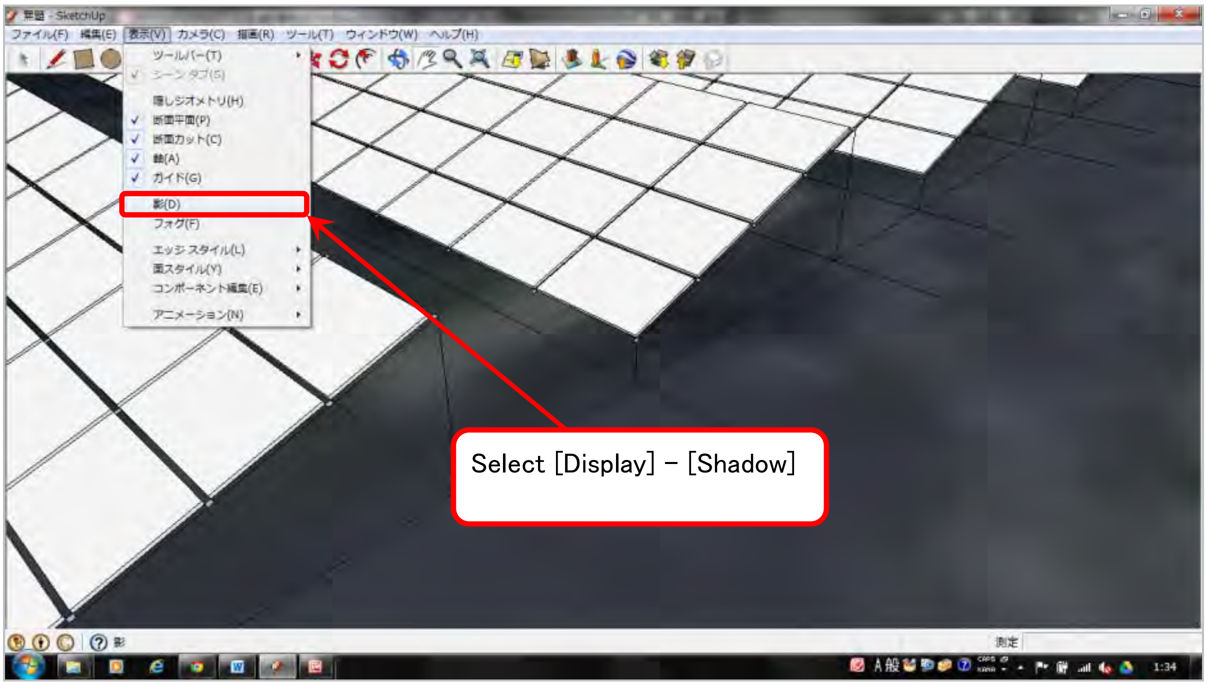


* If there is not enough space, reduce the angle of inclination which reduces separation in the North-South direction, and thus secures more space.
This may be omitted taking 1.5m of separation in the East-West direction as well as maintenance into account.

4. Check for obstructions to sunlight

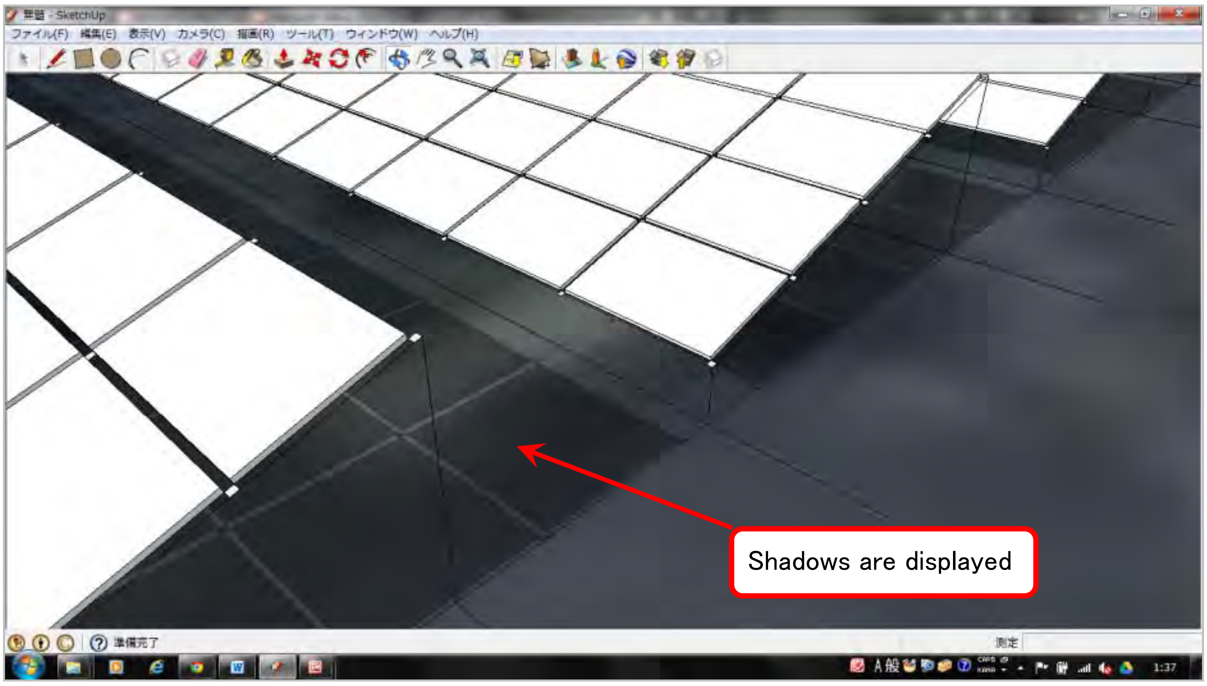
You can also use the [Shadow] tool to check for obstructions to sunlight.

Select [Display] - [Shadow].

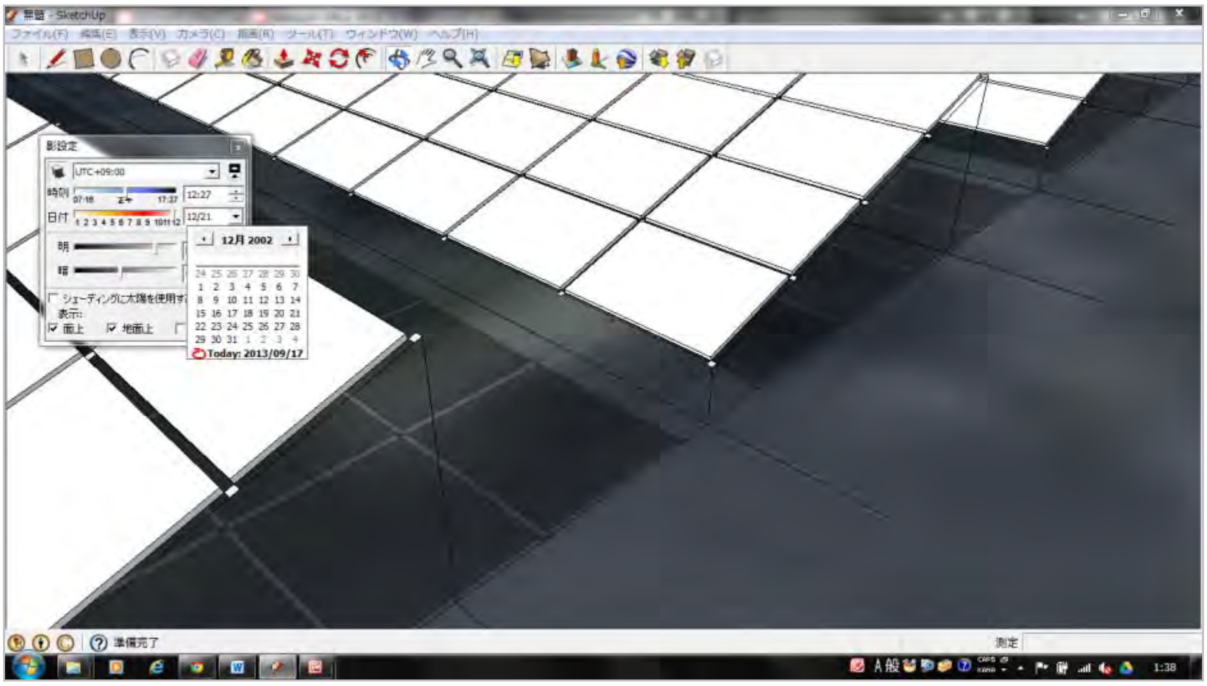


The arrays are displayed with shadows as shown below.

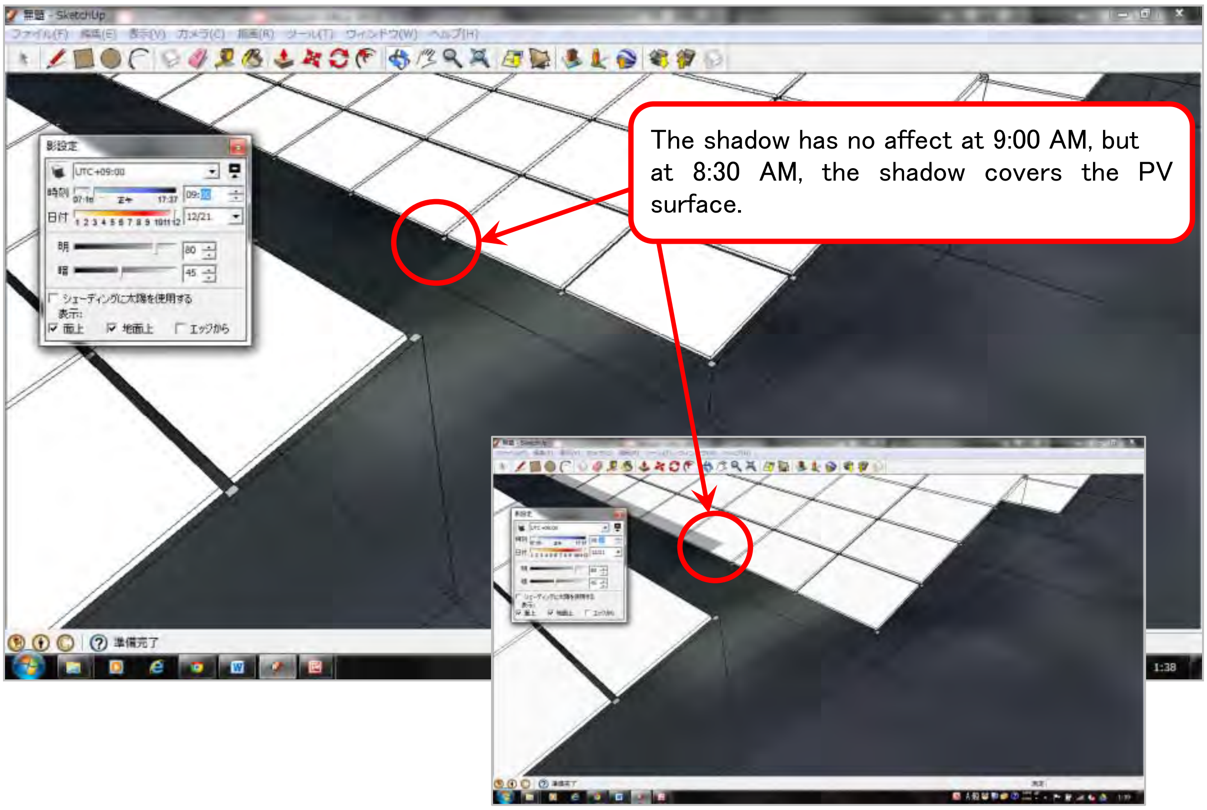
This shadow depends on the latitude and longitude, date, and time set in the [Geolocation] settings.



Select [Window] - [Shadow] to display the shadow settings window and change the date and time settings. Change the date to winter solstice (Dec. 21, 2012 for Okinawa), and the time to 9:00.



Verify that the shadow of the front array does not affect the PV module surface of the rear array.



* This completes the PV array layout plan.

Homer Software

April, 2016
Okinawa Enetech Co., Inc.

What is HOMER

HOMER (Hybrid Optimization of Multiple Electric Renewables).

HOMER simplifies the task of designing of distributed generation (DG) systems - both on and off-grid for a variety of applications.

In configuration of the system helps in

- What components does it make sense to include in the system design
- How many and what size of each component should you use.

HOMER's optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations

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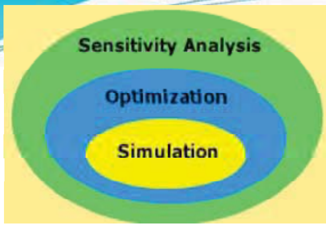

Core capabilities
Simulation, Optimization, Sensitivity Analysis

Simulation: At its core, HOMER is a simulation model. It will attempt to simulate a viable system for all possible combinations of the equipment that you wish to consider. Depending on how you set up your problem, HOMER may simulate hundreds or even thousands of systems.

Optimization: The optimization step follows all simulations. The simulated systems are sorted and filtered according to criteria that you define, so that you can see the best possible fits. Although HOMER fundamentally is an economic optimization model, you may also choose to minimize fuel usage.

Sensitivity analysis: This is an optional step that allows you to model the impact of variables that are beyond your control, such as wind speed, fuel costs, etc, and see how the optimal system changes with these variations

HOMER® Pro can help you design the best micropower system to suit your needs.
HOMER Pro lets you:
Evaluate off-grid or grid-connected power system designs
Choose the best system based on cost, technical requirements, or environmental considerations
Simulate many design configurations under market price uncertainty and evaluate risk
Choose the best addition or retrofit for an existing system
The HOMER Support Site has many resources to help you wit
.**Create a system** with a load, generator, wind turbine, batteries, and a system converter.
.**Perform an economic optimization** to find the best combination of battery bank, converter, generator, and wind turbine quantities and capacities.
.**Perform a sensitivity analysis** to investigate how results are affected by fuel price, wind speed, and load size.
.Explore the effect of **interest rate** on the optimal system type.

STEPS IN THE USE OF HOMER SOFTWARE

Step 1: Create a new HOMER file

- title, author, and notes (project description) if desired.
- Project Location
- Resources(1)
- Sensitive analysis values input

Step 2: Load profile

- Create a synthetic load from a profile
- Import a load from a time series file

Step 3: System Design

- Component settings (Generators, PV, Wind Turbine, battery, Flywheel, Converter

Step 4: Resources

- Input data of Solar, Wind, Temperature, Fuels, Hydrokinetic

Step 5: Calculation & Analysis

- HOMER simulations results

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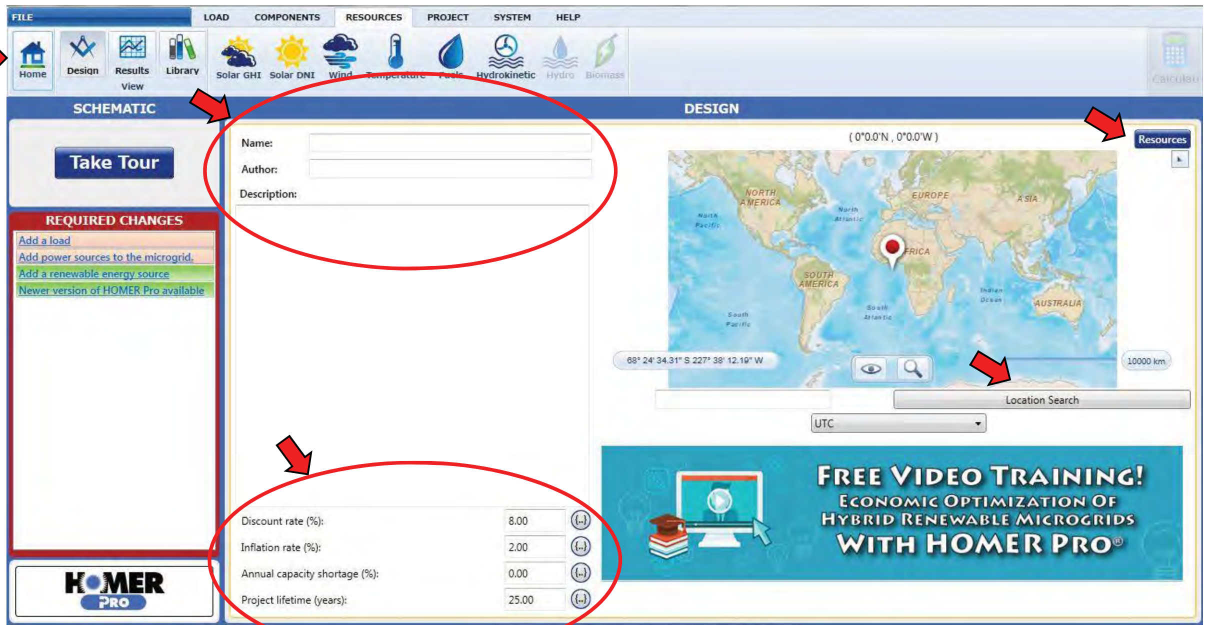
Step 1: Create a new HOMER file

A HOMER file contains all of the information about the technology options, component costs and resource availability required to analyze power system designs. The HOMER file also contains the results of any calculations HOMER makes as part of the optimization and sensitivity analysis processes. HOMER file names end in .hmr, for example:



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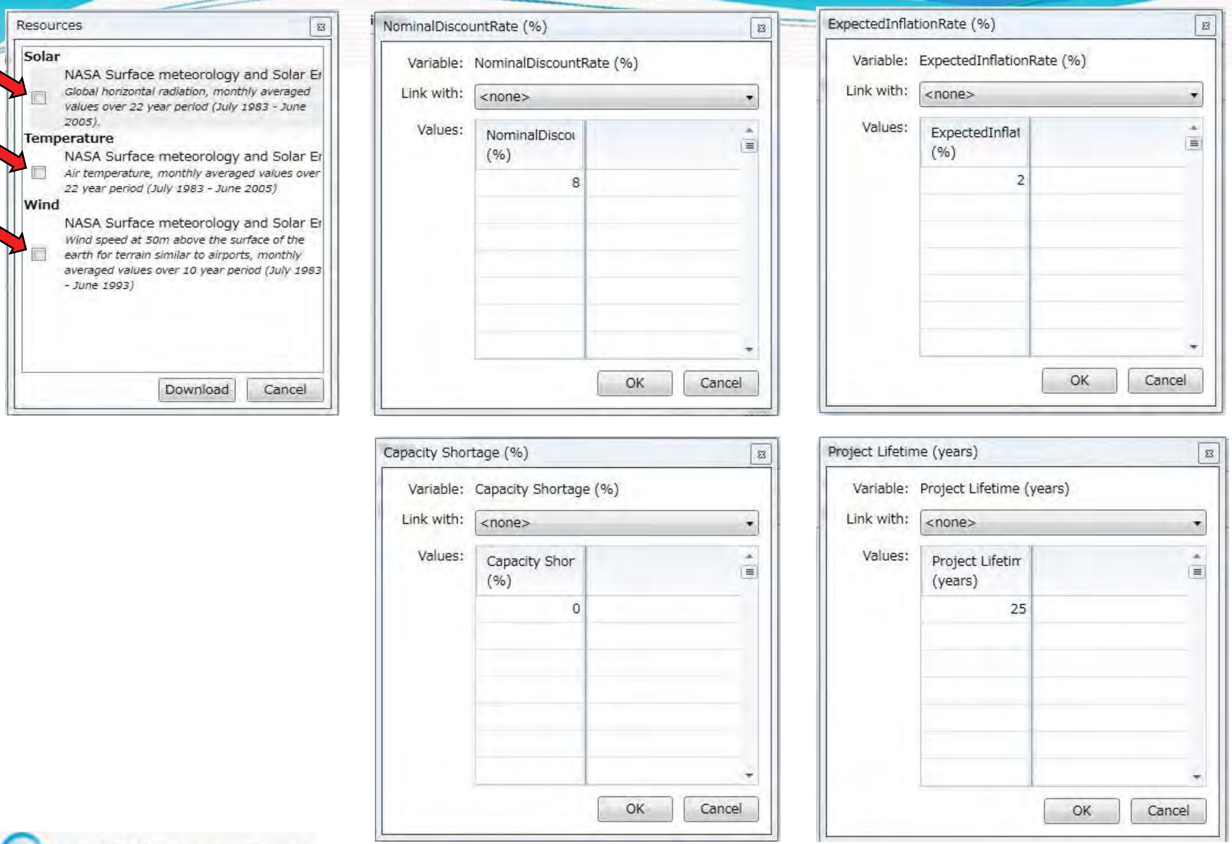
Step 1: Create a new HOMER file



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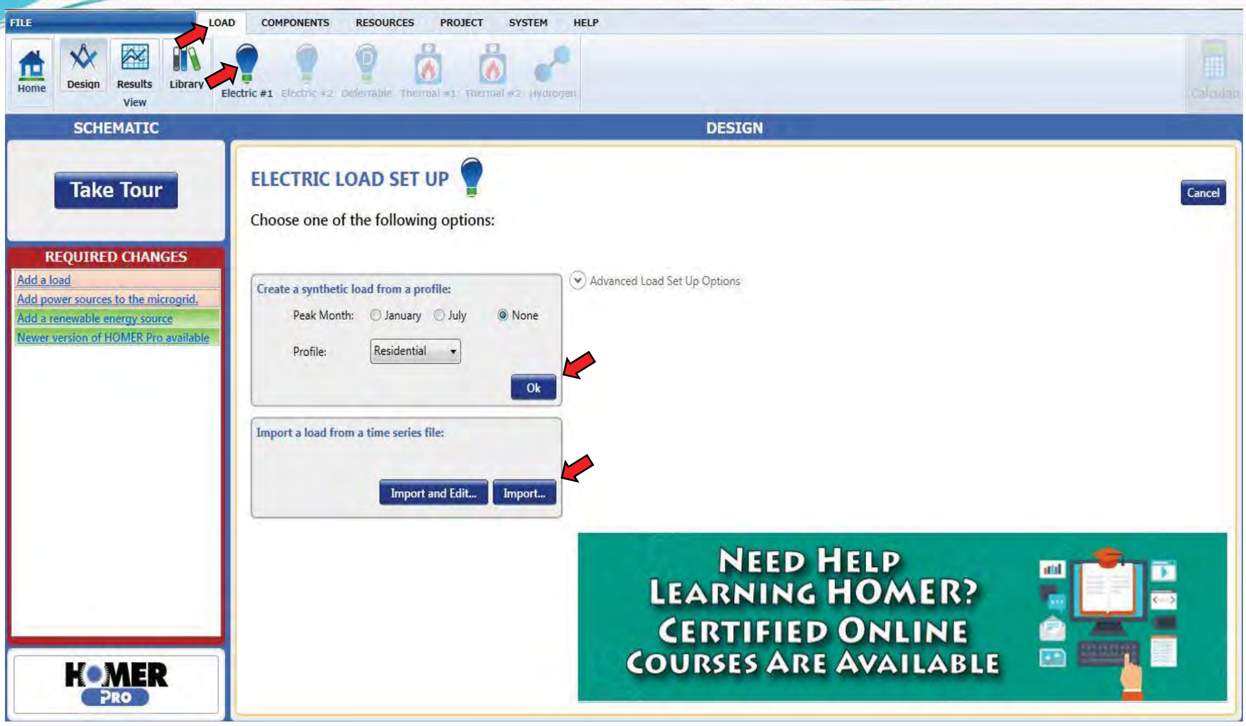
Step 2: Load profile



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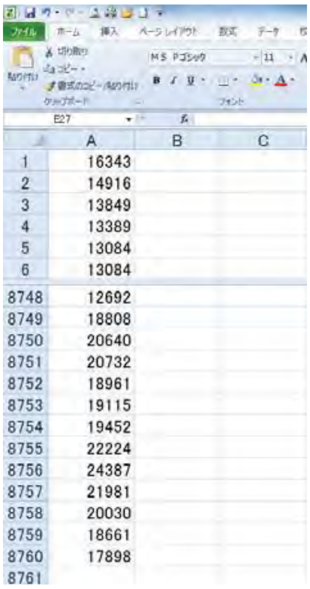
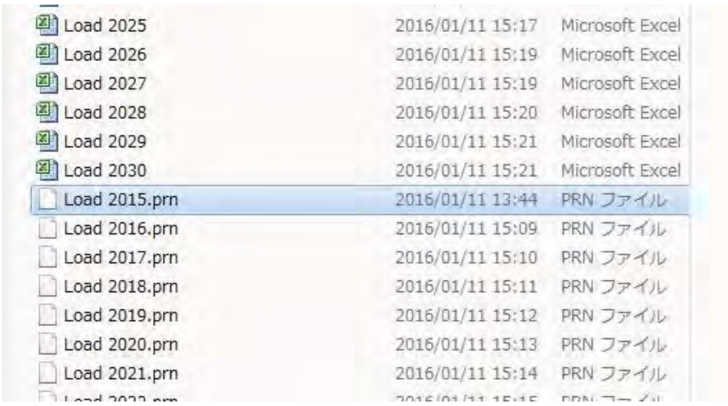
Step 2: Load profile

Step 2: Load profile

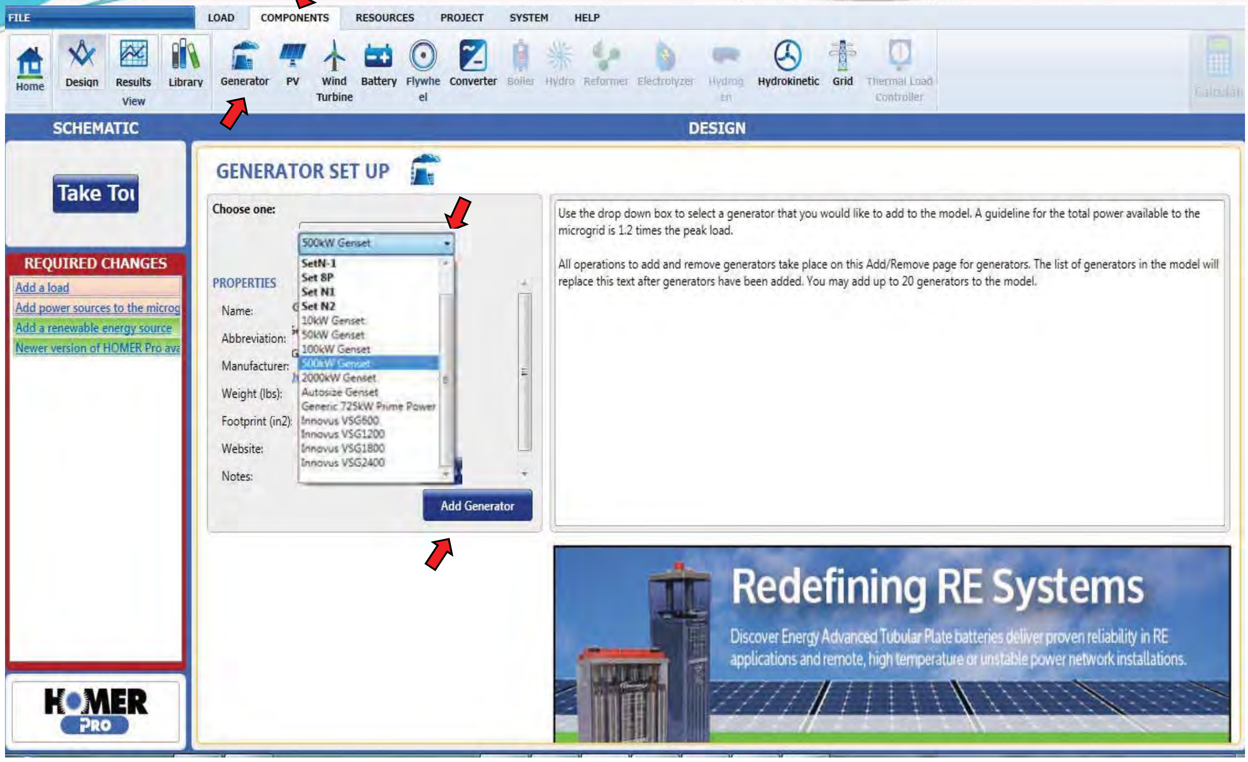


1hour each 365 days data

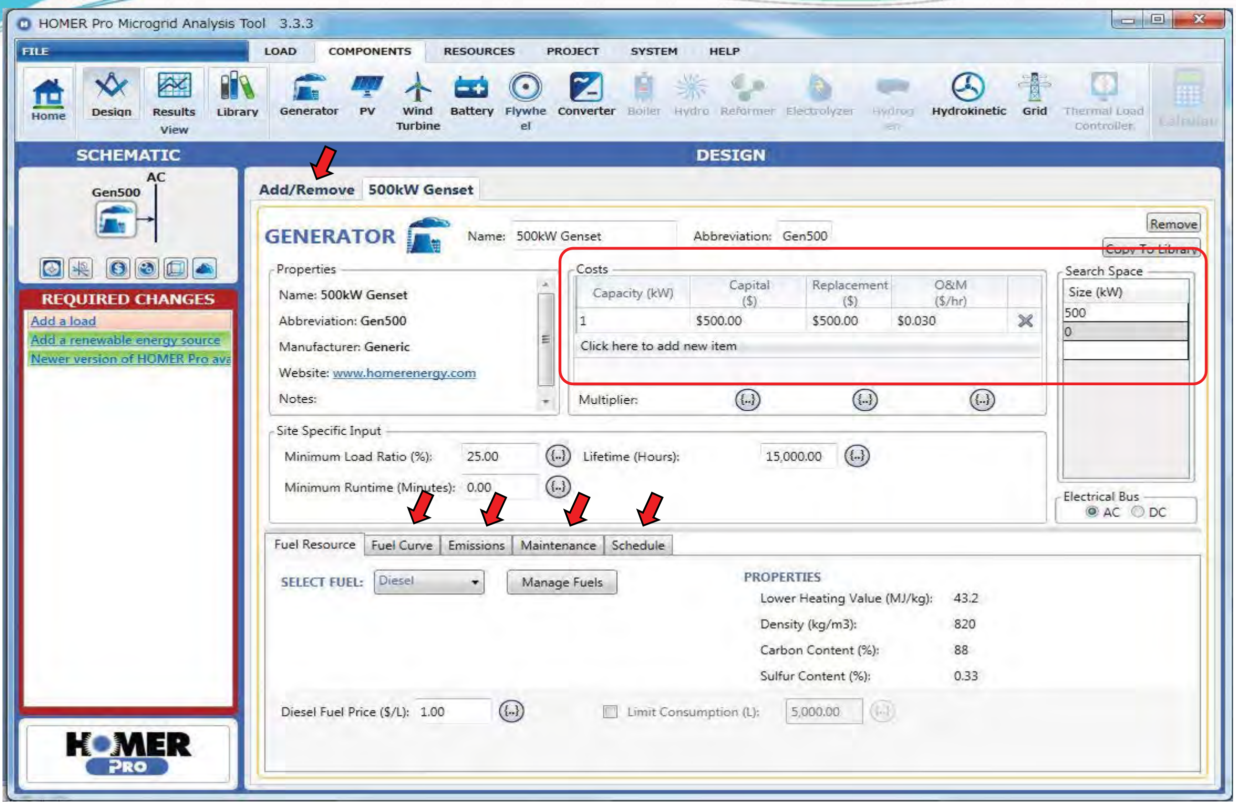


Save in txt. file

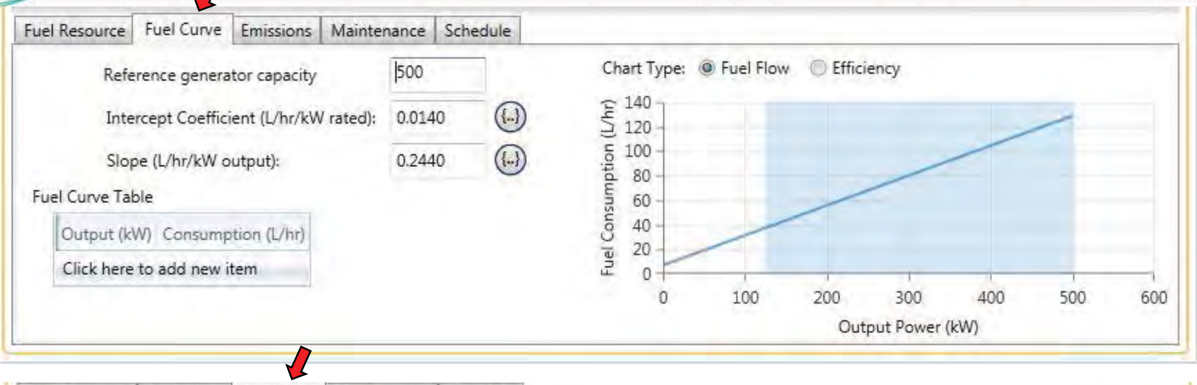
Step 3: System Design (Generator)

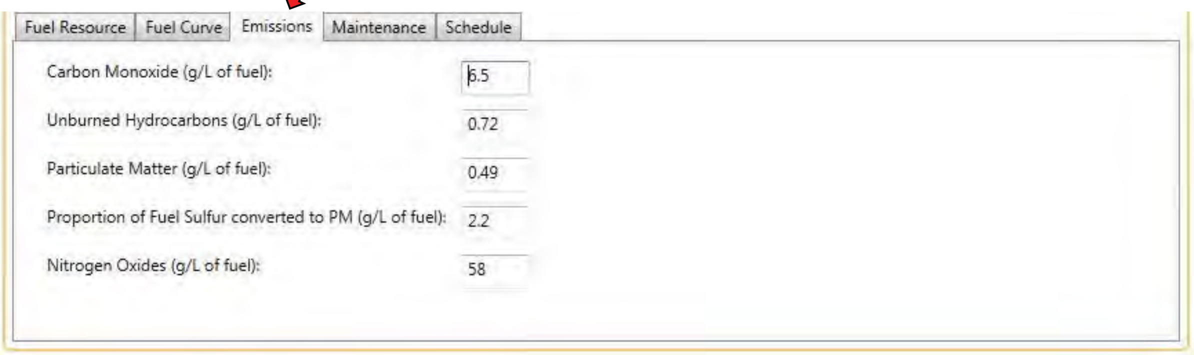


Step 3: System Design (Generator)

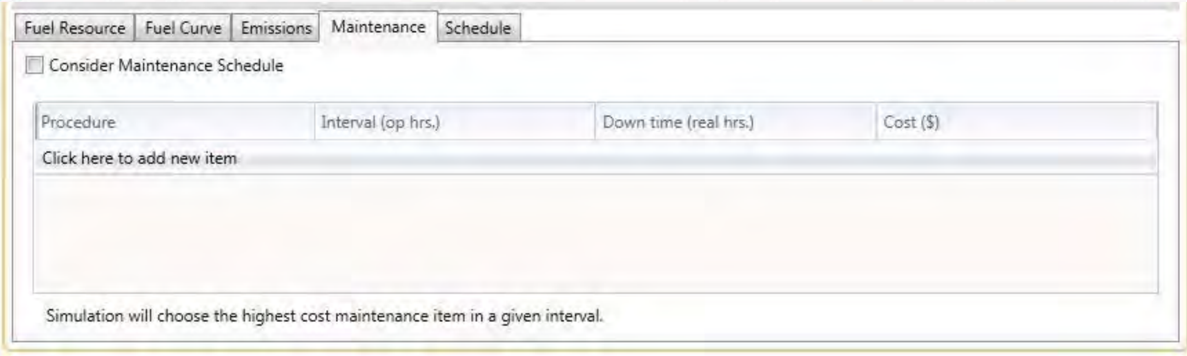


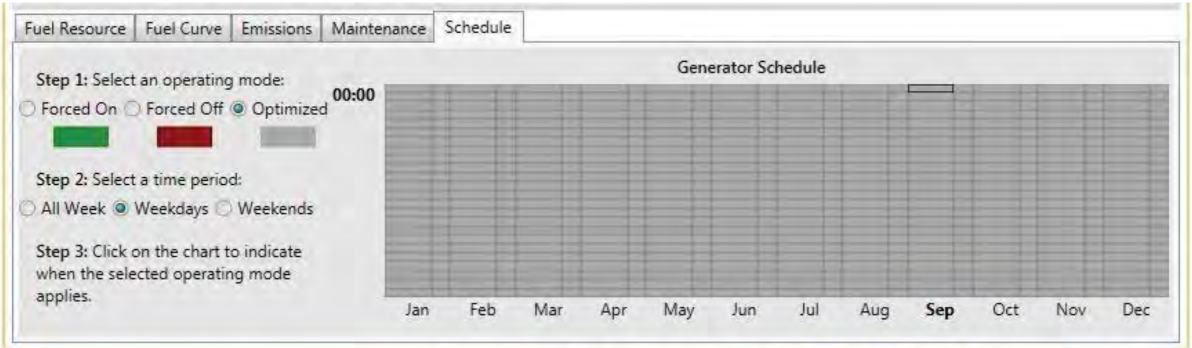
Step 3: System Design (Generator)



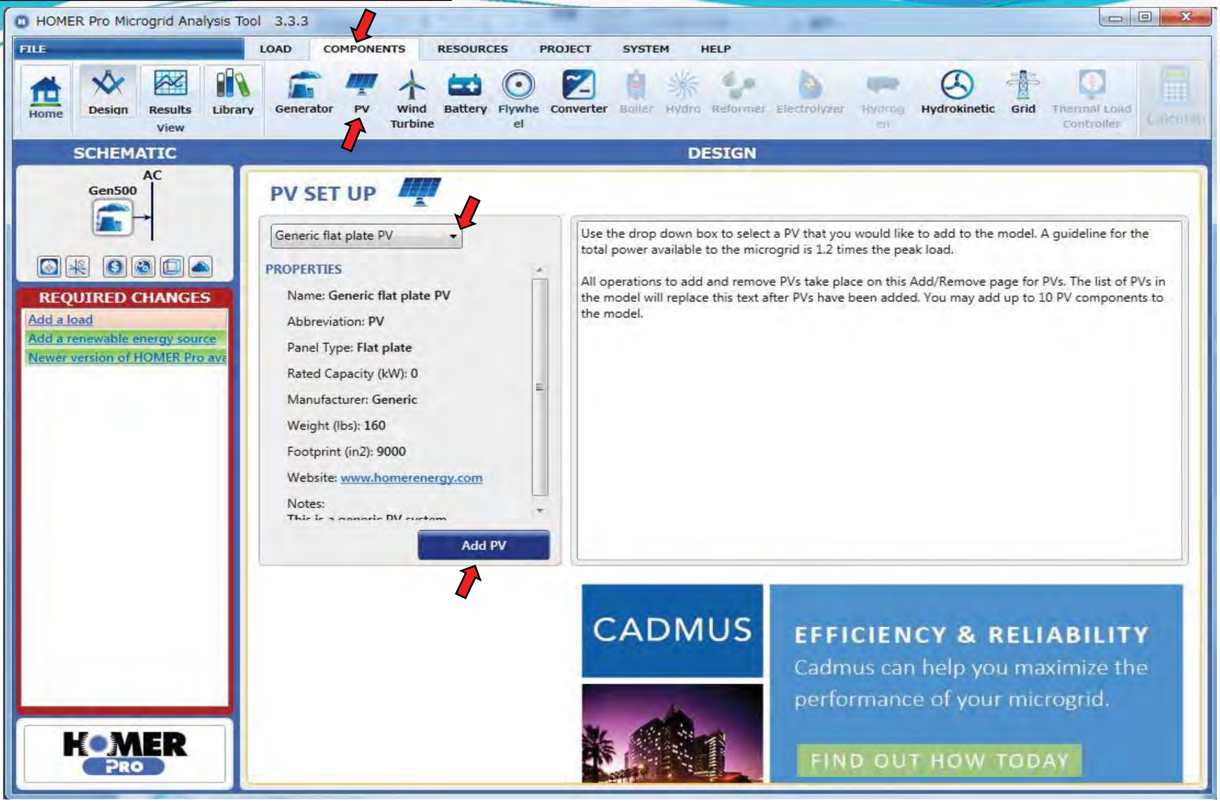


Step 3: System Design (Generator)





Step 3: System Design (PV)



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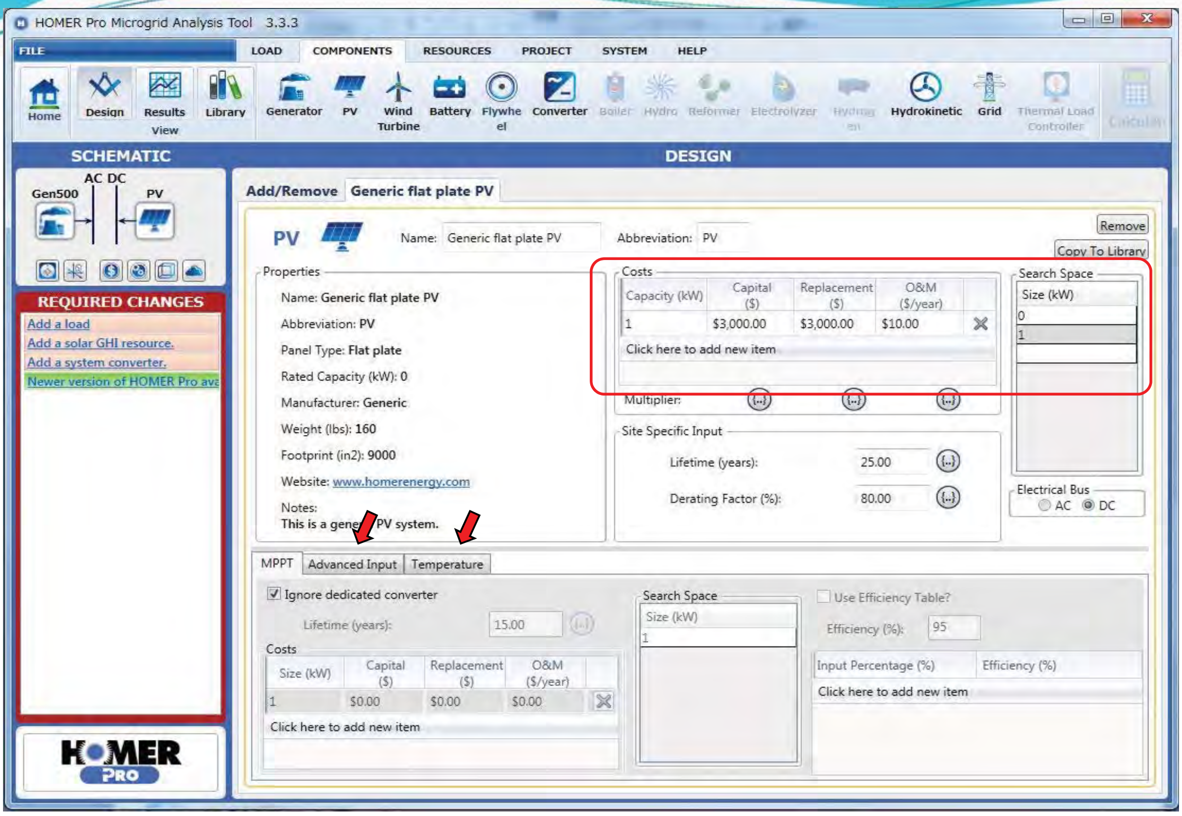
Step 3: System Design (PV)



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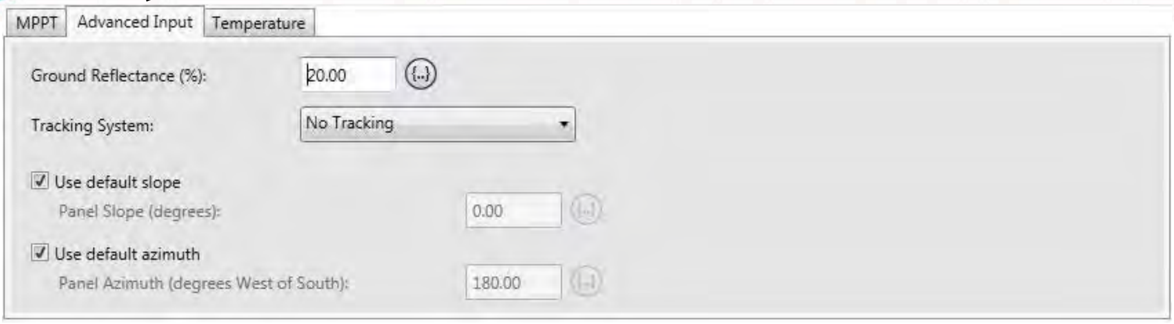
Step 3: System Design (PV)



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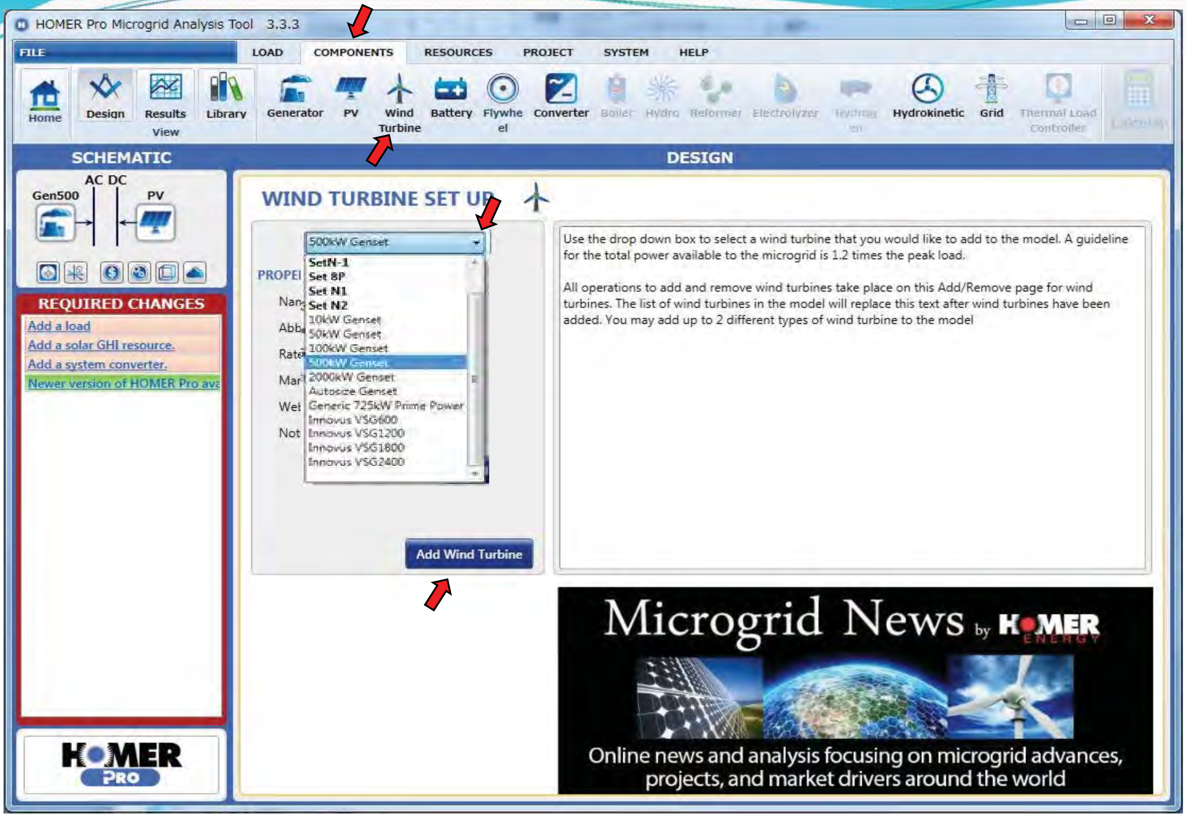
Step 3: System Design (Wind Turbine)



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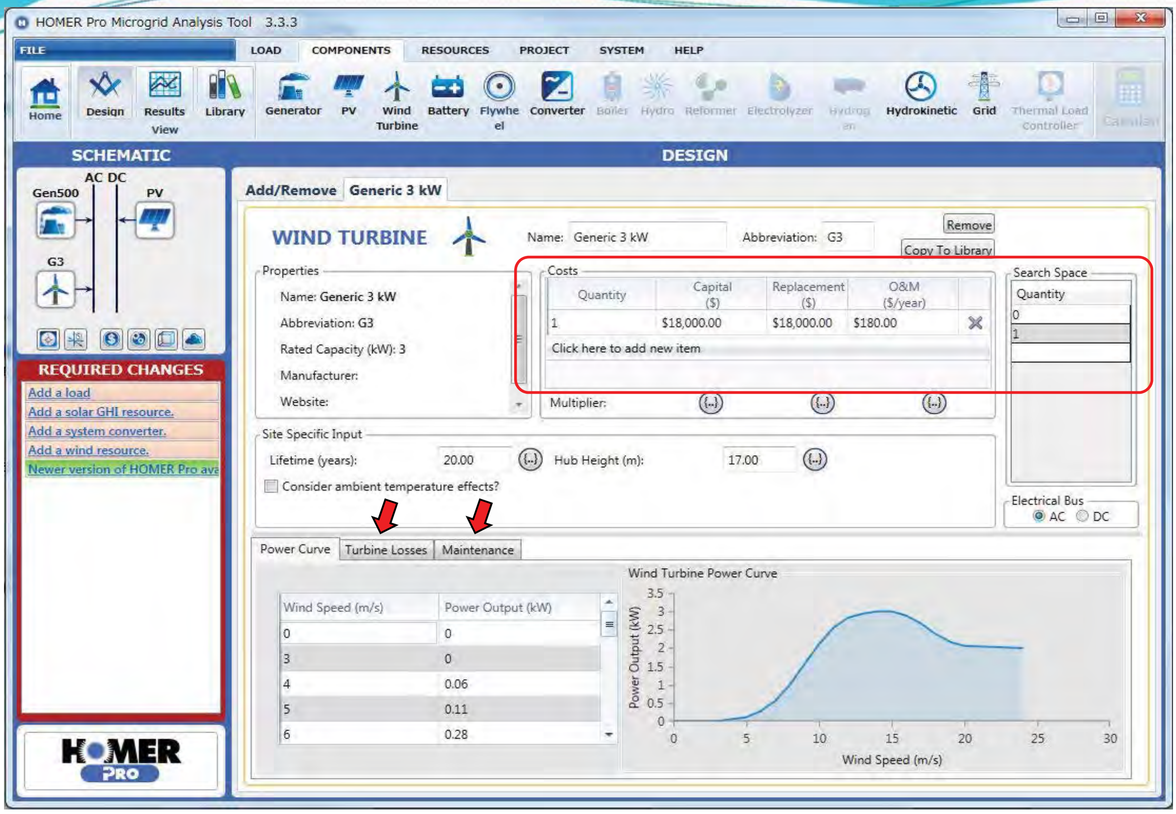
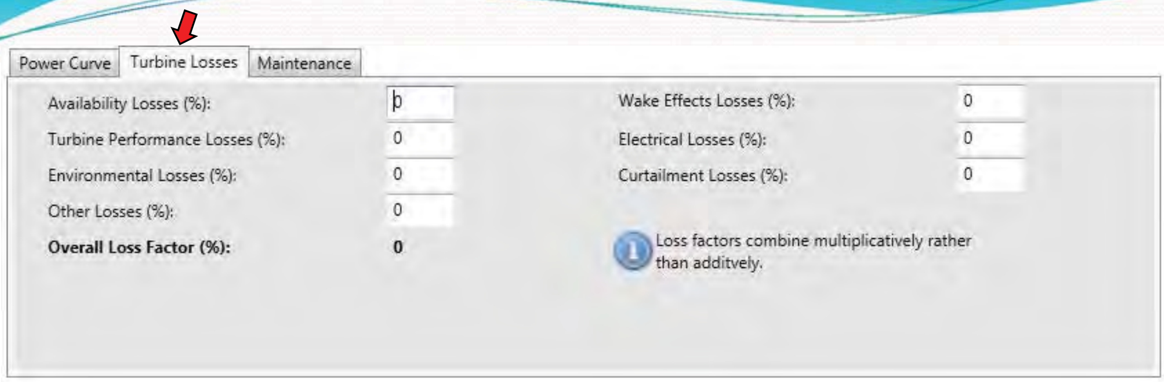
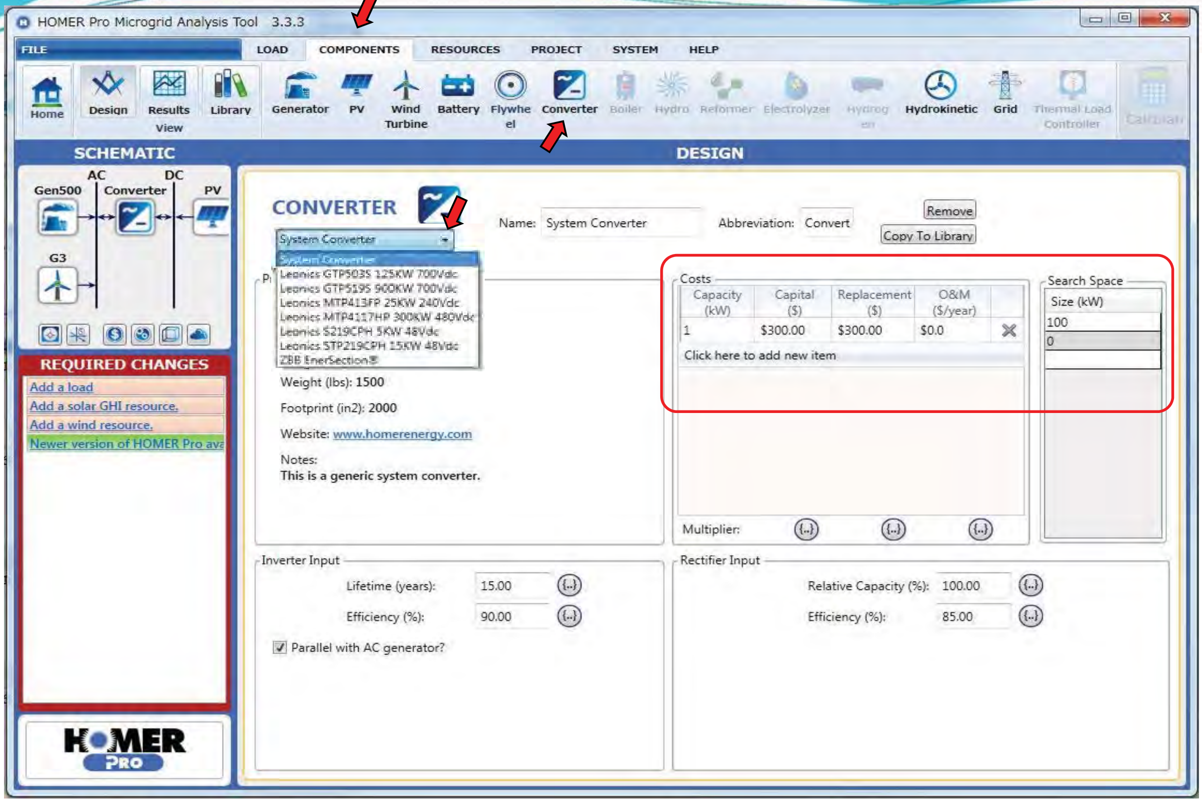
Step 3: System Design (Wind Turbine)



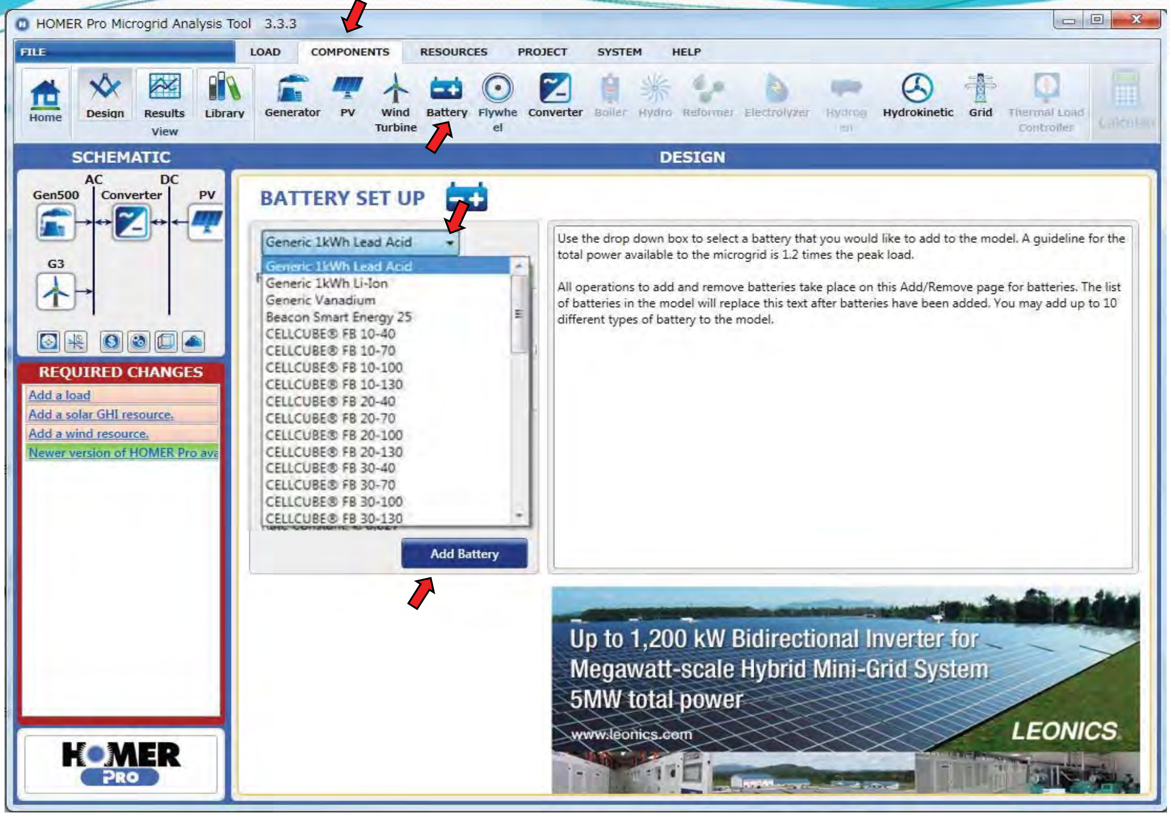
Step 3: System Design (Wind Turbine)



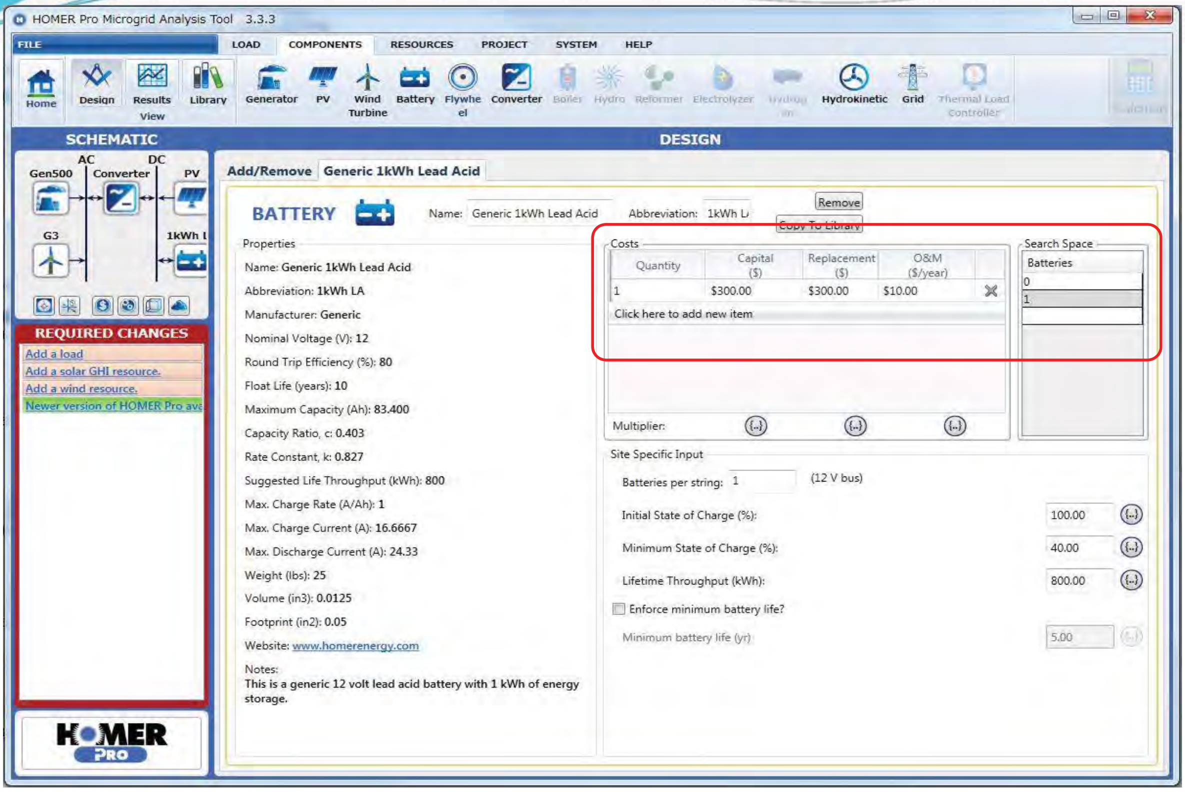
Step 3: System Design (Converter)



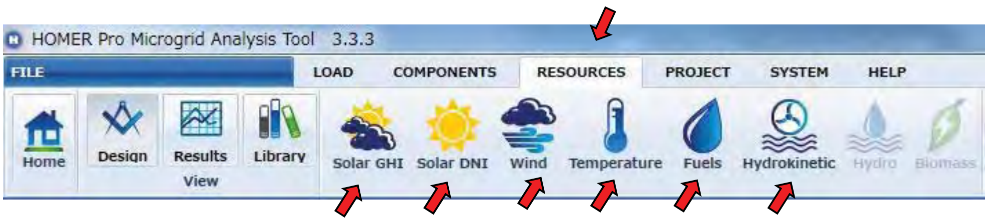
Step 3: System Design (Battery)



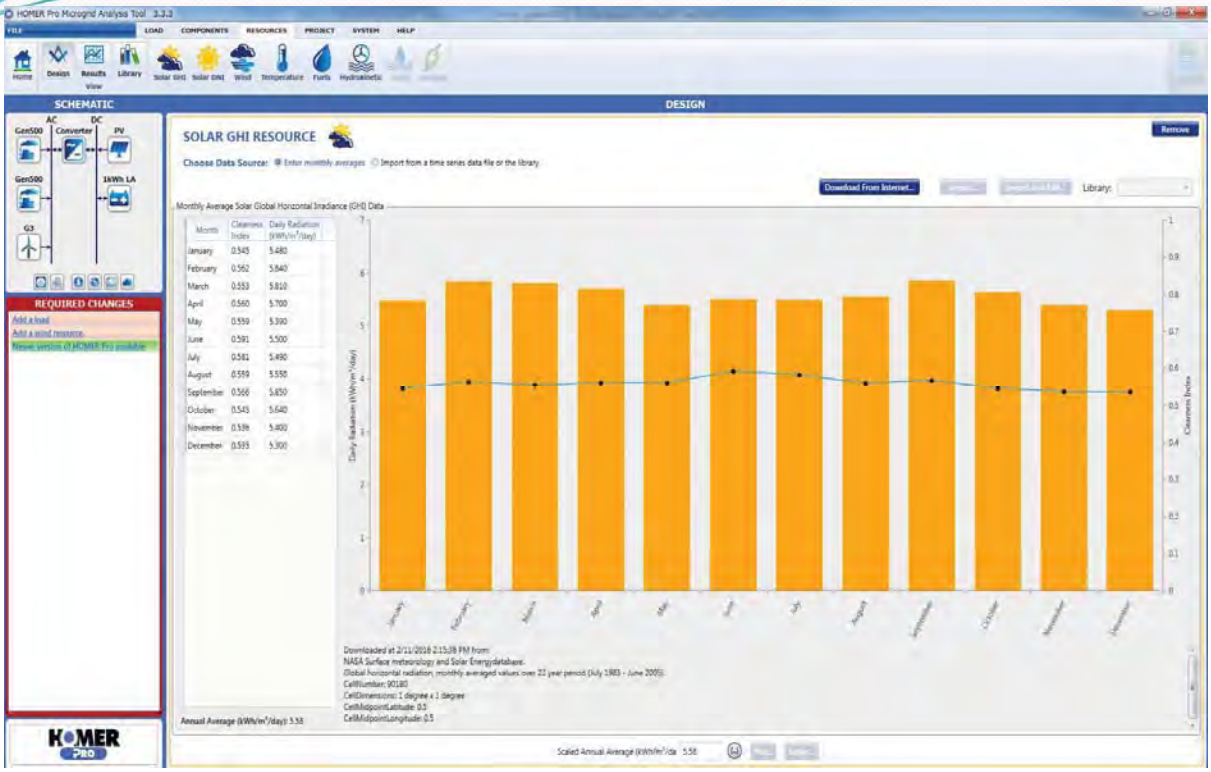
Step 3: System Design (Battery)



Step 4: Resources



Step 4: Resources



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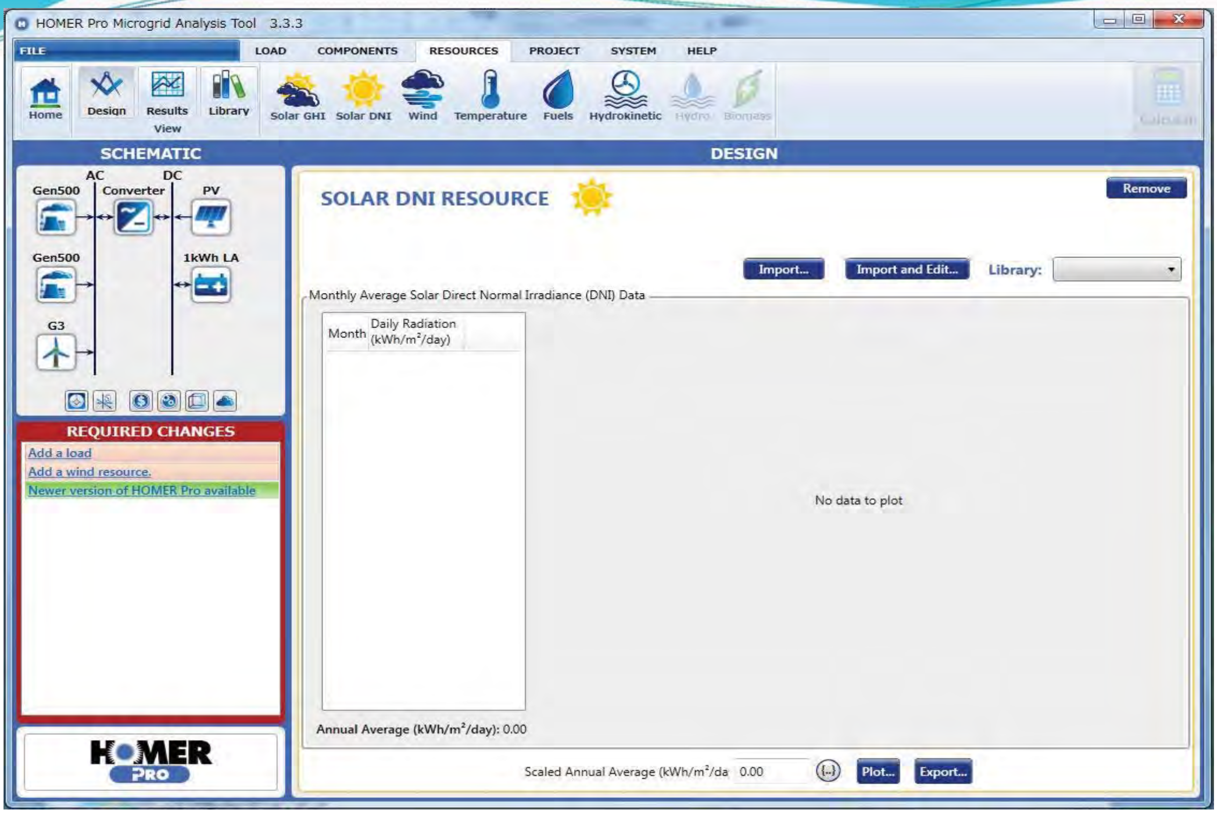
Step 4: Resources



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Step 4: Resources

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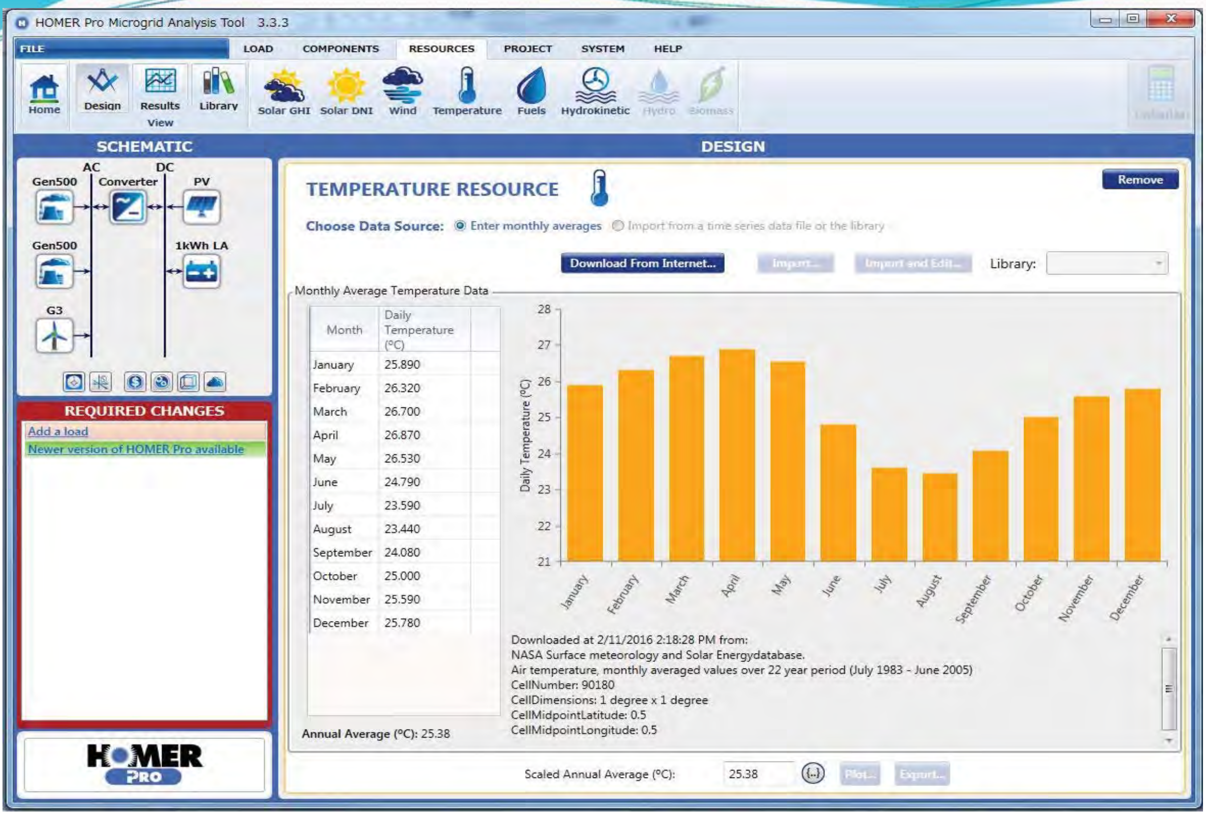
Step 4: Resources



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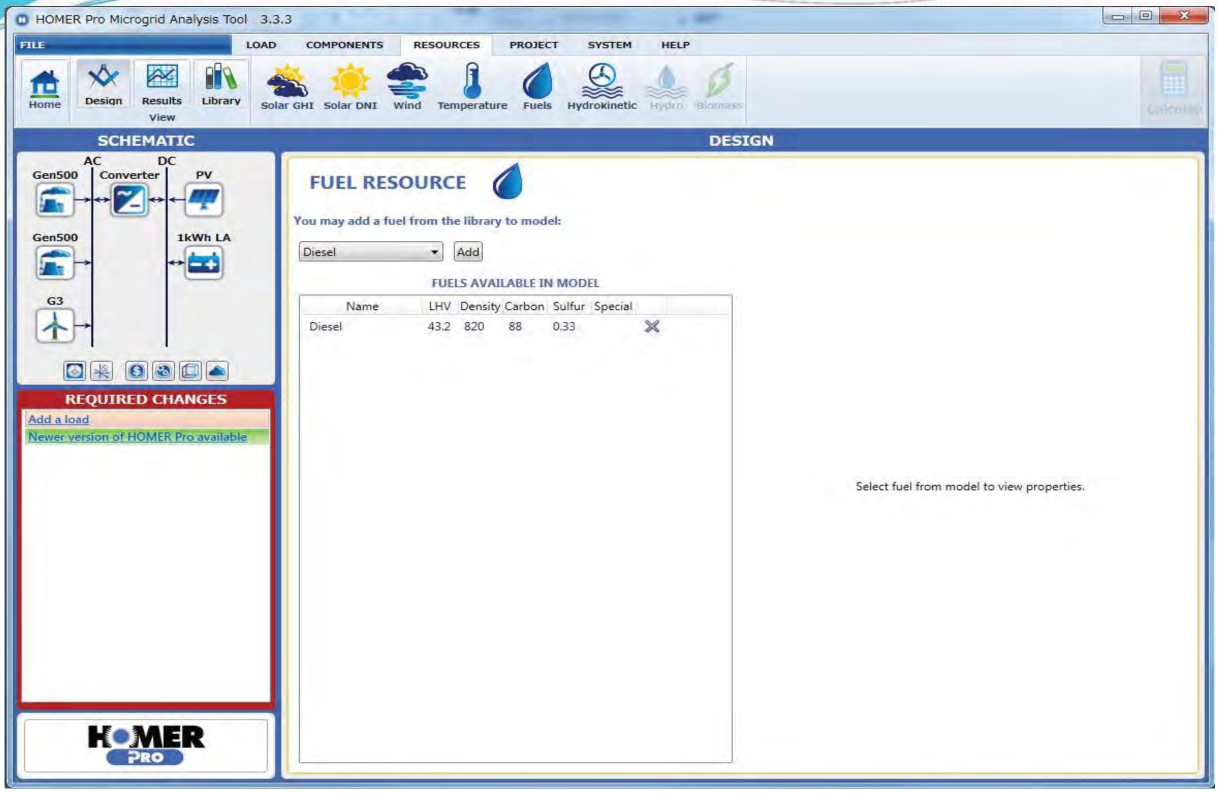
Step 4: Resources



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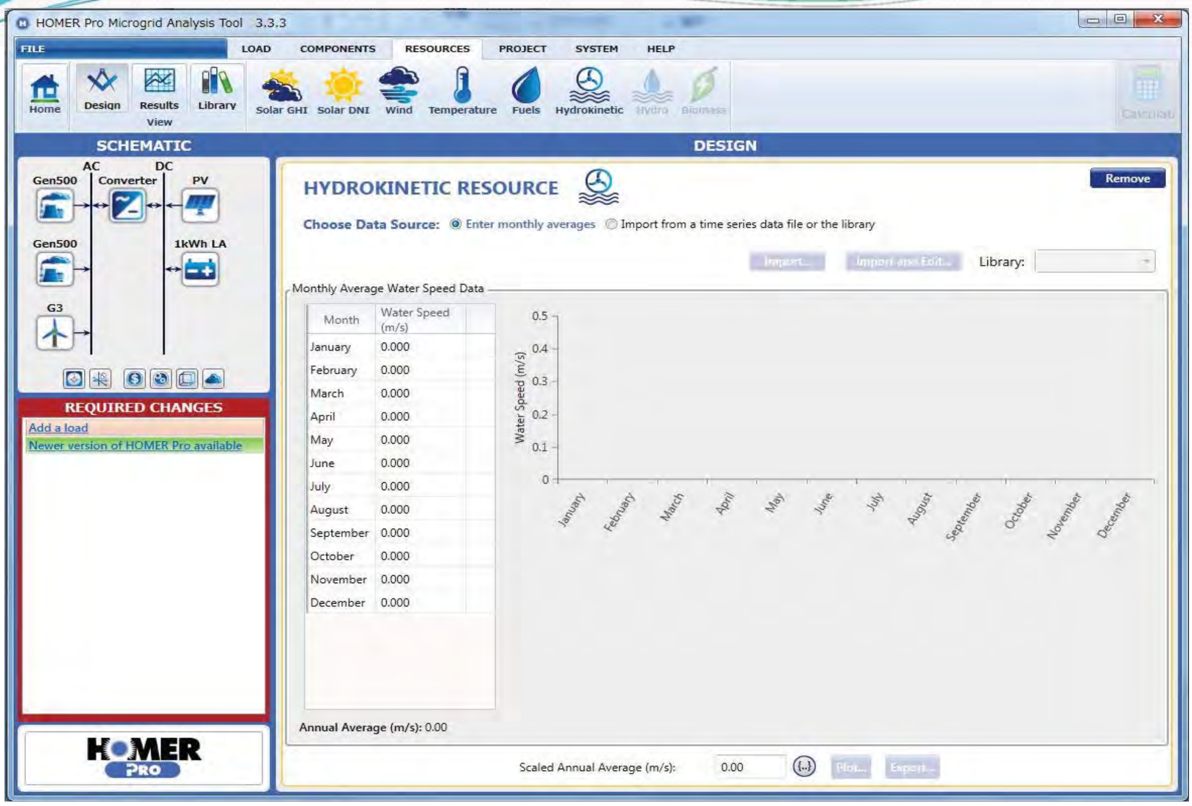
Step 4: Resources



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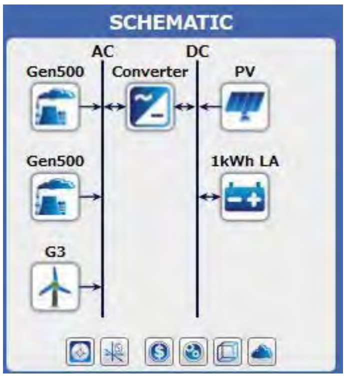
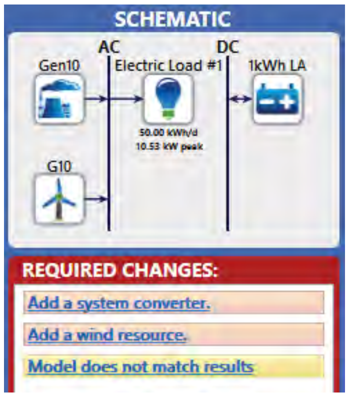
Step 5: Calculation & Analysis

The schematic on the left side of the window :



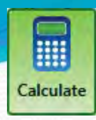


Notice the "Required Changes": add a system converter (since you have components on the AC and DC buses) and add a wind resource (since you have a wind turbine). "Model does not match results" indicates that you have changed the model since the last time "Calculate" was performed. We have added a wind turbine and batteries since then.

Red items are required changes and will prevent calculations. Yellow items are important warnings, and green items are suggestions.

Step 5: Calculation & Analysis

Click the "Calculate" button in the upper-right corner of the HOMER window.



You'll see the results screen, which consists of two related tables. Sensitivity cases are listed in the top table, and simulation runs are listed in the bottom table. You can double click the entry in the lower table to show the detailed "simulation results" for that simulation.

Architecture			Cost				System	Gen10	
	Gen10 (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Fuel (L)	Hours
	15	CC	$1.35	$319,046	$22,939	$22,500	0	16,003	8,760

Export... Optimization Cases: Left Double Click on simulation to examine details. Categorized Overall

Architecture			Cost				System	Gen10	
	Gen10 (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Fuel (L)	Hours
	15	CC	$1.35	$319,046	$22,939	$22,500	0	16,003	8,760

Step 5: Calculations & Analysis

HOMER will run a few thousand simulations, and the results tables will display. In the upper table, each row corresponds to one sensitivity case. For each case, the configuration for the lowest net present cost system is listed.

Click on the column headings to sort by the different parameters. If you select a sensitivity case, the lower table will show all system configurations that were simulated for that case. Infeasible system configurations are not included.

Export... Column Choices... **Sensitivity Cases: Left Click on sensitivity case to see optimization cases.**

Architecture					Cost				System	Gen10	
G10	Gen10 (kW)	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Fuel (L)	Hours
1	15	8	6	CC	$0.81	$191,522	$10,104	$60,900	31	5,883	3,174

Export... **Optimization Cases: Left Double Click on simulation to examine details.** ◉ Categorized ○ Overall

Architecture					Cost				System	Gen10	
G10	Gen10 (kW)	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Fuel (L)	Hours
1	15	8	6	CC	$0.81	$191,522	$10,104	$60,900	31	5,883	3,174
	15	8	6	CC	$1.11	$261,535	$17,841	$30,900	0	11,407	6,104
1	15			CC	$1.17	$275,171	$17,225	$52,500	0	11,579	6,383
	15			CC	$1.35	$319,092	$22,943	$22,500	0	16,012	8,760

Step 5: Calculations & Analysis

Simulation Results

System Architecture: Generic flat plate PV (5200 kW) WT-1 (8) Set A21 (6000 kW) Set A31 (6000 kW) Set A41 (6000 kW) SetB41 (8000 kW) Set B21 (6000 kW) Set B31 (6000 kW) SetB51 (8000 kW) 0SetB11 (6000 kW) Set A51 (8000 kW) Set A61 (8000 kW) Set A11 (6000 kW) System Converter (5200 kW) Load Following

Total NPC: ,302,080.00
Levelized COE: ¥32.03
Operating Cost: ,009,408.00

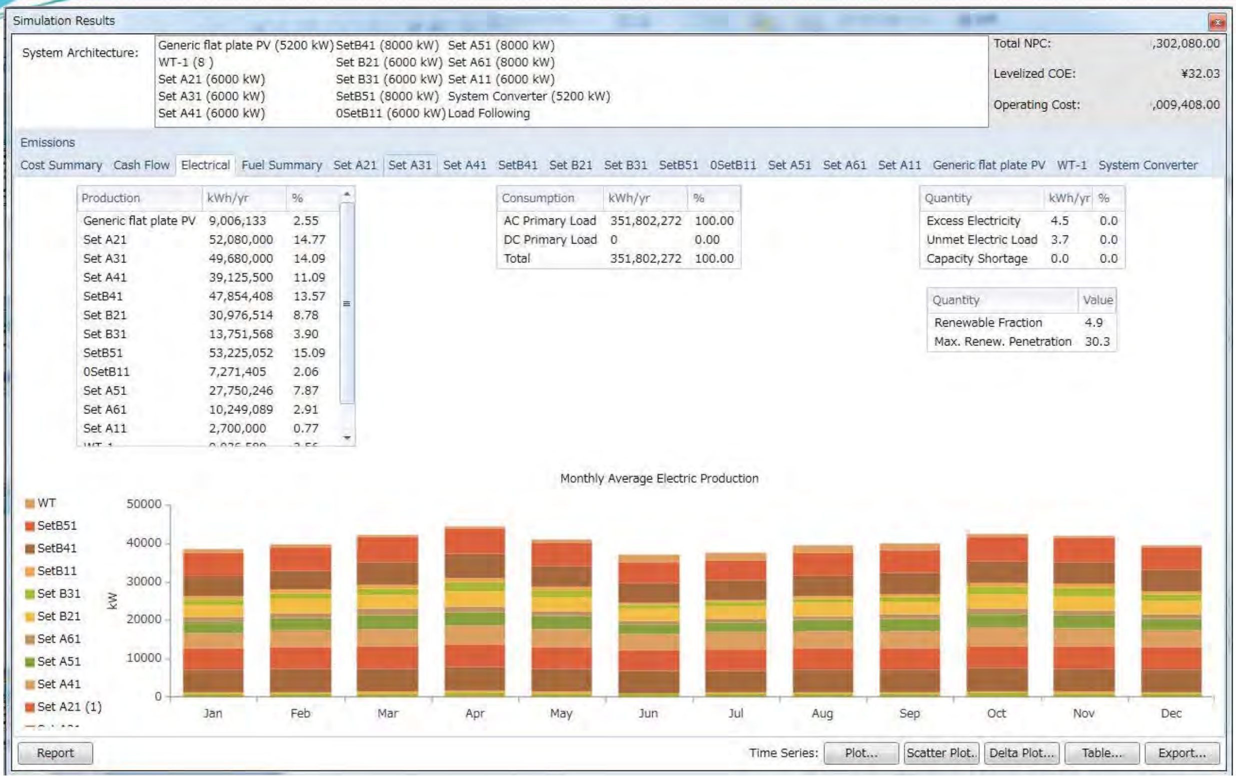
Emissions
Cost Summary | Cash Flow | Electrical | Fuel Summary | Set A21 | Set A31 | Set A41 | SetB41 | Set B21 | Set B31 | SetB51 | 0SetB11 | Set A51 | Set A61 | Set A11 | Generic flat plate PV | WT-1 | System Converter

Cost Type: ◉ Net Present ○ Annualized
Categorize: ◉ By Component ○ By Cost Type
Compare...

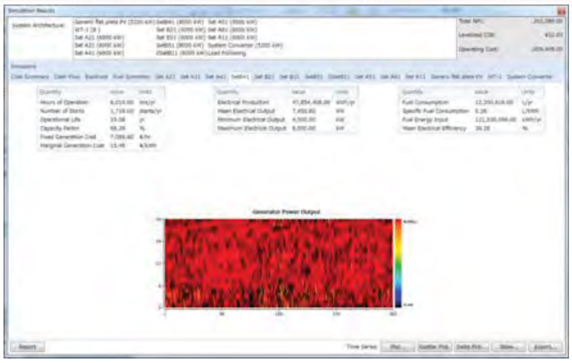
Component	Capital (¥)	Replacement (¥)	O&M (¥)	Fuel (¥)	Salvage (¥)	Total (¥)
Generic flat plate PV	¥0.00	¥0.00	¥0.00	¥0.00	¥0.00	¥0.00
WT-1	¥0.00	¥0.00	¥103,420,088.00	¥0.00	¥0.00	¥103,420,088.00
Set A21	¥0.00	¥170,575,952.00	¥10,098,971,648.00	¥10,995,353,600.00	(¥98,314,416.00)	¥21,166,585,856.00
Set A31	¥0.00	¥161,339,328.00	¥9,633,580,032.00	¥10,488,655,872.00	(¥105,706,464.00)	¥20,177,868,800.00
Set A41	¥0.00	¥0.00	¥7,588,189,696.00	¥8,260,420,608.00	(¥8,833,514.00)	¥15,839,776,768.00
SetB41	¥0.00	¥0.00	¥9,337,281,536.00	¥10,106,651,648.00	(¥24,172,036.00)	¥19,419,760,640.00
Set B21	¥0.00	¥0.00	¥6,244,375,552.00	¥6,553,942,528.00	(¥30,178,090.00)	¥12,768,141,312.00
Set B31	¥0.00	¥0.00	¥3,255,405,568.00	¥2,938,075,648.00	(¥77,653,600.00)	¥6,115,828,224.00
SetB51	¥0.00	¥208,717,744.00	¥12,531,409,920.00	¥11,367,731,200.00	(¥145,919,280.00)	¥23,961,939,968.00
0SetB11	¥0.00	¥0.00	¥2,326,951,424.00	¥1,589,343,744.00	(¥92,400,760.00)	¥3,823,894,528.00
Set A51	¥0.00	¥0.00	¥8,693,491,712.00	¥6,054,447,616.00	(¥34,397,720.00)	¥14,713,542,656.00
Set A61	¥0.00	¥0.00	¥3,929,445,632.00	¥2,278,565,632.00	(¥110,067,784.00)	¥6,097,944,576.00

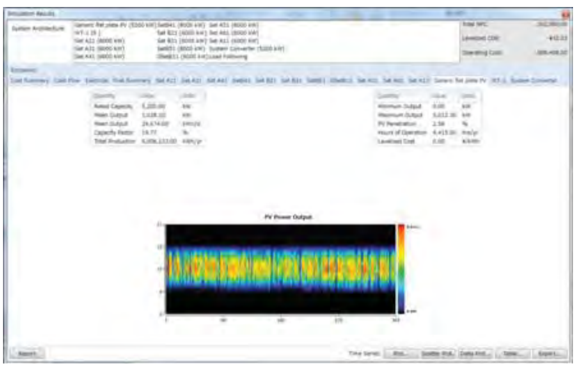
Report | Time Series: Plot... | Scatter Plot... | Delta Plot... | Table... | Export...

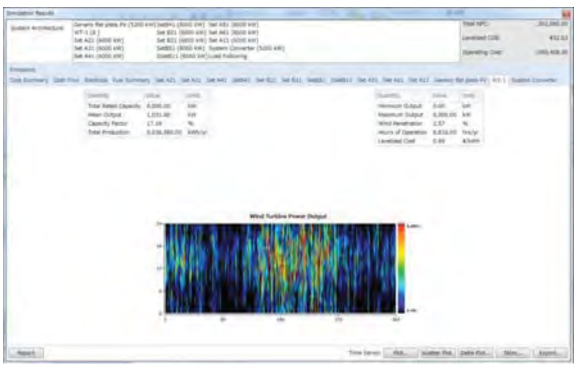
Step 5: Calculations & Analysis



Step 5: Calculations & Analysis







You can also edit the search space in the search space editor. Go to the System tab and click on the "Search Space" button. You will see the values 16 and 24 that you just added to the battery search space.
Add the number 2 to the column "G10 Quantity" to include 2 in the wind turbine search space.
Add 10 and 20 kW to the "Gen10 Capacity" search space. Click OK.

Search Space

This table displays the values of all optimization variables. HOMER simulates the set of all possible combinations of these variables. You can also edit the search space for each component individually in the Component Input menus.

Converter Capacity (kW)	1kWh LA Strings (#)	Gen10 Capacity (kW)	G10 Quantity (#)
6.00	0.00	15.00	0.00
0.00	8.00	0.00	1.00
12.00	16.00	10.00	2.00
	24.00	20.00	

Thank you very much for your attention

ご清聴ありがとうございました

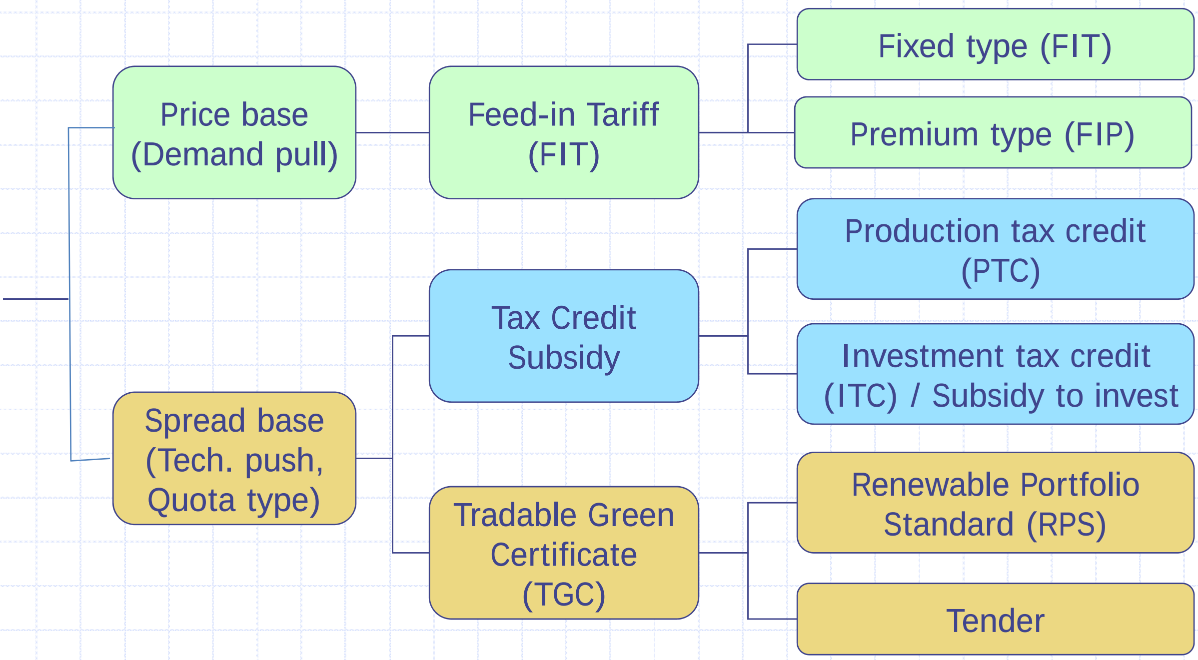
Feed-In Tariff System

August, 2015

Okinawa Enetech

Supporting Instruments for Renewable Energy (RE)

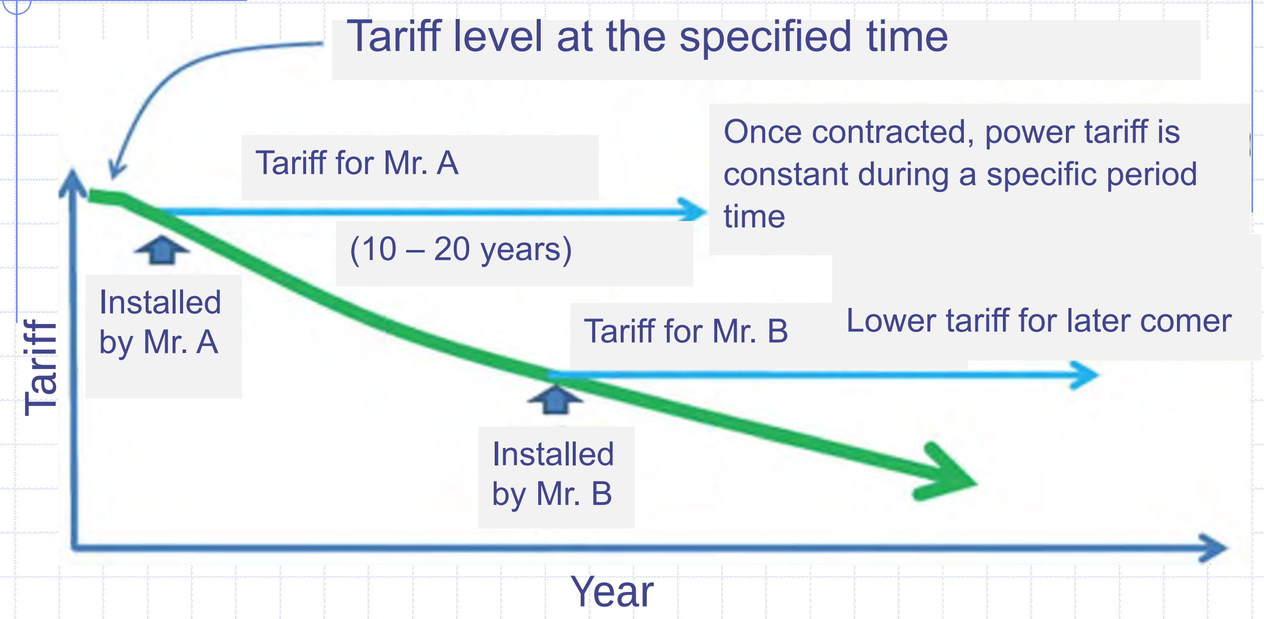
- To promote RE



Feed-In Tariff (FIT)

- An governmental assistance to accelerate dissemination of RE
  - Provides profit by lowering investor's cost at initial stage

Mechanism of FIT



- On installation, tariff during a specific period time is determined.
  - Easy to estimate rough balance at initial stage
- Lowered tariff in later stage is not applied to installed facilities.
- Dissemination speed can be controlled by tariff.

Feed-In Tariff (FIT)

- An governmental assistance to accelerate dissemination of RE
  - Provides profit by lowering investor's cost at initial stage

- Allows RE generators (auto producer) to sell their electricity at a fixed price per kWh
  - Spain and Germany have been applying FIT systems during the last years very successfully
  - But in Japan, ...

Japanese Case

- FIT has been started in 2012. (after Fukushima)
  - 42 JPY (4.43 SCR, 0.34 USD) / kWh for PV, No total limit
  - Resource is avoided fuel cost + surcharge on tariff

⇒ Subdivision business of Mega-solar

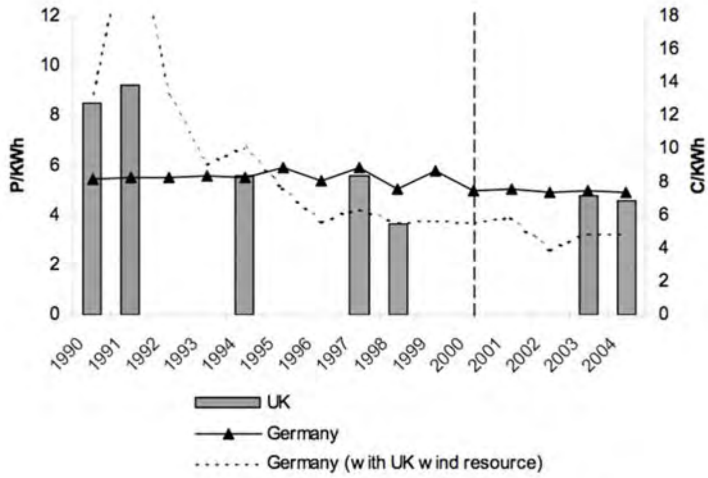
- Elec. Business Act doesn't cover RE < 50kW: no strict regulation

- Revised system in April 2014
  - 38 JPY JPY (4.01 SCR, 0.31 USD) / kWh for PV
  - Prohibited subdivision of mega-solar

⇒ In march, application of 27,000MW PV received

- But, revision was too late.
  - From September 2014, 5 utilities refused new PV connection
  - Unlimited curtailment of PV output w/o compensation

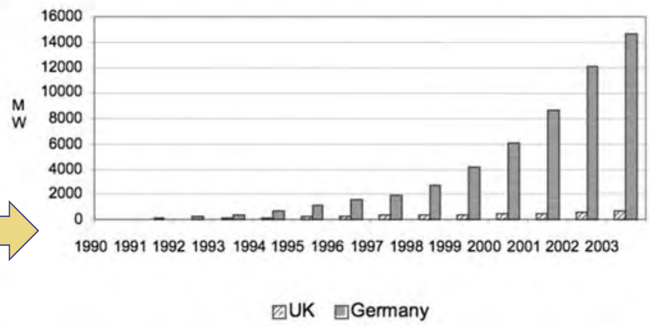
FIT (Germany) vs Quota (UK): Wind Gen.



Striking effect of FIT in cost and dissemination, even though better wind condition in UK.

Anticipated Price of Wind Energy in Germany and the UK

Installed Capacity in Germany and the UK (1990 - 2003)



Lucy Butler et. al. "Comparison of Feed in Tariff, Quota and Auction Mechanisms to Support Wind Power Development"

World trend (Upper-middle income countries - 1)

	REGULATORY POLICIES						FISCAL INCENTIVES				PUBLIC FINANCING	
	Feed-in tariff (incl. premium payment)	Electric utility quota obligation/ RPS	Net metering	Biofuels obligation/ mandate	Heat obligation/ mandate	Tradable REC	Capital subsidy, grant, or rebate	Investment or production tax credits	Reductions in sales, energy, CO_2, VAT, or other taxes	Energy production payment	Public investment, loans, or grants	Public competitive bidding
UPPER-MIDDLE INCOME COUNTRIES $$$												
Algeria	●											
Argentina	●			●			●	●	●	●	●	●
Belarus									●			
Bosnia & Herzegovina	●						●					●
Botswana							●		●			
Brazil				●	○			●	●		●	●
Bulgaria	●			●			●		●		●	
Chile		●			●		●		●		●	
China	●	●		●	●		●			●	●	●
Colombia				●					●			
Costa Rica	●											
Dominican Republic	●		●		●		●	●	●			●
Ecuador	●								●		●	
Grenada									●			

● national-level policy
○ state/provincial policy

World trend (Upper-middle income countries - 2)

UPPER-MIDDLE INCOME COUNTRIES	REGULATORY POLICIES						FISCAL INCENTIVES				PUBLIC FINANCING	
	Feed-in tariff (incl. premium payment)	Electric utility quota obligation/ RPS	Net metering	Biofuels obligation/ mandate	Heat obligation/ mandate	Tradable REC	Capital subsidy, grant, or rebate	Investment or production tax credits	Reductions in sales, energy, CO_2, VAT, or other taxes	Energy production payment	Public investment, loans, or grants	Public competitive bidding
Iran	●							●		●		
Jamaica				●				●	●			
Jordan			●	●					●		●	●
Kazakhstan	●					●						
Latvia	●			●					●		●	●
Lebanon			●						●			
Lithuania	●										●	
Macedonia	●										●	
Malaysia	●	●		●					●		●	●
Mauritius							●					
Mexico			●		●			●			●	●
Palau		●										
Panama	●		●					●	●	●		●
Peru	●			●					●			●
Romania		●		●		●			●		●	
Russia							●					
Serbia	●						●					
South Africa							●					●
Thailand	●			●					●		●	
Tunisia			●				●		●		●	
Turkey	●						●					
Uruguay	●		●	●	●		●		●		●	●

$$$

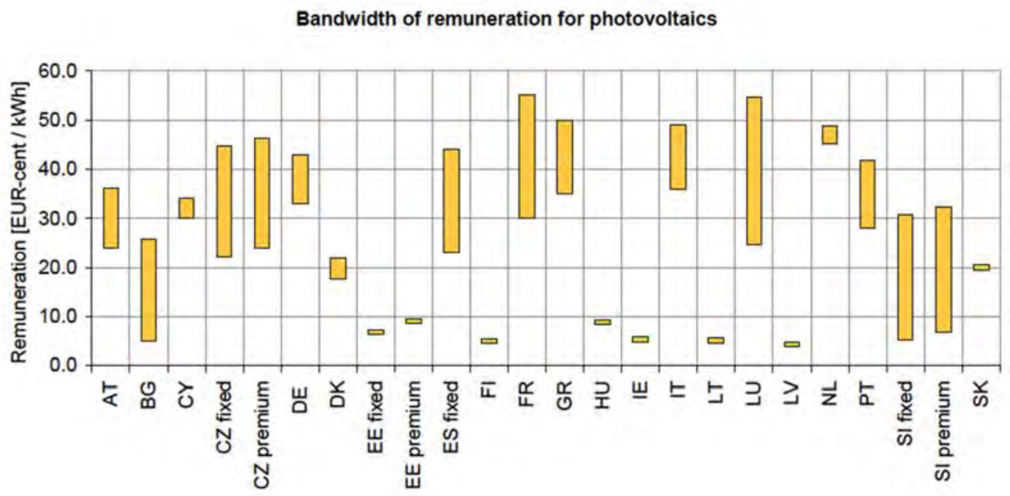
World Trend

- Beginning of 2012
  - 65 countries and 27 states/provinces use FIT.
    - New comer: Netherland, Syria, Palestine and Rwanda
  - 18 countries and 58 states/provinces/ regions use Quota/RPS.
    - US, India, Canada …

- We can apply;
  ①FIT
  ②Other instruments, such as investment subsidy, low interest loan, tax credit and etc.,
  ③①+②

FIT design: General condition

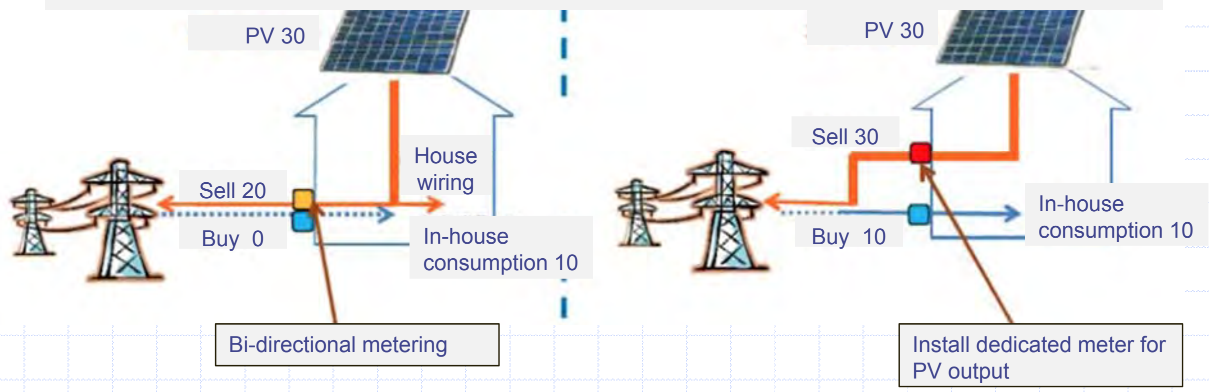
- Tariff & duration
  - Based on generation cost or avoided external cost



- Limit of total RE volume & revision of tariffs
  - Monitoring of PV penetration is essential.

Net Metering (1)

Net Metering (one meter, bi-directional)	FIT



Good for energy saving	Small effect for energy saving
No change for existing wiring	Need change on existing wiring
NG for small energy seller	Good for small energy seller
Typical for residential house	Must for public and industrial user
	Utility and public owned facility

Net Metering (2)

- Measured with a bi-directional meter or a pair of unidirectional meters spinning in opposite directions.

Advantages	Disadvantages
Additional financial incentives for RE	Revenue losses for electricity utilities might induce them to raise their prices
Awareness for energy consumption is enhanced	
Incentives for consumers to adjust their load to their generation	Remuneration too low for PV without further incentives
Decentralization and higher efficiency in electricity-use	Profitable to producers only if consumption is not considerably lower than production in case energy consumed is compensated with energy produced (see Italy)

FIT by Energy Nautics: Methodology & Rates

- With parameters shown in APPENDIX D
- FIT duration: 15 and 20 years
- W/ and w/o PV rebate
- Seychelles FIT MODEL (Excel) with annual 10% of ROE as a Goal
- FIT rates is calculated by Goal Seek function of Excel

Table 61: Proposed FIT Rates for Solar PV and Small Wind

Contract Length & Rebate Assumption	Solar PV 1-10kW	Solar PV 11-100kW	Wind 1-100kW
15-Year (With Rebate)	2.59	3.87	n/a
15-Year (Without Rebate)	3.30	4.05	5.49
20-Year (With Rebate)	2.33	3.52	n/a
20-Year (Without Rebate)	2.97	3.69	4.97

FIT by Energy Nautics: Impact to PUC (1)

Table 66: Summary of deployment scenario assumptions

Deployment Scenario	Residential-scale Solar PV (1-10kW)	Commercial-scale Solar PV (11-100kW)	Commercial-scale Wind (1-100kW)	Total
Scenario A: Residential-Scale Solar	# projects: 1000 System size: 5 kW 433 projects receive PV rebate **Total capacity: 5 MW**	None	None	# projects: 1000 **Total capacity: 5 MW**
Scenario B: Commercial-Scale Solar	None	# projects: 100 System size: 50 kW All receive PV rebate **Total capacity: 5 MW**	None	# projects: 100 **Total capacity: 5 MW**
Scenario C: Residential & Commercial Solar & Wind	# projects: 150 System size: 5 kW All receive PV rebate **Total capacity: 0.75 MW (15%)**	# projects: 75 System size: 50 kW All receive PV rebate **Total capacity: 3.75 MW (75%)**	# projects: 10 System size: 50 kW **Total capacity: 0.5 MW (10%)**	# projects: 235 **Total capacity: 5 MW**

FIT by Energy Nautics: Impact to PUC (2)

Table 67: Summary of Policy Cost Scenarios to PUC (in Millions SR)

Deployment Scenarios:	Policy Scenarios: Scenario 1: Gross FIT	Scenario 2: Net Metering	Scenario 3: No Policy
Scenario A: Residential-Scale Solar	$(0.4)	$(7.6)	$(11.4)
Scenario B: Commercial-Scale Solar	$(6.2)	$(14.7)	$(14.7)
Scenario C: Residential & Commercial Solar & Wind	$(5.6)	$(12.6)	$(13.9)

- Scenario 3 (No Policy): No reverse power flow, no power selling
- Scenario 2, 3 could not be got by re-calculation.
- Reduced fuel cost is added in this analysis. However, this is not valid in Profit/Loss Table calculation in accounting.

FIT by Energy Nautics: Conclusion

- Gross FIT is the cheapest measure
  - Recommend 20 years duration
  - Parallel with existing Net-Metering program
    - Choose between Gross FIT Program or Net Metering in near term
    - Phase-out Net-Metering in 5 years
- More residential PV rather than commercial one
- More PV rather than Wind

FIT by Energy Nautics: Appendix

- APPENDIX E: Sensitivity analysis
  - Parameters
    - PV cost: $2.10/W or $3.20/W
    - Full Load Hour: 1400 FLH or 1500 FLH
  - Get FIT rates and then estimate impacts to PUC
- APPENDIX F: Impacts to installer & PUC in 100kW PV installation
  - Parameters
    - Residential 100kW or Commercial 100kW
  - With very cheap FIT rates
  - From the view point of installer, no merit in FIT.
    - No Policy is better.

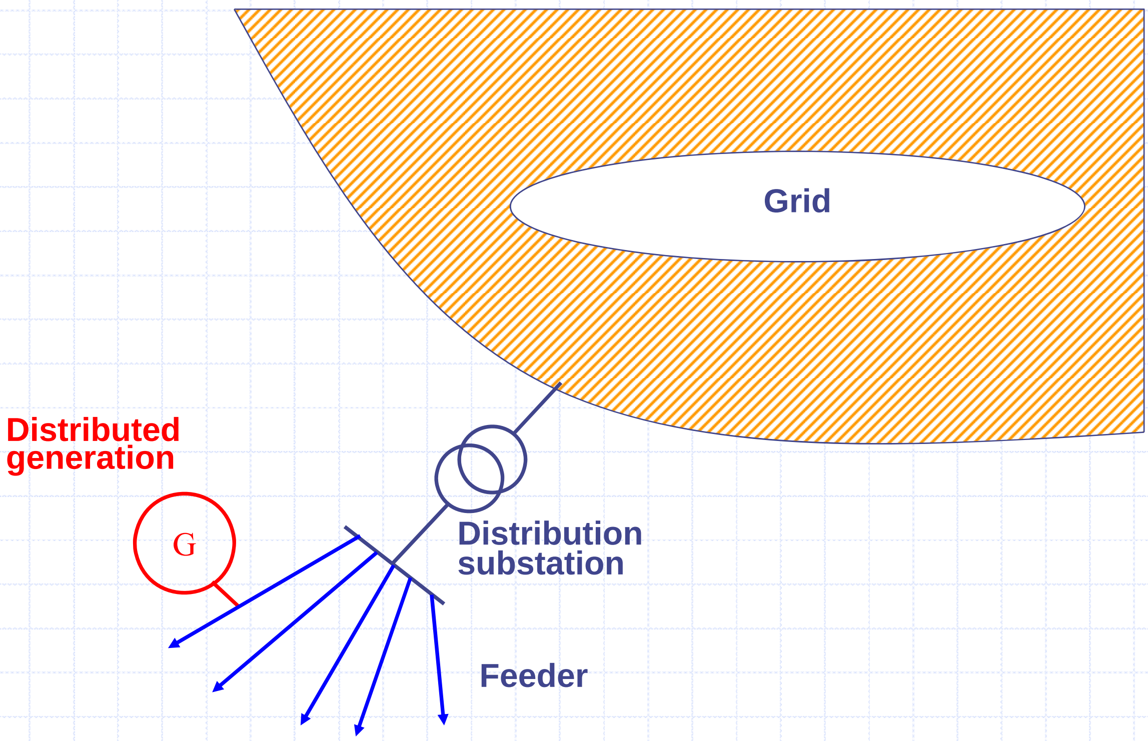
Grid Code

- Technical guideline for grid connection -

August, 2015

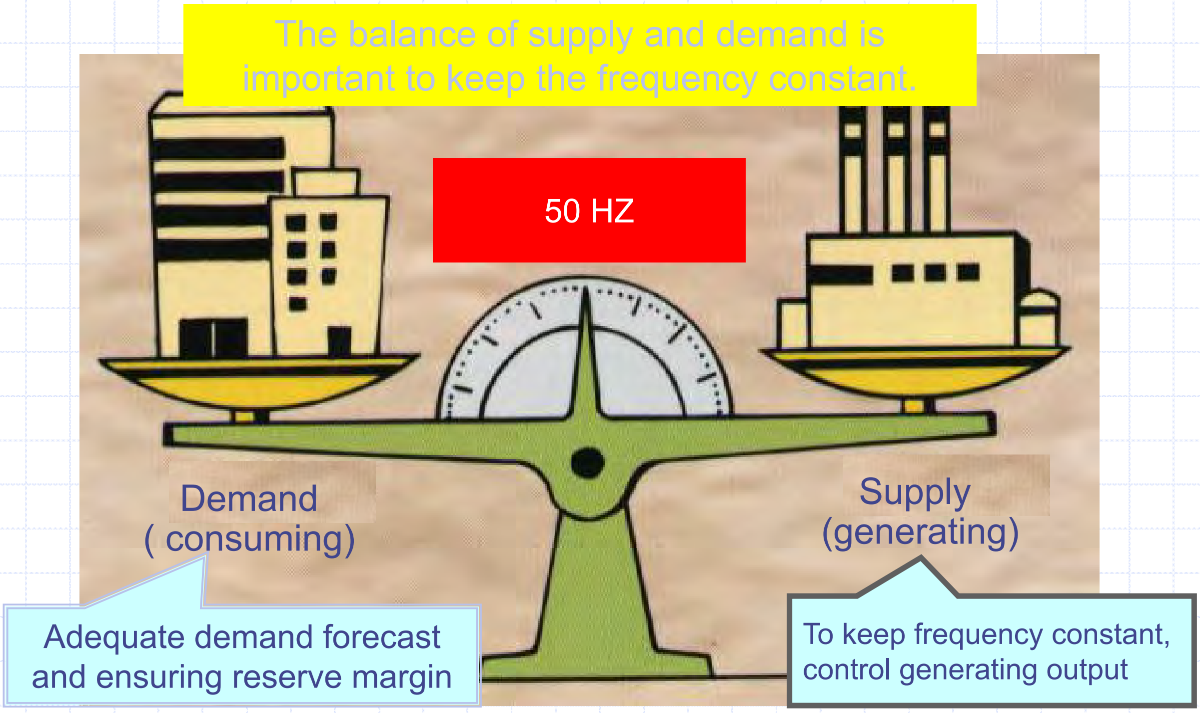
Okinawa Enetech

Distributed Generation



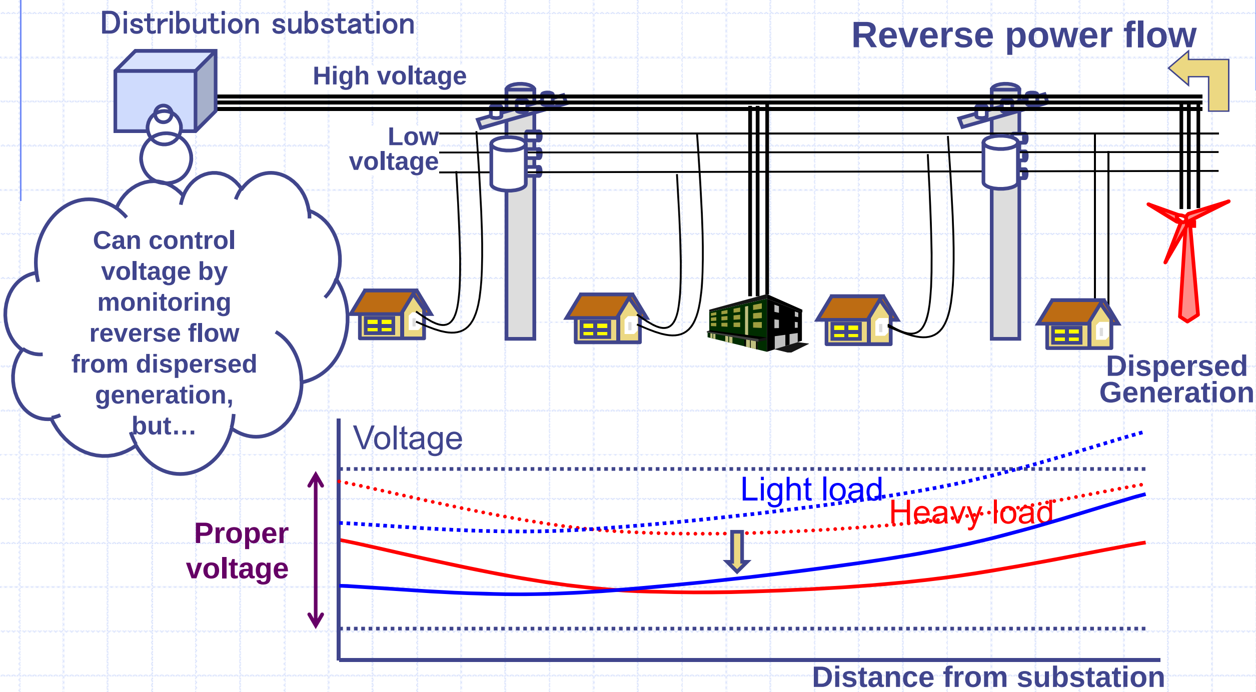
Frequency Control

To keep the frequency constant, the amount of electric power supply and demand must be the same.

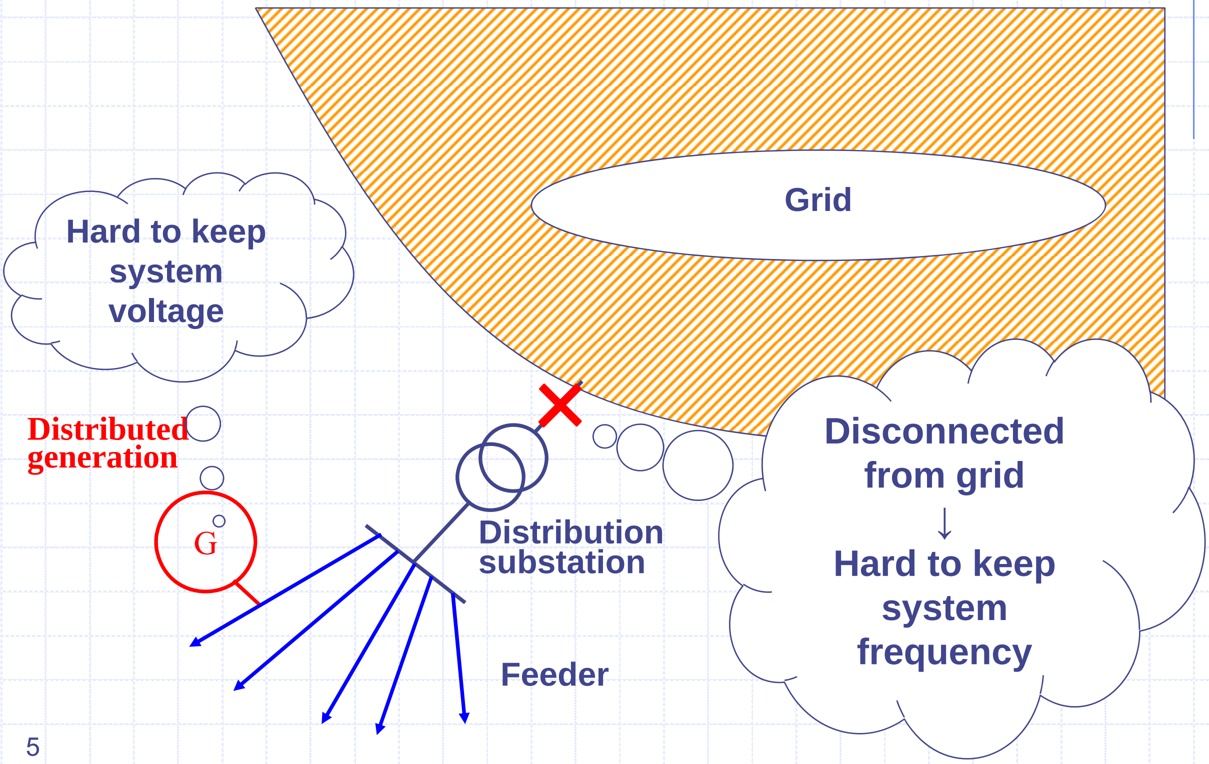


Feeder Voltage

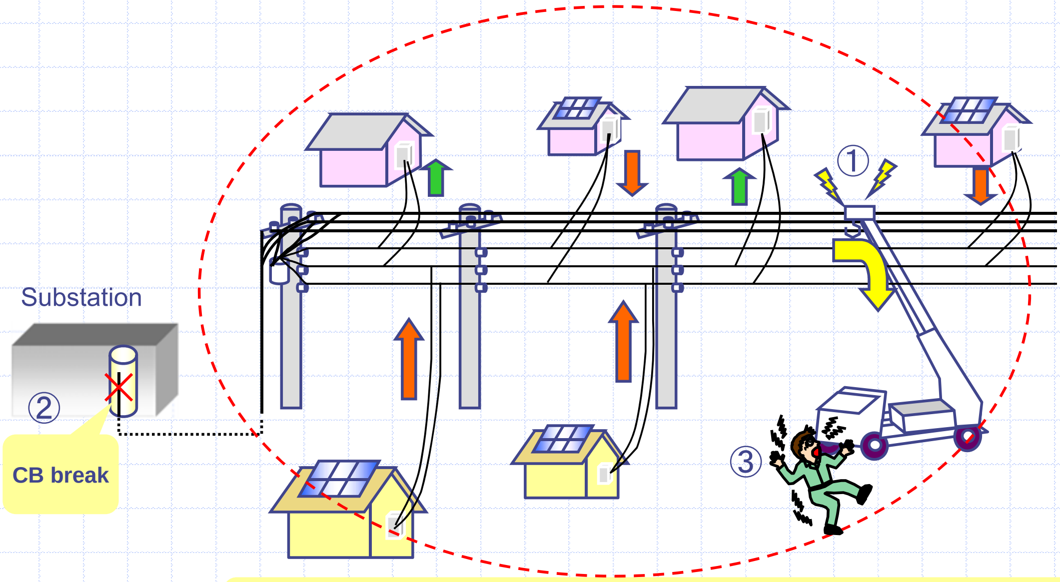
<u>Voltage control of feeder by electric power company</u>



The Merit of Grid interconnection (1)



Islanding Operation



① Crane touches feeder. ② Fault detection, then CB break.

※PV system is running (islanding operation)

③ Threat of electrical shock for worker near crane and public.

Grid Code: Major requirements

- **Grid parameters**
  - Frequency
  - Voltage
- **Power quality**
  - DC injection
  - Flicker
  - Harmonics
  - Surge withstand capability
  - Power factor

• Possibility of harmful effect to other customers via grid
• Become harder to operate grid in maintaining power quality and/or maintenance

- **Safety and isolation**
  - Safe intentional islanding operation
  - Isolation device
  - Operation during utility system outage
  - Control of faults when in grid-connected mode

• Public safety should be assured especially for distribution line which is easily accessible to public.

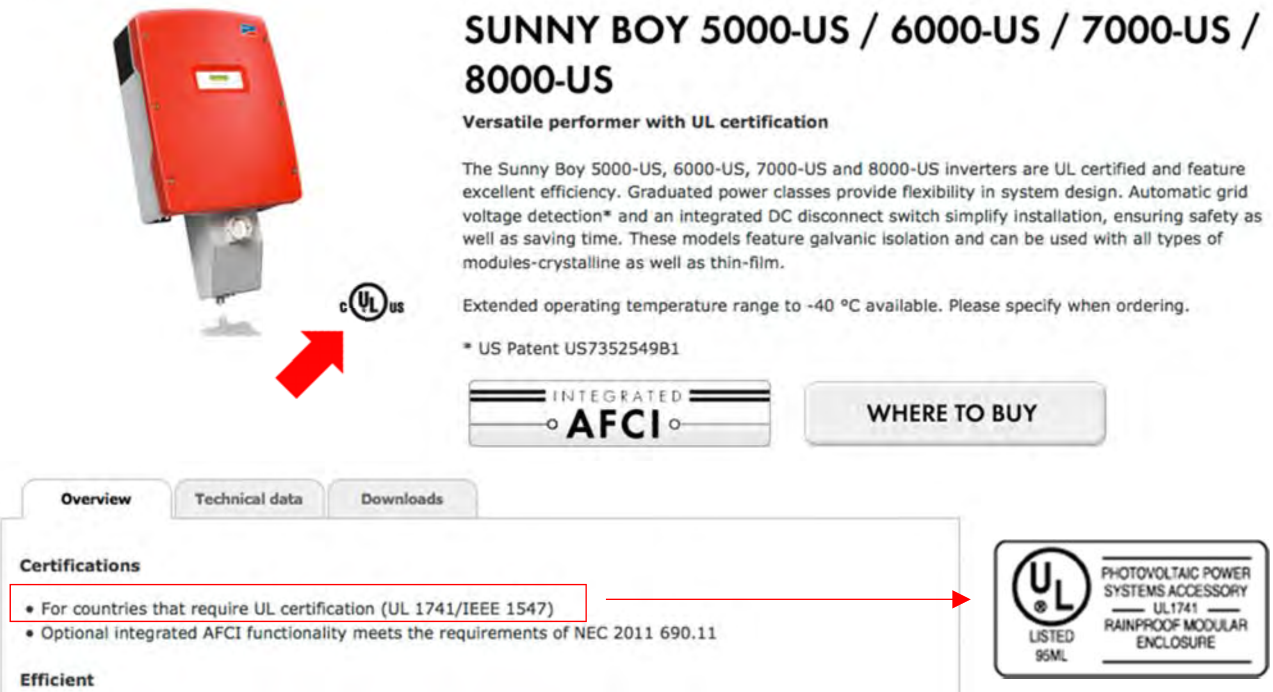
- **Protection requirement**
  - Voltage regulation
  - Frequency disturbance
  - Unintentional islanding detection
  - Fault ride through
  - Disconnection
  - Re-connection and synchronization
  - Grounding
  - Short circuit capacity
- **Others**
  - Harmonization of technical standards among and within countries

Certificate of Inverter

- UL174 / IEEE1547
  - Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
- CAN/CSA-C22.2 NO. 107.1
  - General Use Power Supplies
- AS4777.2 & .3
  - Grid connection of energy systems via inverters Part 2: Inverter requirements, Part 3: Grid protection requirements
- VDE0126-1-1
  - Automatic disconnection device between a generator and the public low-voltage grid
- TÜV / IEC62109-1 IEC62109-2
  - Safety of power converters for use in photovoltaic power systems - Part 1: General requirements, Part 2: Particular requirements for inverters
- EN62109-1 EN62109-2
  - Safety of power converters for use in photovoltaic power system -Part 1: General requirement, Part 2: Particular requirements for inverters

UL 1741 certificate: a recommended inverter

For example, SMA Sunny Boy



Detection of islanding operation

Example of detection method

Active detection

- Add disturbance signal from generator to grid continuously
- On power outage, detect increased response to disturbance signal
- Secure detection, but need several seconds

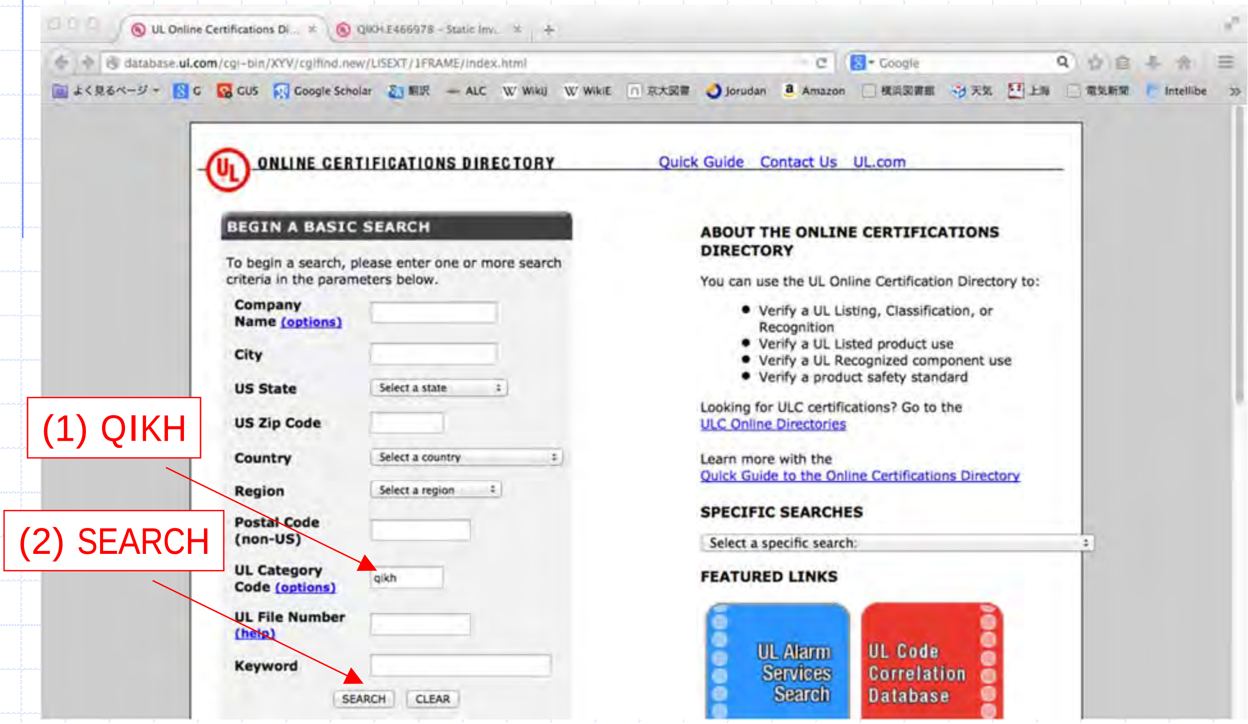
Passive detection

- On power outage, detect phase change of P, Q balance
- Possible instant detection
- But used as backup of active detection for grid connected generator in high voltage, because of little change at rotating generator

→ Use multiple detection to detect surely

Search inverter w/UL 1741 certificate

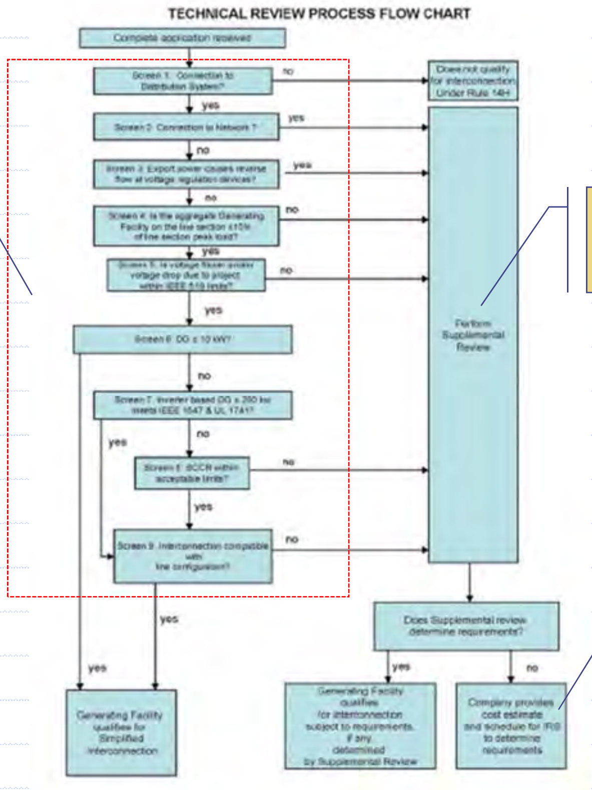
http://database.ul.com/cgi-bin/XYV/cgifind.new/LISEXT/1FRAME/index.html



Grid Connection Approval

- The application Process
- Who is responsible for analysis/approval
- Demarcation of cost for installation & connnection
- Safety and protection requirement
- Testing and commissioning procedure
- Communication and information exchange

Tech. review process flow chart (HECO)



Initial Technical Review

Supplemental Review

Interconnection Requirement Study

SGC13: System Voltage (1)

- The distribution system network operates at the nominal voltages indicated in the table below:

Low Voltage (LV)	230 Volts – phase to neutral 400 Volts – phase to phase
Medium Voltage (MV)	11,000 Volts (11kV) 33,000 Volts (33kV)

- The low voltage range tolerance is 230V +/- 10% (phase to neutral). The resulting voltage at different points on the system is expected to be in accordance with the table below under steady state and normal operating conditions.

Nominal Voltage (phase-phase)	Steady-state Tolerance
400V	+/- 10%
11kV	+/- 10%
33kV	+/- 10%

- Generators may not disconnect due to voltage deviation as long as the system voltage remains within the given ranges.

SGC12: Frequency Rating and Limits (1)

- The nominal frequency of the distribution system voltage is 50Hz. The deviation of the average frequency over a 30-day period should be kept as close to zero as possible by PUC. Under normal operating conditions the mean value measured over 10s of the fundamental frequency shall be within a range of: 50Hz – 5/+3% (i.e. 47.5 to 51.5Hz). Generators shall not disconnect due to frequency deviation as long as the system frequency remains within the following ranges:
  - 47.0 Hz – 47.5 Hz: for 20 seconds
  - 47.5 Hz – 49.0 Hz: for 90 minutes
  - 49.0 Hz – 51.0 Hz: unlimited
  - 51.0 Hz – 51.5 Hz: for 90 minutes
  - 51.5 Hz – 52.0 Hz: for 15 minutes

SGC18: Maximum Frequency Gradient

- Generators shall withstand frequency gradients of up to 2.0 Hz per second in either direction without tripping as long as the steady state frequency limits are not exceeded.

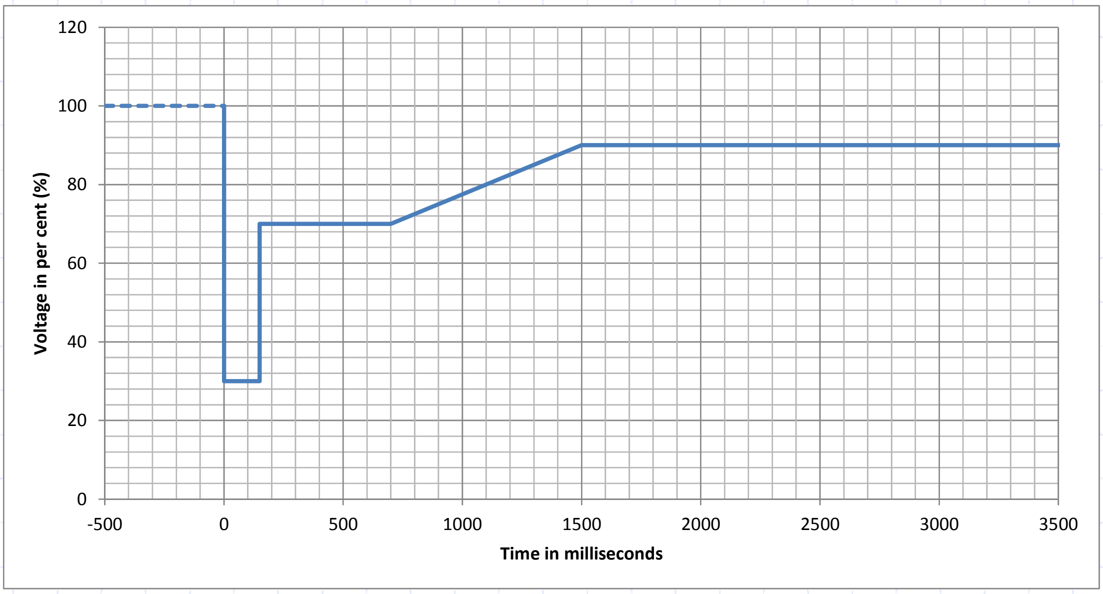
- **Rationale**
- Measurement data from Mahé collected by Energynautics suggest that frequency gradients of more than 1.0 Hz per second can occur occasionally. Such steep frequency gradients are due to the low inertia in the system and should not cause generator tripping, as significant loss of generation would lead to more severe problems.

SGC24: Power factor control mode (1)

- Generation plants that allow control of reactive power output shall operate at a fixed power factor to be assigned by PUC upon installation. If no specific other value is given by PUC, the desired fixed power factor shall be 0.9 (overexcited). Any other power factor assigned by PUC must be within the range specified as required in SGC14. Upon request by PUC, the generator operator shall adjust the configured power factor set-point to a new value within:
- one month for generation plants without a communication and control interface (≤ 100 kW)
- one minute for generation plants with remote control interface (rated power above 100 kW)
- The power factor may be measured at the generator terminals.

SGC25: Fault ride-through (1)

- Generators above 10 kW nominal power must not disconnect from the grid due to voltage drops above the blue line in the following figure, representing the smallest line-to-line voltage at the generator terminals:



SGC27: Description of system protection (1)

- The purpose of system protection is to safely and reliably disconnect the generator from the grid in case of unsafe conditions of voltage and frequency. The following protection functions must be implemented:

Protection against	Name	Limit	Disconnection Time
Undervoltage	U<	0.8 p.u.	1.5...2.4 s*
Overvoltage (1)	U>	1.1 p.u.	1 min
Overvoltage (2)	U>>	1.15 p.u.	100 ms
Underfrequency	f<	47.0 Hz	100 ms
Overfrequency	f>	52.0 Hz	100 ms

* Time to be assigned by PUC

- Limits apply to the half-cycle effective value (RMS), except for "U>" (Overvoltage (1)), which shall be based upon a 10- minute moving average. Any single limit violation must reliably trigger disconnection.
- Generators below 10 kW nominal power may disconnect due to "U<" (Undervoltage) or "U>" (Overvoltage (1)) with shorter time delays than the disconnection times listed above.
- Generators above 100 kW nominal power must automatically disconnect from the grid after 0.5 seconds if all line-line voltages are below 0.85 p.u. and the generator consumes inductive reactive power at the same time.

Example: Trip Setting of SMA Sunny Boy

11.6 Trip Limits/Trip Times

Frequency

Nominal Frequency	Trip Limit	Trip Frequencies	Trip Times
60 Hz	> 60.5 Hz	60.45 Hz ··· 60.55 Hz	max. 0.1602 s
	< 57.0 Hz ··· 59.8 Hz (standard 59.3 Hz)	56.95 Hz ··· 59.85 Hz (standard 59.25 Hz ··· 59.35 Hz)	adjustable, 0.16 s ··· 300 s (standard max. 0.1602 s)
	< 57.0 Hz	56.95 Hz ··· 57.05 Hz	max. 0.1602 s

Voltage

Nominal Voltage	Trip Limit	Trip Voltages Conductor-Neutral Conductor*	Trip Voltages Conductor-Conductor*	Trip Times
208 V	50 %	57.6 V ··· 62.4 V	99.8 V ··· 108.2 V	max. 0.1602 s
	88 %	103.2 V ··· 108.0 V	178.9 ··· 187.2 V	max. 2.002 s
	110 %	129.6 V ··· 134.4 V	224.6 V ··· 233.0 V	max. 1.001 s
	120 %	141.6 V ··· 146.4 V	245.4 V ··· 253.8 V	max. 0.1602 s
240 V	50 %	57.6 V ··· 62.4 V	115.2 V ··· 124.8 V	max. 0.1602 s
	88 %	103.2 V ··· 108.0 V	206.4 V ··· 216.0 V	max. 2.002 s
	110 %	129.6 V ··· 134.4 V	259.2 V ··· 268.8 V	max. 1.001 s
	120 %	141.6 V ··· 146.4 V	283.2 V ··· 292.8 V	max. 0.1602 s
277 V	50 %	133.0 V ··· 144.0 V	Not applicable	max. 0.1602 s
	88 %	238.2 V ··· 249.3 V		max. 2.002 s
	110 %	299.2 V ··· 310.2 V		max. 1.001 s
	120 %	326.9 V ··· 337.9 V		max. 0.1602 s

* The intervals result from the measuring accuracies listed below.

Accuracy

Trip limits: ±2 % of nominal grid voltage

Trip time: ±0.1 % of nominal trip time

Trip frequency: ±0.1 % of nominal frequency

Republic of Seychelles
Project for Formulation of Master Plan for Development of Micro Grid System

Okinawa Enetech Co. Inc. Energy Development Department
Luis Kakefuku, Masanori Shimabuku, Chihiro Tobaru, Yuma Uezu
Jun Hagihara, Noboru Yumoto

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1. Okinawa Enetech Overview

■ Company Overview

■ Background

Okinawa Enetech was established as an affiliated company of Okinawa Electric Power Co. Inc. in May 1994 specializing in research, design, and construction supervision of electric power facilities.

■ Corporate info

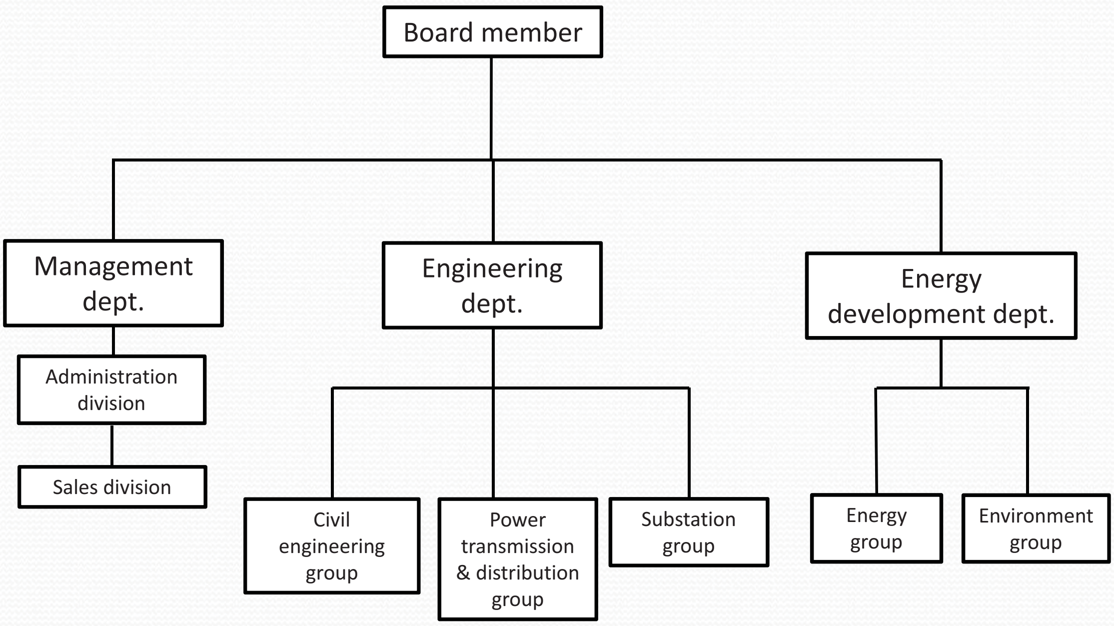
- Name : Okinawa Enetech Co. , Ltd.
- Location : Urasoe, Okinawa Prefecture
- Capital : 40 million yen
- Established : May 10, 1994
- No. of employees : 63

■ Business areas

(1) Civil engineering design
(2) Building & facilities design
(3) Environmental survey
(4) Design of power facilities
(5) Renewable energy
(6) Overseas projects

1. Okinawa Enetech Overview

■ Organization chart



1. Okinawa Enetech Overview

■ Introduction of domestic energy-related business

Electric Power
- Generation facilities
- Substation facilities
- Transmission and distribution facilities

Renewables Energy
- Hybrid system
- Wind power
- Hydro power
- Biomass power
- Solar power

Survey & Design | Research | Technical study | Construction supervision | Consulting

1. Okinawa Enetech Overview

■ Electric Power related works

Support of engineers for management of construction work at Yoshinoura LNG power generation plant

Survey, basic planning, detailed design, and construction work management for the installation of new DGs in remote islands

Survey, planning, and design of transmission lines

Underground power line construction work management

Planning and design of power generation facilities (fuel storage tank)

Source: Okinawa Electric Power Company
Okinawa electric Power Company 2010 - 2011 」

1. Okinawa Enetech Overview

■ Renewables Energy related works

Structural reengineering of foreign-made WT tower to ensure compliance with Japanese standard

Survey, planning, and construction work management of 4 MW solar power project in Miyako Island

Survey, planning, and construction work management of 200 kW PV project in Kita Daito Island

Survey, planning, and construction management of 240 kW PV project at an agricultural products processing plant in Higashi Village (Okinawa mainland)

1. Okinawa Enetech Overview

■ Overseas Renewable Energy Related Works

1. Okinawa Enetech Overview

■ Overseas Renewable Energy Related Works

Participation in OEPC NEDO project in Laos. General base plan, PV system design, construction work management, and validation Research (Micro Hydro + PV + capacitor)

Participation in demonstrative research project for interconnected PV system in Thailand

Performance evaluation of renewable energy system in Mongolia

Preparatory study for sustainable system development project for remote islands (operation of diesel generators) (JICA project)

2. Project Introduction

2. Project Introduction

■ Background

- Republic of Seychelles targets for Renewable Energy
  5% by 2020, 15% by 2030
- Renewable energies such as wind and solar power are already grid-connected in Seychelles. Currently, 6 MW of wind power and about 1.2 MW of solar power.
- There are concerns that the grid on Mahe, the main island, and others will become unstable.

↓

- The Government of Seychelles requested the transfer of technology and human resources development using Japanese experience in microgrid operations in island regions.
- In October 2014, an agreement between relevant institutions of Seychelles and JICA was signed for the implementation of the "Project for Formulation of Master Plan for Development of Micro Grid in Remote Islands."

2. Project Introduction

■ Purpose of the Project

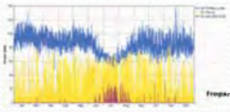
The purpose is to help develop a microgrid deployment plan for remote islands in Seychelles and an operating structure for grid stabilization technology based on Japan's experience in island regions.

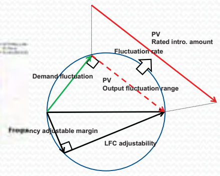
■ Support areas for the project

- ✓ Evaluation method to determine the RE integration capacity.
- ✓ Technical and economic study on the efficient use of diesel generators.
- ✓ Planning and designing PV-diesel hybrid power generation equipment.
- ✓ Proposal of a remote island microgrid deployment plan suitable to the characteristics of the power grid.
- ✓ Development of institutions for stable remote island microgrid operation.
- ✓ Introduction to grid stabilization technology for island regions of Japan through the training program in Japan.

2. Project Introduction

■ Support areas for the project





[Required Specifications]
① LFC adjustability
⇒ Operation method/specifications for generator

② Frequency adjustable margin
⇒ Total demand (kW)
⇒ System constant (% kW / Hz)
⇒ Allowable frequency fluctuation range (Hz)

③ Demand fluctuation
⇒ Demand data (resolution: a few seconds)

④ PV connectable to the grid (fluctuation rate)
⇒ Solar radiation intensity data (resolution: a few seconds)

Maximum allowable amount of renewables

Planning of PV system

Seychelles

Optimizing operation of existing diesel gen. sets

Legal system related to renewables

- Praslin 島での燃料測定

燃料流量計　　機関出力一定調整状況

2. Project Introduction

■ Expected results of the project

✓ Formulation of a remote island microgrid master plan.

✓ Evaluation of the maximum allowable amount of RE that can be interconnected to the grid and transfer of the evaluation methods.

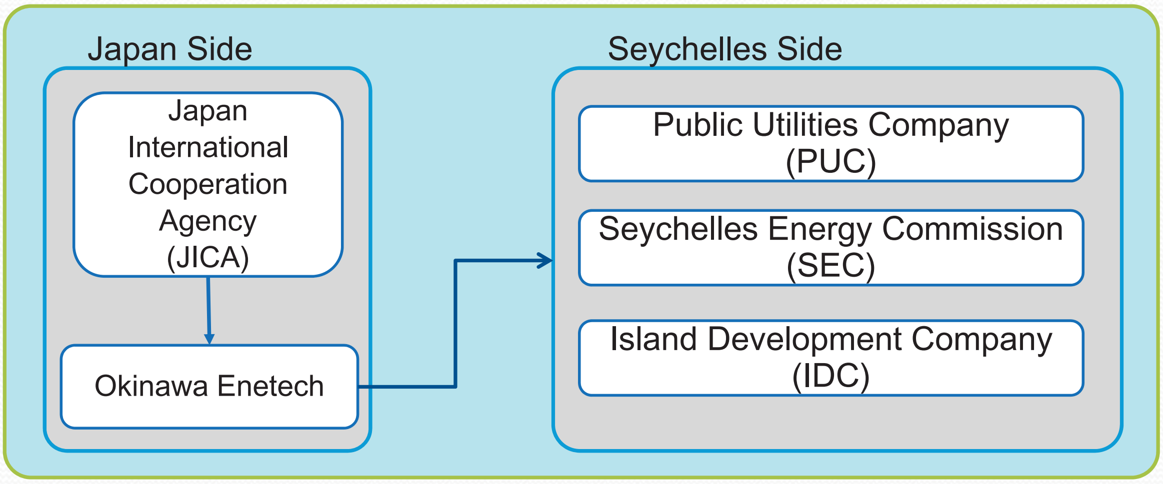
✓ Presentation of sample plans and designs of hybrid systems (photovoltaic-diesel generation), and transfer of design technology.

✓ Proposal for improving power plant efficiency by improving power plant operation and transfer of optimization technology

2. Project Introduction

■ Implementation cooperation structure

Project for Formulation of Master Plan for Development of Micro Grid in Remote Islands.



■ Schedule

This project is conducted from March 2015 through June 2016.

Event	2015										2016							
	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Field Survey			■			■				■			■			■		
Training in Japan								▼										
Seminar in Seychelles																	Final Report	▼

2. Project Introduction

■Target island for the project

The survey was conducted on Mahe Island, Praslin Island, La Digue Island, Curieuse Island, and Desroches Island.

www.Africaguide.com

3. Support areas for the project

3.1 Maximum allowable amount of renewables

- Summary of issues with stable grid operations due to high RE penetration
- Short-period issues-Shortage of frequency adjustability
- Long-period issues – Surplus energy
- Sorting out PV interconnection constraints

3. Support areas for the project

3.1 Maximum allowable amount of renewables

➢Issues with the implementation of RE

PV Features	Impact	Issues	Summary
Connection to distribution system	Distribution system	① Failure restoration	If a blackout area arising from a distribution line failure receives electricity from another power distribution line, since the shared power must also make up for the power that was generated by the stopped PV in the area, it may result in excess current flowing through the distribution line sharing power.
		② Voltage management	With the increase of reverse power flow to the distribution system from PV, distribution line voltage management becomes difficult.
Output fluctuation	Entire grid	③ Surplus power (Long-period constraints)	In order for thermal power generation to maintain operation, output must be maintained at or over a certain value. Even when demand is low, since output can not be decreased below this value, power supply would exceed demand due to RE power generation.
		④ Frequency adjustability (short-period constraints)	A shortage in frequency adjustability occurs due to the expansion of PV and wind power output fluctuation range, and thus results in larger frequency fluctuations.
Impact of PCSs	Entire grid	⑤ Grid stability during failures	Due to a decrease in the number of thermal generators in operation, synchronizing capacity decreases. Unnecessary disconnections during frequency and voltage disturbances foster power system disturbances.

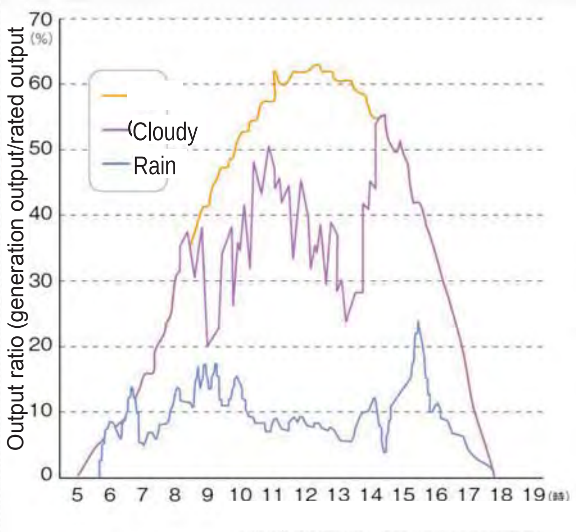
3. Support areas for the project

3.1 Maximum allowable amount of renewables

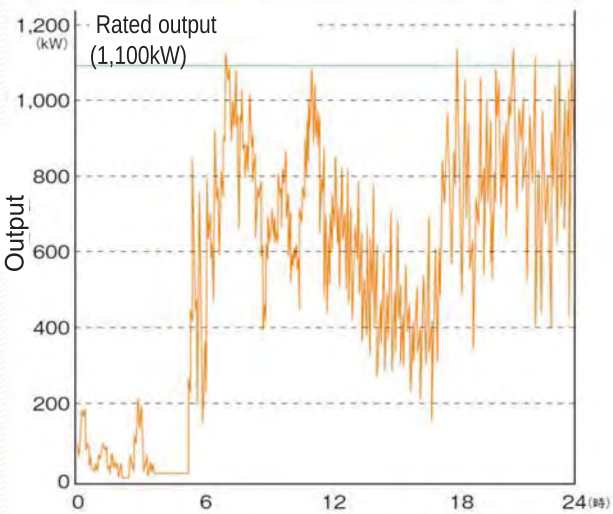
➢Short-period issues・ Variability of RE

PV and wind power output fluctuates according to changes in weather conditions such as solar radiation and wind speed.

● PV power generation



● Wind power generation



Source： The Federation of Electric Power Companies of Japan, Electric business and new energy 2009-2010

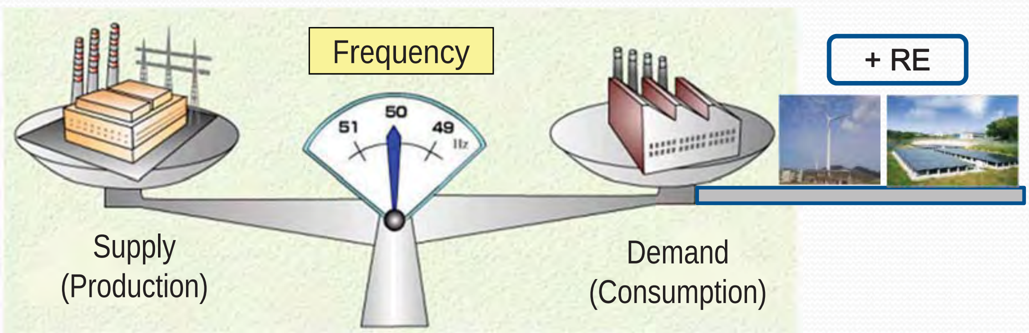
3. Support areas for the project

3.1 Maximum allowable amount of renewables

➢Short-period issues・Energy Balance

- **Influence of frequency fluctuation**

Since electricity cannot be stored, the amount of production and consumption has to be equal (principle of the same amount at a time). If this is not maintained, frequency varies.



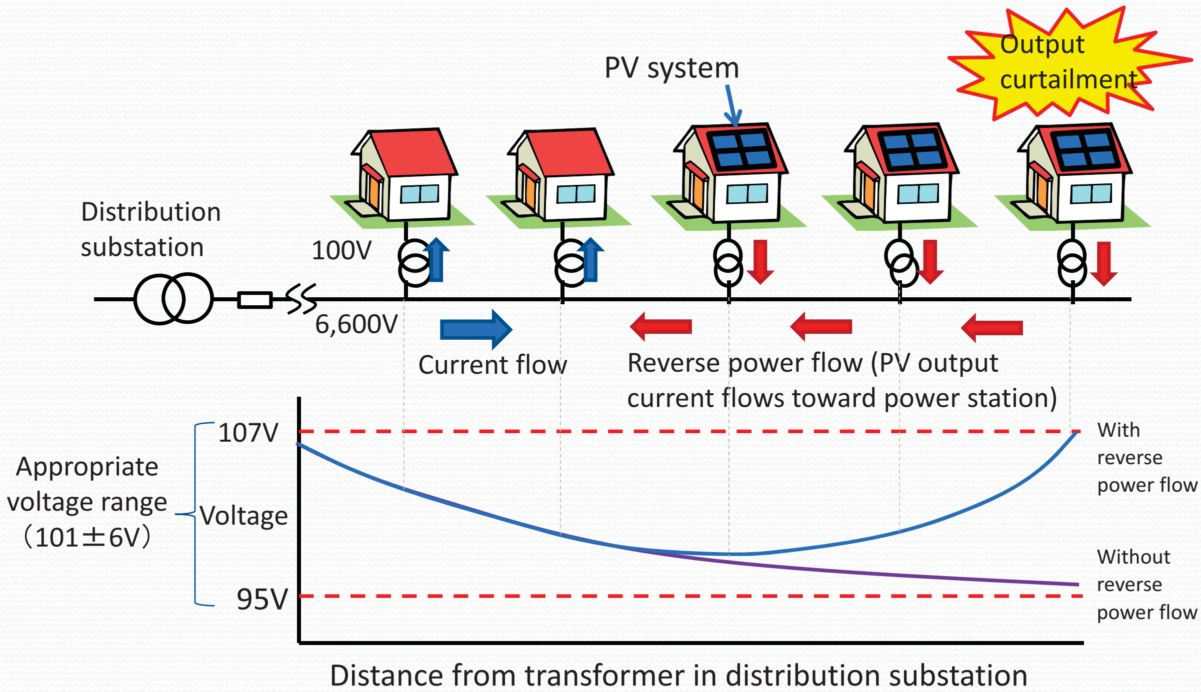
Demand (consumption) ＞ Supply (production) ⇒Frequency drop
Demand (consumption) ＜ Supply (production) ⇒Frequency increase

When exceeding a certain amount, fluctuations cannot be compensated for by increasing or decreasing the output of thermal power generators which may lead to the inability to maintain a constant frequency (60 Hz).

3. Support areas for the project

3.1 Maximum allowable amount of renewables

➢Issues of voltage increasing in distribution lines

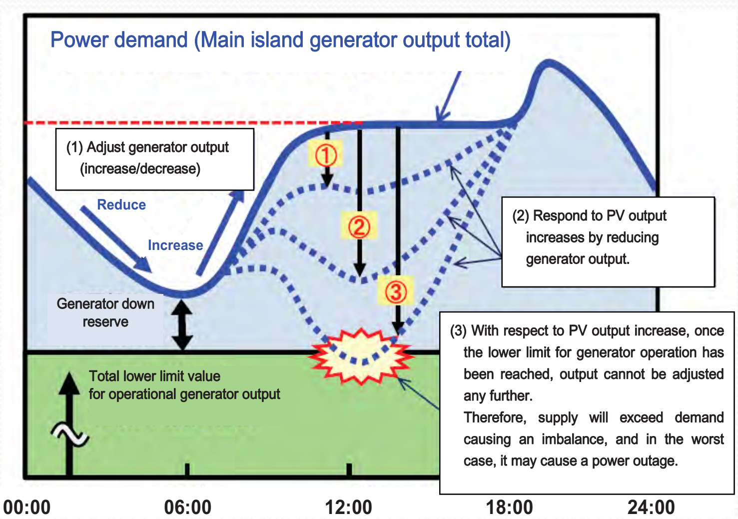


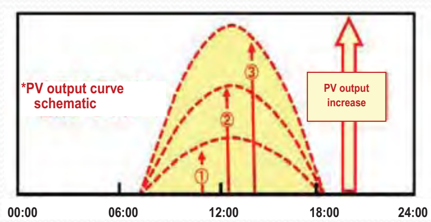
3. Support areas for the project

3.1 Maximum allowable amount of renewables

➢Long-period issues・ Surplus energy

Thermal power generators have an operational lower limit, and output cannot be reduced below this value. When this level is reached, the total power generation amount of the PV and thermal power generators exceeds the demand causing the frequency to rise. This affects the stable operation of the thermal power generators, and in the worst case, it could cause a power outage.

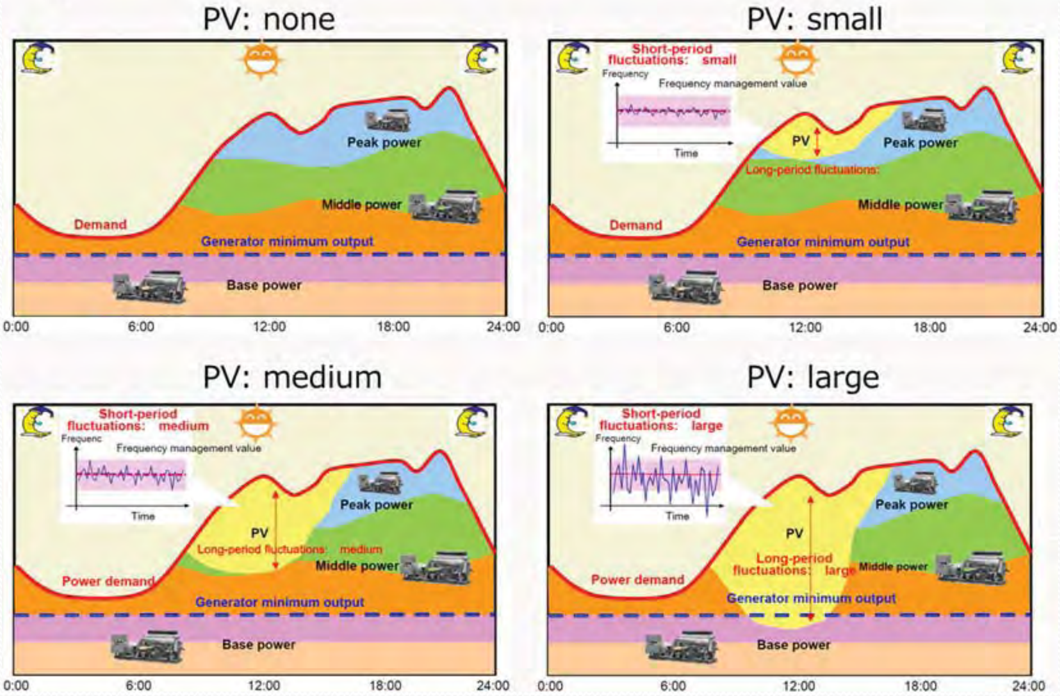




3. Support areas for the project

3.1 Maximum allowable amount of renewables

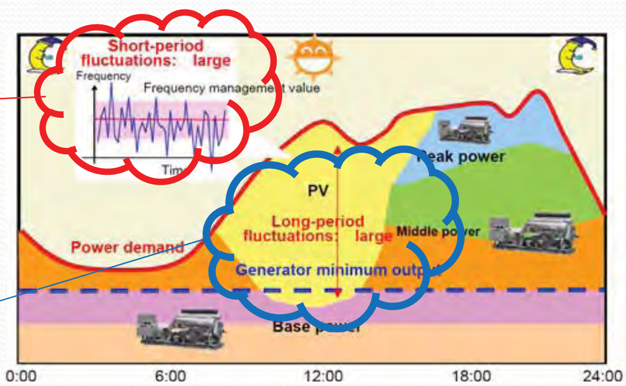
➢Changes in generator load sharing associated with the PV integration



3. Support areas for the project

3.1 Maximum allowable amount of renewables

➢Sorting out PV interconnection constraints



Short-Period Constraint
- Algebraic Method
- Y Method Simulation

Long-Period Constraint
- Homer

Distribution line constraints (Voltage constraints)
- Feeder reverse power flow

Large scale PV (over 50 kW)
- Commercial

Small scale PV (under 50 kW)
- Residential

3.2 Method for caculating the amount of RE deployable

- Algebraic method / short-period constraints
- Using Homer software / long-period constraints

3. Support areas for the project

3.2 Method for caculating the amount of RE deployable

(1) Algebraic method (simplified method)

- This estimation method is simple and clear.
- It has been proven in Japan and is highly reliable.
- Model construction of generators is unnecessary, and when expanding the adjustability of generators and storage batteries, estimation is possible by applying it to the LFC value.

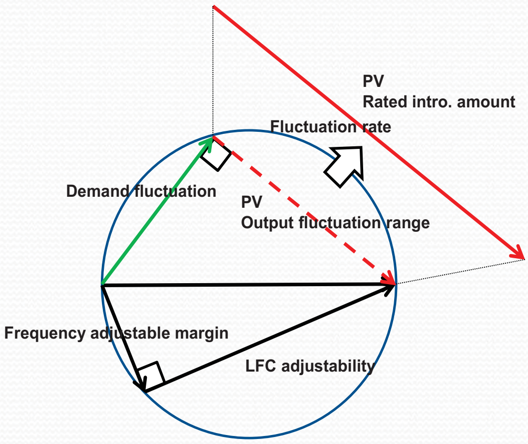
(2) Simulation method (detailed method)

- This method reflects the grid's unique characteristics and is used in order to verify the validity of the algebraic method.
- Real wind and solar power data is used, so it is highly reliable.
- It requires dedicated tools for calculating and highly specialized knowledge.

Short-Period Constraint

3. Support areas for the project

3.2 Method for calculating the amount of RE deployable (Algebraic Method)



[Required Specifications]
① LFC adjustability
⇒ Operation method/specifications for generator

② Frequency adjustable margin
⇒ Total demand (kW)
⇒ System constant (% kW / Hz)
⇒ Allowable frequency fluctuation range (Hz)

③ Demand fluctuation
⇒ Demand data (resolution: a few seconds)

④ PV connectable to the grid (fluctuation rate)
⇒ Solar radiation intensity data (resolution: a few seconds)

$$PV = \frac{\sqrt{(Frequency\ \ adjustable\ \ margin)^2 + (LFC)^2 - (Demand\ \ fluctuation)^2}}{Fluctuation\ \ Rate}$$

Connectable amount (short-period) = Allowable amount of PV fluctuation / PV output fluctuation rate

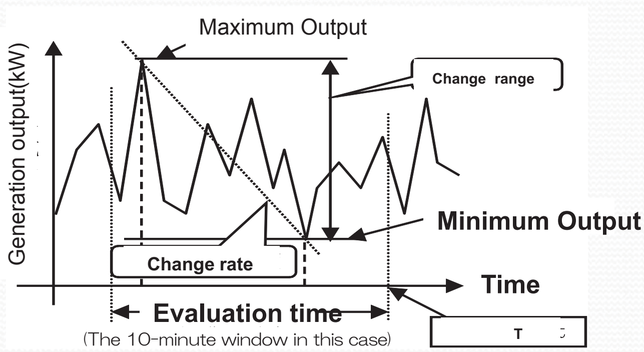
Short-Period Constraint

3. Support areas for the project

3.2 Method for calculating the amount of RE deployable (Algebraic Method) Definition of PV output fluctuation range and change rate

- The evaluation time window is set at 10 min, and the "output fluctuation range“ is the difference between the maximum output and minimum output during this time.

  * Since Okinawa is a small island, the simulation is conducted with the time window set at 10 minutes as this is believed to be most suitable.
- The "output change rate" is the result of the fluctuation range divided by the time required for the fluctuation range.



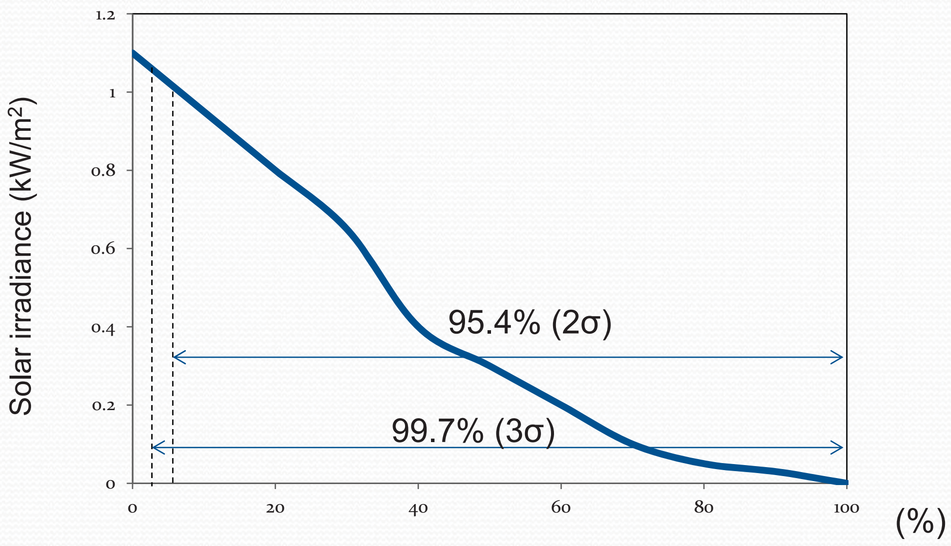
Definition of evaluation time window, output fluctuation range, and output change rate

Short-Period Constraint

3. Support areas for the project

3.2 Method for calculating the amount of RE deployable (Algebraic Method)

About Probability (3σ)



Short-Period Constraint

3. Support areas for the project

3.2 Method for calculating the amount of RE deployable (Algebraic Method) Result of load rejection test

The formula below expresses the relationship between power fluctuation of the grid ΔP and frequency fluctuation. Here, constant value is defined as the system constant. If the system constant for the grid is known, the amount of power fluctuation that occurred can be inversely calculated from frequency deviation. The algebraic method uses the system constant, which was estimated when conducting a load rejection test to calculate the allowable adjustable margin, to calculate the value for the maximum allowable power fluctuation.

Test situation

Time of test	16/03/2016 9:17			
			Run	Trip
Rated Output (MW)	SET 8B	6.00	○	
	SET A21	6.00		○
	SET A31	6.00	○	
	SET A41	6.00		
	SET A51	8.00	○	
	SET A61	8.00	○	
	SET B11	6.00	○	
	SET B21	6.00	○	
	SET B31	6.00	○	
	SET B41	8.00	○	
	SET B51	8.00	○	
Generator Output (MW)	SET 8B	4.50		
	SET A21	2.06		
	SET A31	4.31		
	SET A41			
	SET A51	6.49		
	SET A61	6.59		
	SET B11	4.47		
	SET B21	4.53		
	SET B31	4.05		
	SET B41	6.72		
	SET B51	7.26		
Demand (MW)	50.98			

Resut of test

Original frequency(Hz)	50.05
Bottom frequency(Hz)	49.21
Frequency deviation(Hz)	0.84
Dropout generator output(MW)	4.14
Time of bottom frequency(s)	1.32
End frequency(Hz)	49.87

System constant

System constant(%MW/Hz)	7.99

ΔP (%MW) = ΔP (MW) / total rated output of parallel input generators

K (%MW/Hz) = ΔP／ΔF

K : system constant

Short-Period Constraint

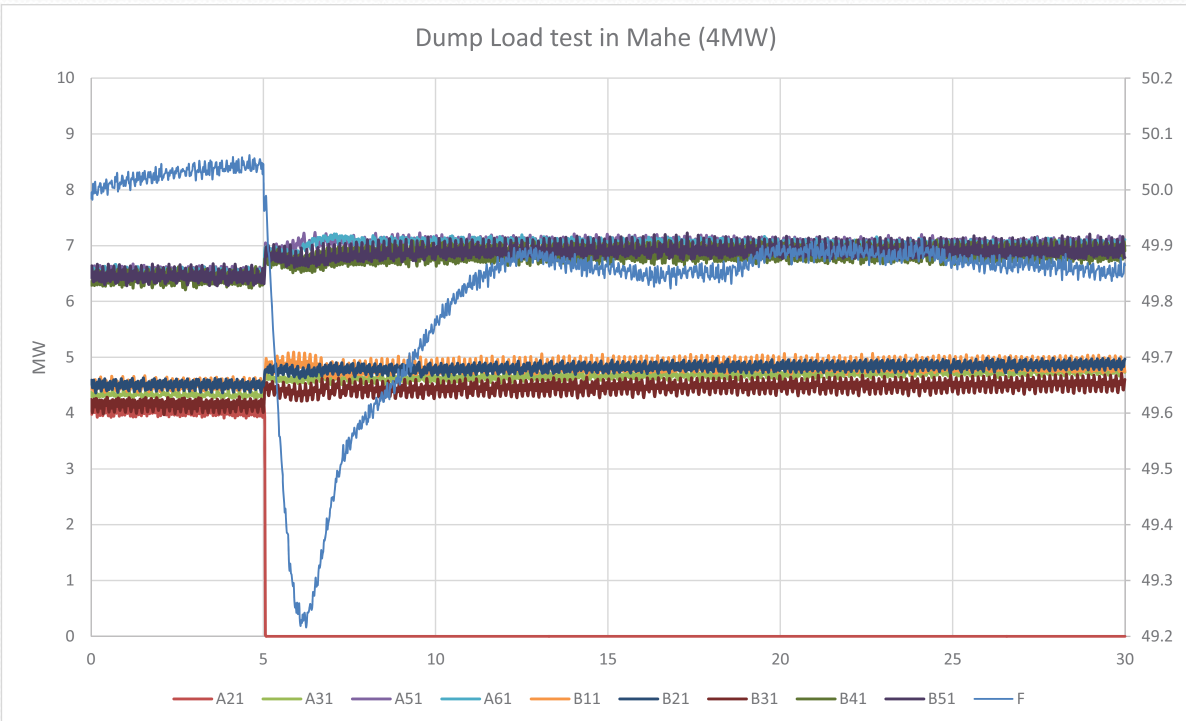
3. Support areas for the project

3.2 Method for calculating the amount of RE deployable (Algebraic Method) Result of load rejection

Short-Period Constraint

3. Support areas for the project

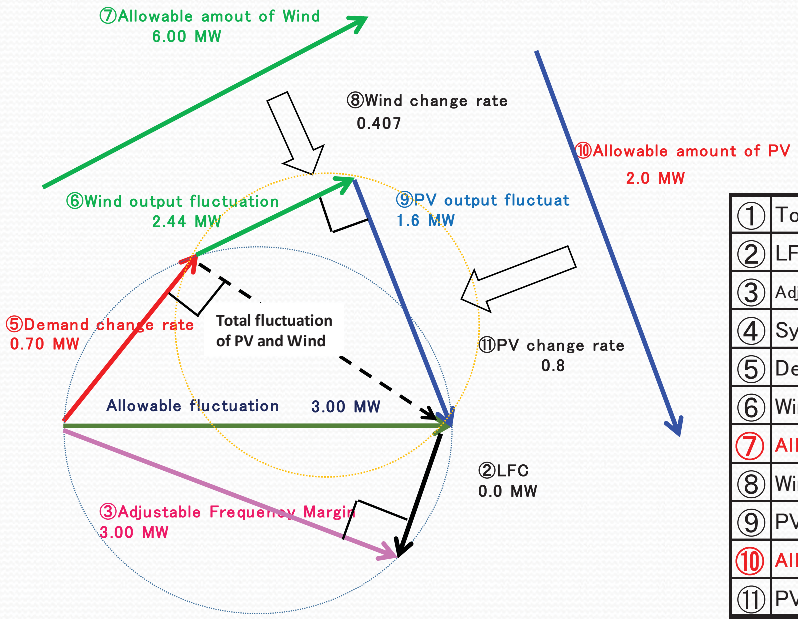
3.2 Method for calculating the amount of RE deployable (Algebraic Method) Result of load rejection test



Short-Period Constraint

3. Support areas for the project

3.2 Method for calculating the amount of RE deployable (Algebraic Method) Result of load rejection test



①	Total demand	50.0	MW
②	LFC	0.0	MW
③	Adjustable Frequency Margin	3.0	MW
④	System constant	8.0	%/Hz
⑤	Demand change rate	0.7	MW
⑥	Wind output fluctuation	2.4	MW
⑦	Allowable amout of Wind	6.0	MW
⑧	Wind change rate	0.4	–
⑨	PV output fluctuation	1.6	MW
⑩	Allowable amount of PV	2.0	MW
⑪	PV change rate	0.8	–
	Total amount of RE	8.0	MW

Short-Period Constraint

3. Support areas for the project

3.2 Method for calculating the amount of RE deployable (Algebraic Method) Result of load rejection test

Mahe Is.	Demand (MW)	PV Fluctuation rate (%)	PV (MW)	WT (MW)	RE (MW)
Probability (95%)	32	80	0	6	6
	40		0		6
	50		2		8
16/03/2016	50	100	1.6	6	7.6

Praslin Is.	Demand (MW)	PV Fluctuation rate (%)	PV (MW)	WT (MW)	RE (MW)
Probability (95%)	4.5	80	0.41	0	0.41
	5.5		0.50		0.5
	6.5		0.59		0.59
23/03/2016	6.5	50	0.94	0	0.94

When system demand is low, it is difficult interconnect PV due to small system constant.

Long-Period Constraint

3. Support areas for the project

3.2 Maximum allowable amount of renewables (Using Homer software)

HOMER (Hybrid Optimization of Multiple Electric Renewables).

HOMER simplifies the task of designing distributed generation (DG) systems - both on and off-grid for a variety of applications.

For configuration of the system, it helps in determining:

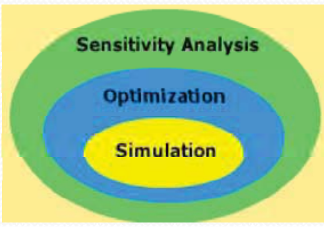
- What components does it make sense to include in the system design
- How many and what size of each component should be used

HOMER's optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations.

Long-Period Constraint

3. Support areas for the project

3.2 Maximum allowable amount of renewables (Using Homer software)



Core capabilities
Simulation, Optimization, Sensitivity Analysis

Simulation: At its core, HOMER is a simulation model. It will attempt to simulate a viable system for all possible combinations of the equipment that you wish to consider. Depending on how you set up your problem, HOMER may simulate hundreds or even thousands of systems.

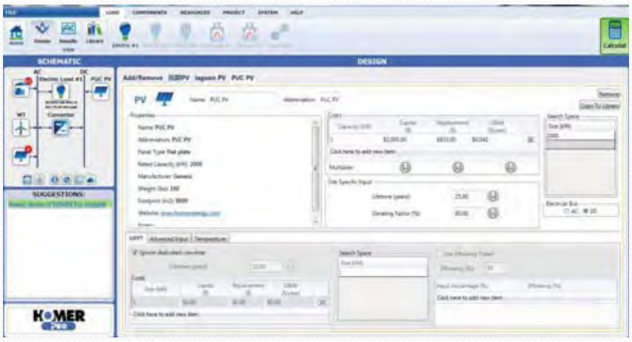
Optimization: The optimization step follows all simulations. The simulated systems are sorted and filtered according to criteria that you define, so that you can see the best possible fits. Although HOMER fundamentally is an economic optimization model, you may also choose to minimize fuel usage.

Sensitivity analysis: This is an optional step that allows you to model the impact of variables that are beyond your control, such as wind speed, fuel costs, etc, and see how the optimal system changes with these variations.

Long-Period Constraint

3. Support areas for the project

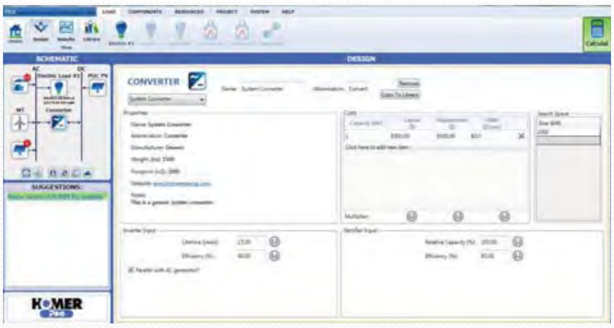
3.2 Maximum allowable amount of renewables (Using Homer software)



Long-Period Constraint

3. Support areas for the project

3.2 Maximum allowable amount of renewables (Using Homer software)



3. Support areas for the project

3.2 Maximum allowable amount of renewables (Using Homer software)

Homer Simulation Result in Mahe Is.

Scenario				Cost of energy	Power generated	Excess of energy	PV generation rate	WT generation rate	% of RE	Max. RE rate	Estimated Inicial Cost
RE implementation (kW)	PV (kW) PUC	PV (kW) Domestic PV	WT(kW)	$/kWh	kWh	%	%	%	%	%	$
7,200	0	1,200	6,000	0.286	313,118,114	0.0	0.66	2.89	3.55	24.4	0
8,200	1,000	1,200	6,000	0.286	313,365,024	0.0	1.22	2.88	4.10	26.2	2,800,000
9,200	2,000	1,200	6,000	0.286	313,611,968	0.1	1.76	2.88	4.64	28.8	5,600,000
10,200	3,000	1,200	6,000	0.286	313,858,848	0.1	2.32	2.88	5.20	31.4	8,400,000
11,200	4,000	1,200	6,000	0.287	314,105,824	0.1	2.87	2.88	5.75	34.0	11,200,000
12,200	5,000	1,200	6,000	0.287	314,352,704	0.1	3.41	2.87	6.28	36.6	14,000,000
13,200	6,000	1,200	6,000	0.287	314,599,616	0.2	3.96	2.87	6.83	39.3	16,800,000
14,200	7,000	1,200	6,000	0.287	314,846,496	0.2	4.51	2.87	7.38	41.9	19,600,000
15,200	8,000	1,200	6,000	0.287	315,093,472	0.2	5.06	2.87	7.93	44.5	22,400,000
16,200	9,000	1,200	6,000	0.287	315,340,384	0.2	5.60	2.87	8.47	47.1	25,200,000
17,200	10,000	1,200	6,000	0.288	315,588,096	0.3	6.15	2.86	9.01	49.7	28,000,000
18,200	11,000	1,200	6,000	0.288	315,836,896	0.3	6.69	2.86	9.55	52.4	30,800,000
19,200	12,000	1,200	6,000	0.288	316,086,624	0.3	7.24	2.86	10.10	55.0	33,600,000
20,200	13,000	1,200	6,000	0.288	316,338,784	0.3	7.78	2.86	10.64	57.6	36,400,000
21,200	14,000	1,200	6,000	0.288	316,596,512	0.4	8.32	2.85	11.17	60.2	39,200,000
22,200	15,000	1,200	6,000	0.288	316,863,392	0.4	8.86	2.85	11.71	62.8	42,000,000
23,200	16,000	1,200	6,000	0.289	317,143,008	0.4	9.40	2.85	12.25	65.5	44,800,000
24,200	17,000	1,200	6,000	0.289	317,435,776	0.5	9.93	2.85	12.78	68.6	47,600,000
25,200	18,000	1,200	6,000	0.289	317,748,800	0.5	10.46	2.84	13.30	71.6	50,400,000
26,200	19,000	1,200	6,000	0.289	318,088,992	0.6	11.00	2.84	13.84	74.7	53,200,000
27,200	20,000	1,200	6,000	0.289	318,463,776	0.7	11.53	2.84	14.37	77.8	56,000,000
28,200	21,000	1,200	6,000	0.290	318,882,208	0.7	12.06	2.83	14.89	80.8	58,800,000
29,200	22,000	1,200	6,000	0.290	319,357,376	0.8	12.58	2.83	15.41	83.9	61,600,000
30,200	23,000	1,200	6,000	0.290	319,900,928	1,0	13.10	2.82	15.92	86.9	64,400,000
31,200	24,000	1,200	6,000	0.290	320,519,424	1.1	13.62	2.82	16.44	90.0	67,200,000
32,200	25,000	1,200	6,000	0.291	321,218,304	1.3	14.13	2.81	16.94	93.0	70,000,000
33,200	26,000	1,200	6,000	0.291	321,998,976	1.5	14.63	2.81	17.44	96.1	72,800,000
34,200	27,000	1,200	6,000	0.292	322,856,640	1.7	15.12	2.80	17.92	99.1	75,600,000
35,200	28,000	1,200	6,000	0.292	323,794,240	2.0	15.62	2.79	18.41	102.2	78,400,000
36,200	29,000	1,200	6,000	0.293	324,805,632	2.3	16.10	2.78	18.88	105.2	81,200,000
37,200	30,000	1,200	6,000	0.293	325,886,944	2.6	16.58	2.77	19.35	108.3	84,000,000

Use of Battery Storage system for long-period constraint

3. Support areas for the project

3.2 Maximum allowable amount of renewables (Using Homer software)

Homer Simulation Result in Praslin (+ La Digue) Is.

組合せ例		Cost of energy	Power generated	Excess of energy	PV generation rate	Max. RE rate	Estimated Inicial Cost
RE implementation (kW)	PV(kW) PUC	$/kWh	kWh	%	%	%	$
0	0	0.264	42,872,584	0.0	0.00	0.0	0
100	100	0.264	42,897,248	0.0	0.40	2.5	230,000
200	200	0.264	42,921,928	0.0	0.81	5.0	460,000
300	300	0.263	42,946,596	0.0	1.21	7.4	690,000
400	400	0.263	42,971,300	0.1	1.61	9.9	920,000
500	500	0.263	42,995,992	0.1	2.01	12.4	1,150,000
600	600	0.262	43,020,696	0.1	2.42	14.9	1,380,000
700	700	0.262	43,045,356	0.1	2.82	17.4	1,610,000
800	800	0.262	43,070,060	0.2	3.22	19.9	1,840,000
900	900	0.261	43,094,724	0.2	3.62	22.3	2,070,000
1,000	1,000	0.261	43,119,432	0.2	4.02	24.8	2,300,000
1,100	1,100	0.261	43,144,100	0.2	4.42	27.3	2,530,000
1,200	1,200	0.260	43,168,776	0.2	4.82	29.8	2,760,000
1,300	1,300	0.260	43,193,468	0.2	5.21	32.3	2,990,000
1,400	1,400	0.260	43,218,180	0.3	5.61	34.7	3,220,000
1,500	1,500	0.259	43,242,864	0.3	6.01	37.2	3,450,000
1,600	1,600	0.259	43,267,564	0.3	6.41	39.7	3,680,000
1,700	1,700	0.259	43,292,244	0.3	6.80	42.2	3,910,000
1,800	1,800	0.258	43,316,940	0.3	7.20	44.7	4,140,000
1,900	1,900	0.258	43,341,616	0.4	7.59	47.2	4,370,000
2,000	2,000	0.257	43,366,316	0.4	7.99	49.6	4,600,000
2,100	2,100	0.257	43,391,004	0.4	8.38	52.1	4,830,000
2,200	2,200	0.257	43,415,672	0.4	8.78	54.6	5,060,000
2,300	2,300	0.256	43,223,656	0.4	9.17	57.1	5,290,000
2,400	2,400	0.256	43,238,916	0.5	9.57	59.6	5,520,000
2,500	2,500	0.256	43,489,760	0.5	9.96	62.1	5,750,000
2,600	2,600	0.255	43,269,444	0.5	10.35	64.5	5,980,000
2,700	2,700	0.255	43,284,720	0.5	10.74	67.0	6,210,000
2,800	2,800	0.255	43,300,000	0.5	11.13	69.5	6,440,000
2,900	2,900	0.254	43,315,244	0.5	11.53	72.0	6,670,000
3,000	3,000	0.254	43,613,208	0.6	11.92	74.5	6,900,000

Use of Battery Storage system for long-period constraint

3.3 Planning and designing PV-diesel hybrid system

- Technical assistance in planning and design
- Use of SketchUp software

Introduction

★ With small-scale power systems, due to limitations on scale and adjustment capacity, they are sensitive to the output fluctuations of renewable energy such as grid-connected PV systems.

★ If these fluctuations are large, balancing supply and demand and securing power quality become difficult.

★ When deploying a high percentage of grid-connected PV systems, a hybrid system which supplies power in coordination with the existing diesel generators (DG) is regarded as promising.

Introduction of the PV-diesel hybrid system developed in Okinawa

★ The 3 basic types are shown below.

① PV-diesel hybrid system

② PV-WT-diesel hybrid system

③ PV-battery-diesel hybrid system

- Keeping in mind that in any case, the deployment will take place on a small remote island, the configuration will consist of multiple generators.
- We believe that by using a multi-unit configuration, serviceability can be enhanced on small remote islands where backup and repair are not easy.

3. Support areas for the project
3.3 Planning and designing PV-diesel hybrid system

① PV-diesel hybrid system

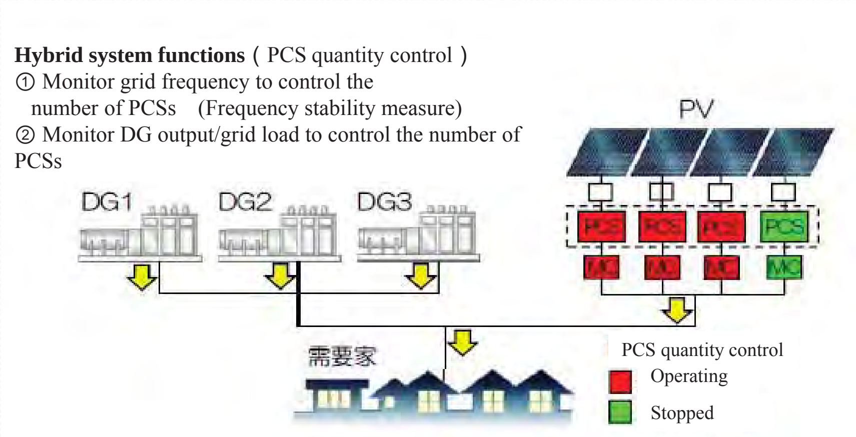
In most cases, a system stabilizing device such as storage batteries is incorporated in PV-diesel hybrid systems. However, power system stabilizers are expensive, so if such equipment is incorporated, the economic burden on Seychelles to deploy the system alone is heavy and makes it unfeasible. Therefore, in this project, we will propose and design a system that does not feature a stabilizer such as a power storage battery. An example system is described below.

3. Support areas for the project
3.3 Planning and designing PV-diesel hybrid system

【Example】① PV-diesel hybrid system

＜PV system without use of storage batteries＞

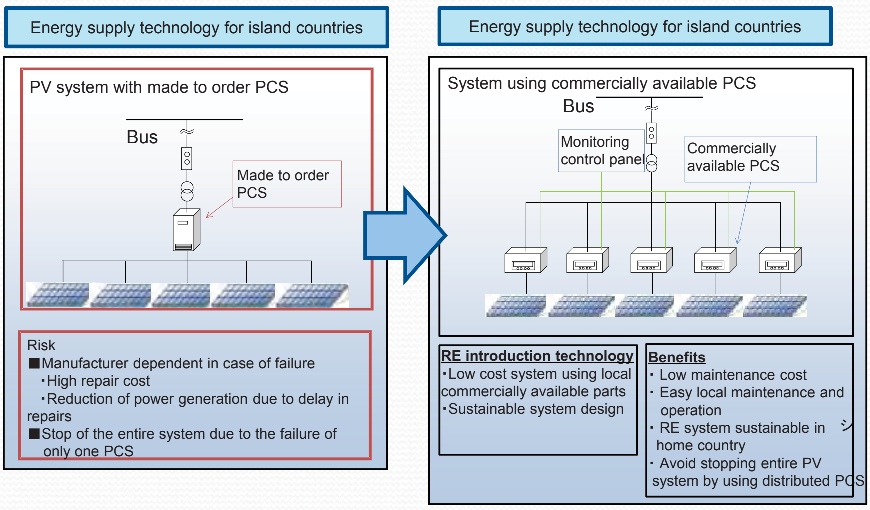
- A system with improved frequency stability through quantity control of the PCSs that come with the PV systems
- A system that takes into account low-output DG operation measures through quantity control of power conditioners (PCS)



3. Support areas for the project
3.3 Planning and designing PV-diesel hybrid system

【Example】① PV-diesel hybrid system

<Features/advantages of the system>



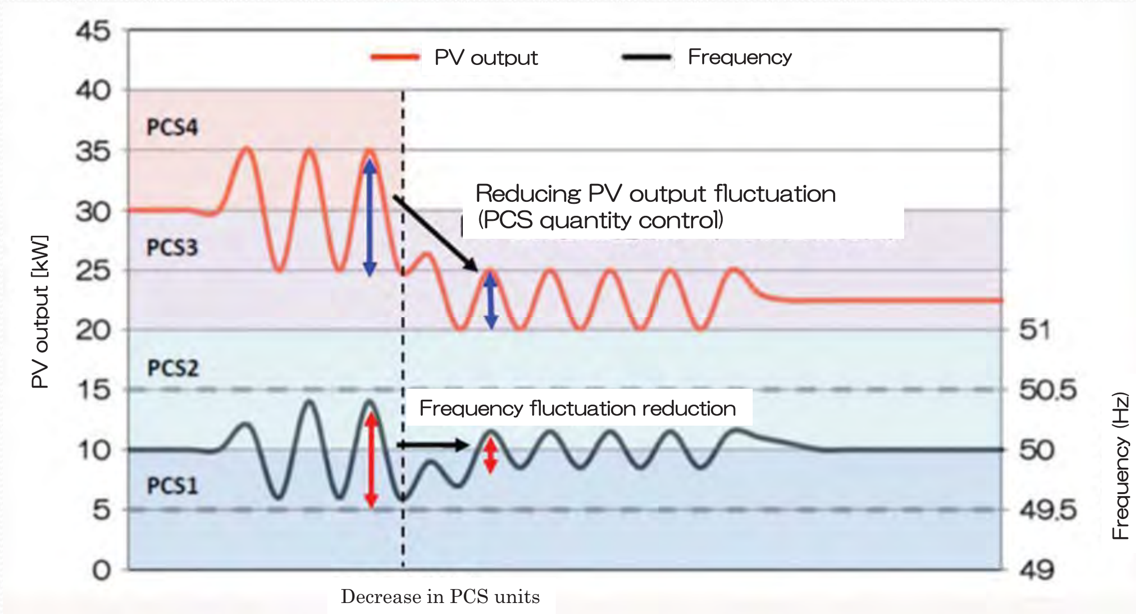
Ex. Sustainable PV System configuration

3. Support areas for the project

3.3 Planning and designing PV-diesel hybrid system

【Example】① PV-diesel hybrid system

＜Schematic of frequency stabilization measures through PCS quantity control＞

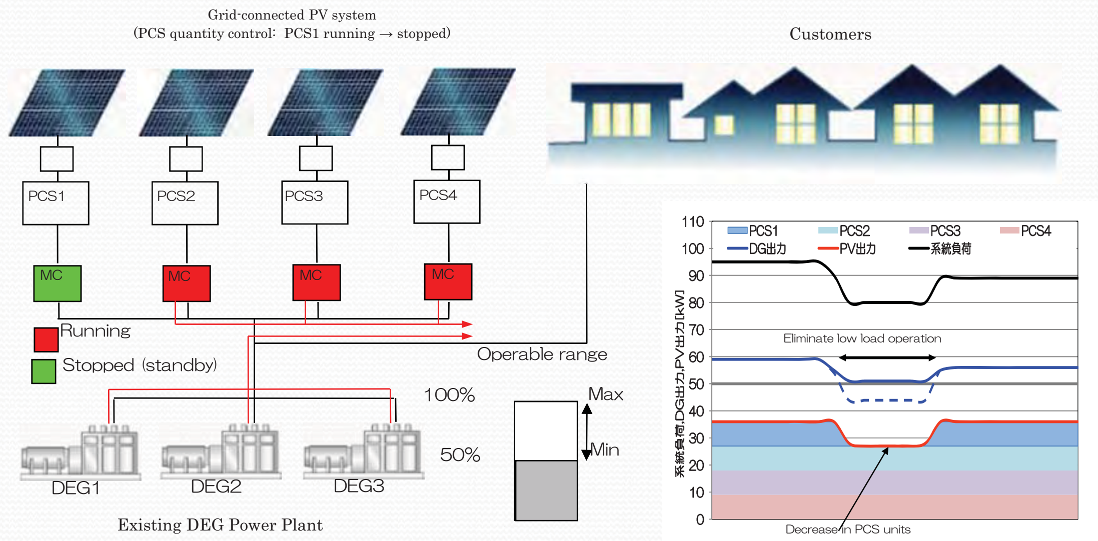


3. Support areas for the project

3.3 Planning and designing PV-diesel hybrid system

【Example】① PV-diesel hybrid system

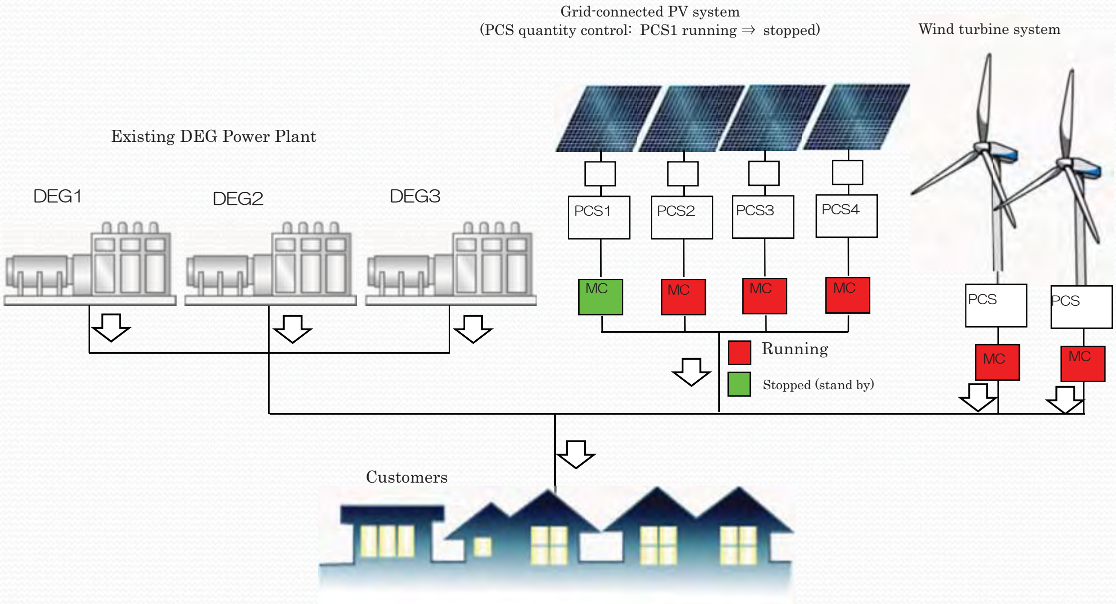
＜Schematic of measures for low-load DG operation through PCS quantity control＞



3. Support areas for the project
3.3 Planning and designing PV-diesel hybrid system

【Example】② PV-WT-diesel hybrid system

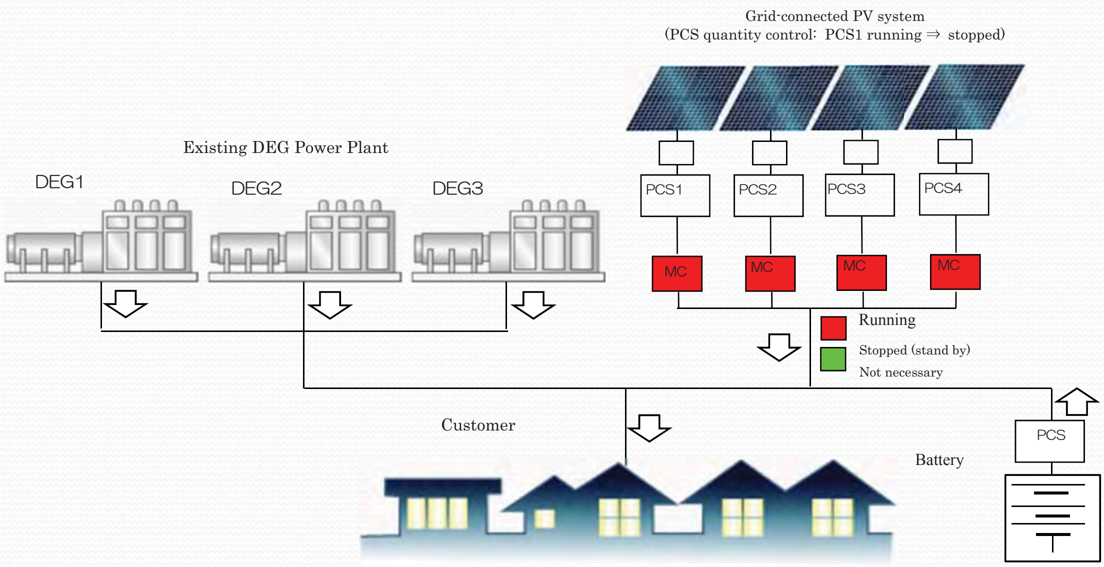
＜Schematic diagram of PV-WT-DG hybrid system without battery system＞



3. Support areas for the project
3.3 Planning and designing PV-diesel hybrid system

【Example】③ PV-Battery-DG hybrid system

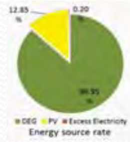
＜Schematic of a PV-Battery-DG hybrid system＞

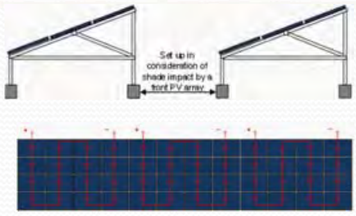


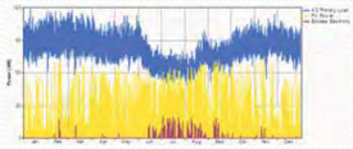
3. Support areas for the project

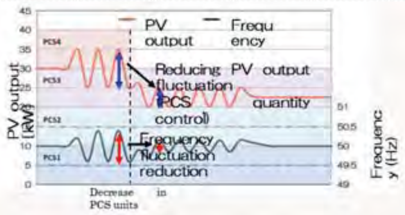
3.3 Planning and designing PV-diesel hybrid system

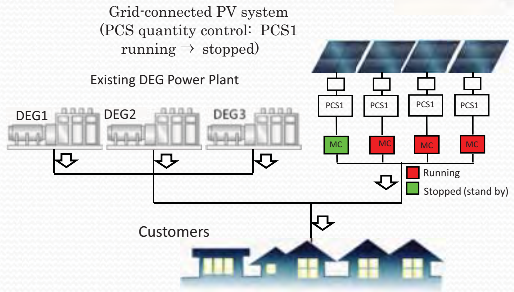
- Selection of tilt angle and azimuth of PV panel
- ↓ Selection of PV module
- ↓ Selection of PCS
- ↓ Study on the number of series connection of PV modules
- ↓ Study on a PV array configuration
- ↓ Study on a PV array arrangement
- ↓ Estimation of annual energy production
- ↓ Study on a system configuration







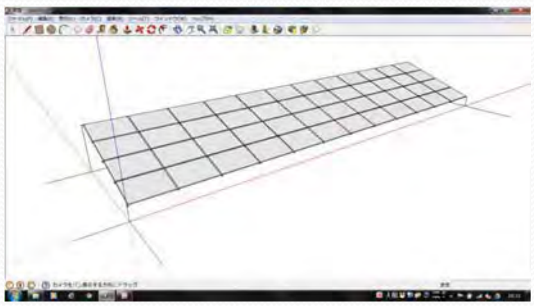




3. Support areas for the project

3.3 Planning and designing PV-diesel hybrid system

➢ Facility Planning Method using SketchUp software



3. Support areas for the project

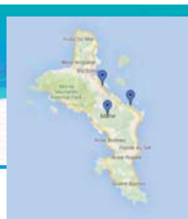
3.3 Planning and designing PV-diesel hybrid system

➢ Facility Planning Method using SketchUp software

3.4 Results of the project

- Mahe Is.
- Praslin Is., La Digue Is.
- Desroches Is.
- Curieuse Is.

3.4 Result of Planning of PV-DEG Hybrid System ･Mahe Is.

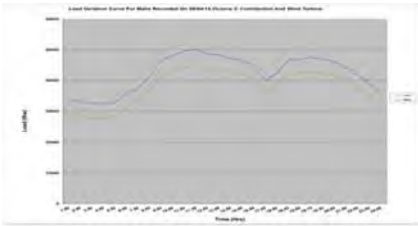


Victoria B Power Station
16.7 MW (28.8 MW)

Wind farm
750 kW × 8 = 6.0 MW

Peak Load 50 MW

(PV 1.2 MW)



Victoria C Power Station
58.0 MW (60.4 MW)

Metric	Baseline	Scaled
Average (kWh/d)	857,856	857,856
Average (kW)	35,744	35,744
Peak (kW)	50,000	50,000
Load Factor	.71	.71

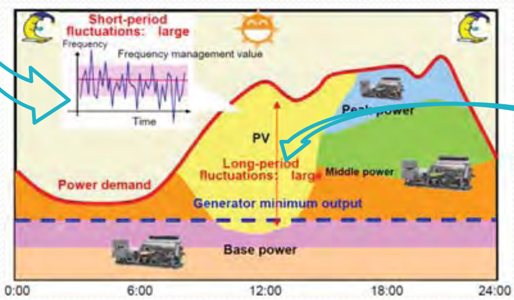
3.4 Result of Planning of PV-DEG Hybrid System (Mahe Is.)

Supply-demand balance simulation

Short period constraint

①	Total demand	50.0	MW
②	LFC	0.0	MW
③	Adjustable Frequency Margin	3.0	MW
④	System constant	8.0	%/Hz
⑤	Demand change rate	0.7	MW
⑥	Wind output fluctuation	2.4	MW
⑦	Allowable amount of Wind	6.0	MW
⑧	Wind change rate	0.4	–
⑨	PV output fluctuation	1.6	MW
⑩	Allowable amount of PV	2.0	MW
⑪	PV change rate	0.8	–
	Total amount of RE	8.0	MW

- For short-period constraints, PV systems of **50 kW** or more are taken into account, and if total output exceeds **2,000 kW**, implementation of a stabilization device such as a battery system to suppress frequency fluctuations is required.
- For long period constraints, the expected PV integration capacity is about **10 MW**. Integration of more than 10 MW is expected to require the implementation of a stabilization device such as a battery storage system to absorb the excess energy from RE.



Long period constraint

3.4 Result of Planning of PV-DEG Hybrid System（Mahe Is.)

▪Electric rate simulation

Battery storage capacity →

RE amount ↓

unit:US＄

Cost of energy		unit	output limit	Long term issues battery implementation				
Battery system capacit		kWh	0	30,000	50,000	100,000	150,000	200,000
PCS output		kW	0	30,000	50,000	100,000	150,000	200,000
RE implementation	WT	PV						
現状	6,000	1,200	0.232	–	–	–	–	–
計画	–			–	–	–	–	–
1,000	0	1,000	0.232	–	–	–	–	–
2,000	0	2,000	0.233	–	–	–	–	–
3,000	0	3,000	0.233	–	–	–	–	–
4,000	0	4,000	0.233	–	–	–	–	–
5,000	0	5,000	0.233	–	–	–	–	–
6,000	0	6,000	0.233	–	–	–	–	–
7,000	0	7,000	0.234	–	–	–	–	–
8,000	0	8,000	0.234	–	–	–	–	–
9,000	0	9,000	0.234	–	–	–	–	–
10,000	0	10,000	0.234	0.233	0.236	0.254	0.272	0.290
11,000	0	11,000	0.235	0.229	0.236	0.255	0.272	0.291
12,000	0	12,000	0.235	0.229	0.237	0.255	0.273	0.290
13,000	0	13,000	0.235	0.228	0.235	0.254	0.271	0.289
14,000	0	14,000	0.235	0.228	0.235	0.253	0.271	0.289
15,000	0	15,000	0.235	0.228	0.235	0.253	0.271	0.289
16,000	0	16,000	0.236	0.228	0.235	0.253	0.271	0.288
17,000	0	17,000	0.236	0.227	0.234	0.253	0.270	0.288
18,000	0	18,000	0.236	0.226	0.234	0.252	0.270	0.287
19,000	0	19,000	0.236	0.225	0.232	0.251	0.269	0.287
20,000	0	20,000	0.237	0.225	0.231	0.250	0.268	0.286
21,000	0	21,000	0.237	0.225	0.230	0.249	0.267	0.285
22,000	0	22,000	0.237	0.224	0.228	0.247	0.266	0.284
23,000	0	23,000	0.237	0.225	0.227	0.246	0.265	0.283
24,000	0	24,000	0.238	0.225	0.226	0.245	0.263	0.282
25,000	0	25,000	0.238	0.225	0.225	0.243	0.262	0.280
26,000	0	26,000	0.238	0.226	0.224	0.241	0.260	0.279
27,000	0	27,000	0.239	0.226	0.224	0.240	0.259	0.278
28,000	0	28,000	0.239	0.227	0.225	0.239	0.257	0.276
29,000	0	29,000	0.240	0.227	0.225	0.237	0.256	0.275
30,000	0	30,000	0.240	0.227	0.226	0.236	0.255	0.274

Cost of energy increase →

- A sensitivity analysis on the correlation of battery capacity and electric rates was conducted using HOMER Pro when deploying more than 10,000 kW of PV. As a result, electric rates tended to decrease when batteries were deployed. The optimal combination would be to add 22,000 kW of PV and a 30,000 kWh battery system to the current system.

3.4 Result of Planning of PV-DEG Hybrid System（Mahe Is.)

Supply-demand balance simulation

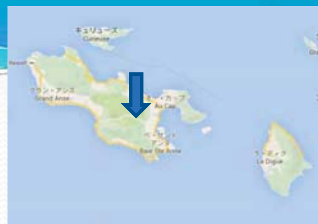
Summary

- The integration capacity for long-period constraints on Mahe Island was approximately 10,000 kW.
- The cost benefits of PV integration in Mahe Island is low with the current fuel price of 0.32 USD.
- Cost benefits of PV integration arise when fuel prices exceed the 0.8 USD.
- According to the battery capacity sensitivity analysis, electric rates tended to decrease when batteries were deployed.
- For the time being, aiming for deployments of 10,000 kW of PV, which does not require a battery system, is recommended.

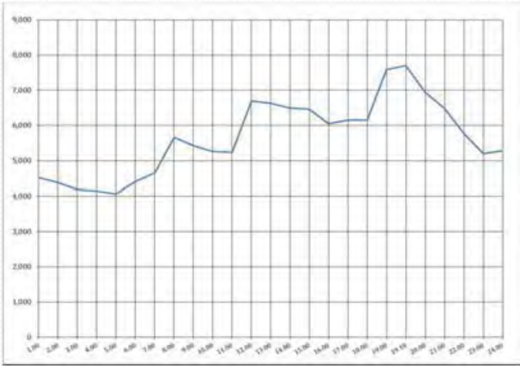
3.4 Result of Planning of PV-DEG Hybrid System
・Praslin Is.

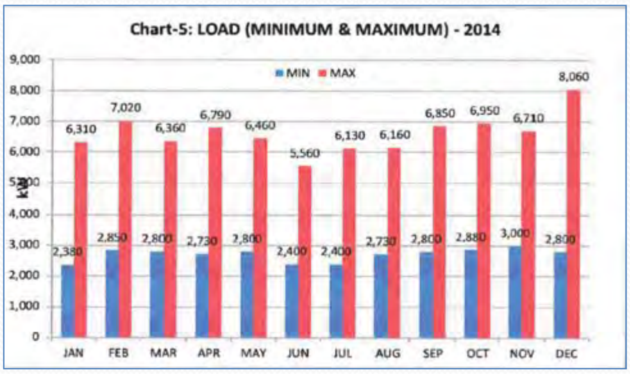
Praslin Island Power Station
11.05 MW(12.78 MW)

(PV 0.177 MW)



Peak Load 8.06 MW



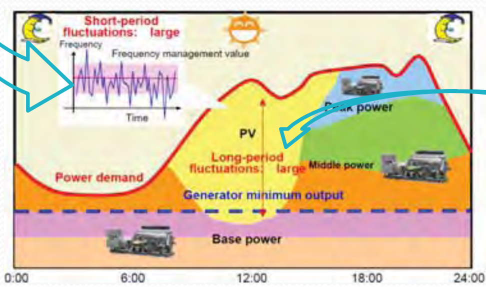


3.4 Result of Planning of PV-DEG Hybrid System
(Praslin Is.+ La Digue Is.) Supply-demand balance simulation

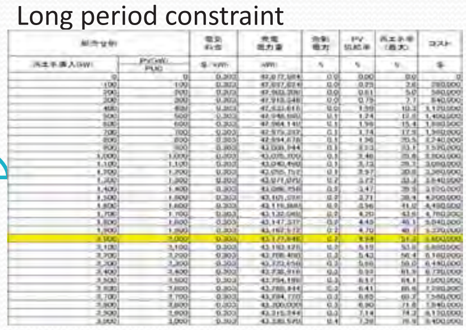
Short period constraint

①	Total demand	6500	kW
②	LFC	0	kW
③	Adjustable Frequency Margin	477	kW
④	System constant	9.8	%/Hz
⑤	Demand change rate	85	kW
⑥	Wind output fluctuation	0	kW
⑦	Allowable amout of Wind	0	kW
⑧	Wind change rate	–	–
⑨	PV output fluctuation	470	kW
⑩	Allowable amount of PV	600	kW
⑪	PV change rate	0.8	–
	Total amount of RE	600	kW

- For short-period constraints, PV systems of **50 kW** or more are taken into account, and if total output exceeds **600 kW**, implementation of a stabilization device such as a battery system to suppress frequency fluctuations is required.
- For long period constraints, the expected PV integration capacity is about **1,900 kW**. Integration of more than **2,000 kW** is expected to require the implementation of a stabilization device such as a battery storage system to absorb the excess energy from RE.



Long period constraint



3.4 Result of Planning of PV-DEG Hybrid System (Praslin Is.+ La Digue Is.) / electric rate simulation

Battery storage capacity →

RE amount ↓

unit : US $

Cost of energy		unit	output limit	Long term issues battery implementation				
Battery system capacity		kWh	0	1,000	3,000	5,000	8,000	10,000
PCS output		kW	0	1,000	3,000	5,000	8,000	10,000
RE implementation	WT	PV						
現状	0	0	0.264	–	–	–	–	–
計画	–			–	–	–	–	–
100	0	100	0.264	–	–	–	–	–
200	0	200	0.264	–	–	–	–	–
300	0	300	0.263	–	–	–	–	–
400	0	400	0.263	–	–	–	–	–
500	0	500	0.263	–	–	–	–	–
600	0	600	0.262	–	–	–	–	–
700	0	700	0.262	–	–	–	–	–
800	0	800	0.262	–	–	–	–	–
900	0	900	0.261	–	–	–	–	–
1,000	0	1,000	0.261	–	–	–	–	–
1,100	0	1,100	0.261	–	–	–	–	–
1,200	0	1,200	0.260	–	–	–	–	–
1,300	0	1,300	0.260	–	–	–	–	–
1,400	0	1,400	0.260	–	–	–	–	–
1,500	0	1,500	0.259	–	–	–	–	–
1,600	0	1,600	0.259	–	–	–	–	–
1,700	0	1,700	0.259	–	–	–	–	–
1,800	0	1,800	0.258	–	–	–	–	–
1,900	0	1,900	0.258	–	–	–	–	–
2,000	0	2,000	0.257	0.254	0.257	0.262	0.269	0.275
2,100	0	2,100	0.257	0.254	0.257	0.262	0.269	0.274
2,200	0	2,200	0.257	0.254	0.256	0.261	0.269	0.274
2,300	0	2,300	0.256	0.253	0.256	0.261	0.268	0.274
2,400	0	2,400	0.256	0.253	0.256	0.261	0.268	0.273
2,500	0	2,500	0.256	0.253	0.256	0.261	0.268	0.273
2,600	0	2,600	0.255	0.252	0.255	0.260	0.267	0.273
2,700	0	2,700	0.255	0.252	0.255	0.260	0.267	0.272
2,800	0	2,800	0.255	0.252	0.255	0.260	0.267	0.272
2,900	0	2,900	0.254	0.252	0.254	0.259	0.266	0.272
3,000	0	3,000	0.254	0.251	0.254	0.259	0.266	0.271

Cost of energy increase →

- A sensitivity analysis on the correlation of battery capacity and electric rates was conducted using HOMER Pro when deploying more than 2,200 kW of PV. As a result, implementing more than 2,300 kW of PV (high penetration) requires a large battery storage system, and thus results in a high cost of energy and initial cost.

3.4 Result of Planning of PV-DEG Hybrid System (Praslin Is.+ La Digue Is.) Supply-demand balance simulation

La Digue Island power supply

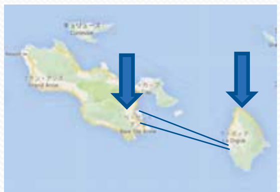
Power is supplied through two submarine cables.

・ From Praslin Power Plant to La Digue.

・ From Praslin Power Plant to La Digue via Eva Island. (sea water desalination plant in Round Island)

Planning for the construction of a third submarine cable.

Planning for La Digue Green Island (100% RE)



Possible sites for PV installation

Logan Hospital

La Digue District Administration

La Digue primary school

3.4 Result of Planning of PV-DEG Hybrid System (Praslin Is.+ La Digue Is.)

PV facility simulation (La Digue school) approx. 100 kW

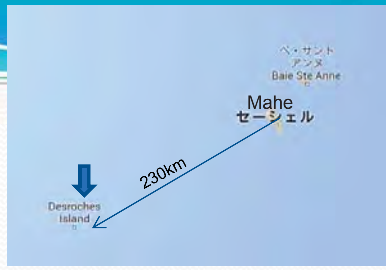
3.4 Result of Planning of PV-DEG Hybrid System (Praslin Is.+ La Digue Is.)

Supply-demand balance simulation

Summary

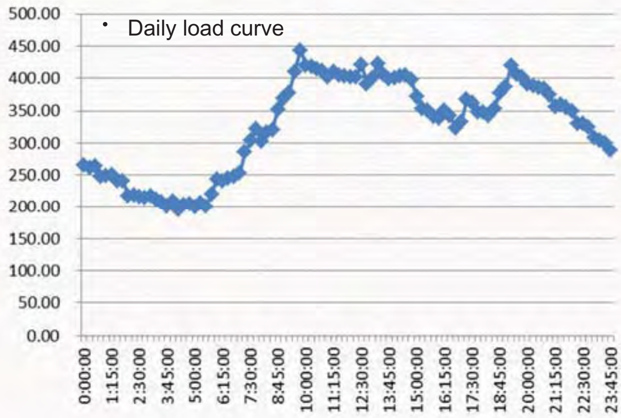
- The integration capacity for long period constraints on Praslin Island was approximately 2,000 kW.
- The cost benefits of PV integration in Praslin Island is low with the current fuel price of 0.49 USD.
- Electric rates tended to decrease with a battery capacity ranging 1,500 kWh – 2,000 kWh.
- For the time being, aiming for deployments of 2,000 kW of PV, which does not require a battery system, is recommended.

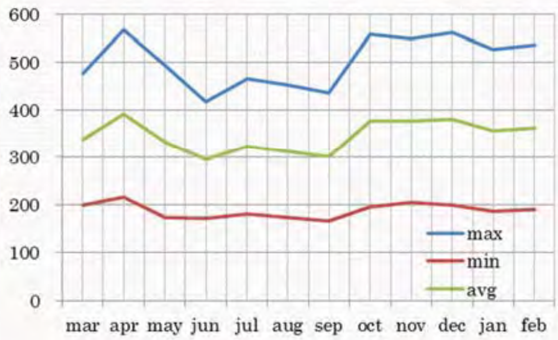
3.4 Result of Planning of PV-DEG Hybrid System
･Desroches Is. (Actual)



Power Station 1.74 MW(580 kW × 3)

- Peak Load 0.6 MW
- Average 0.3 to 0.4 MW
- Normally the power is supplied by one unit.

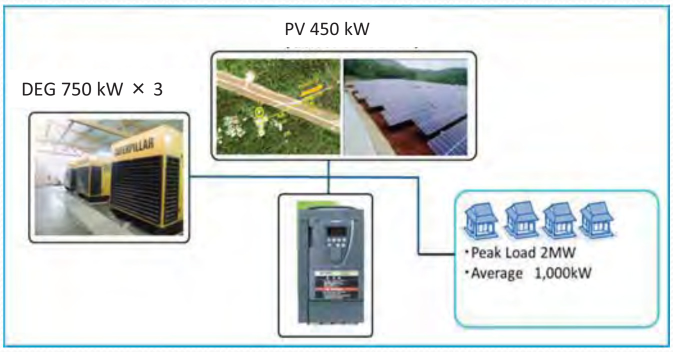




3.4 Result of Planning of PV-DEG Hybrid System
･Desroches Is. (Future plan)

Future plan for Desroches Is.

- Peak load 2.0 MW
- Replacement of all existing diesel generators



Study results using Homer software

- Diesel generator configuration 750 kW × 3 units
- Maximum PV implementation without battery storage system 450 kW
- PCS 300 kW
- COE 0.534 USD/kWh

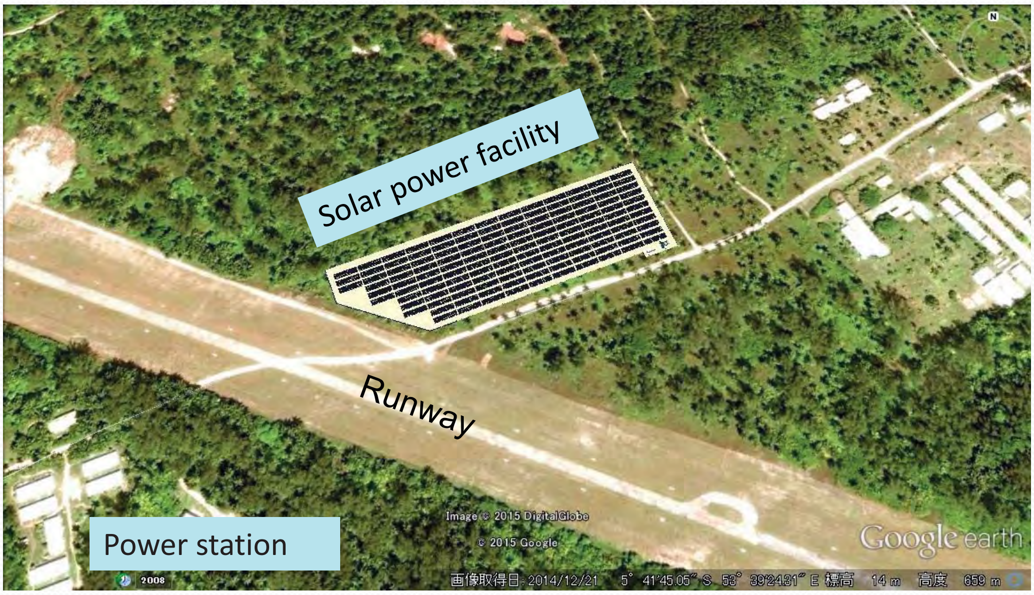
PV(kW)	DEG1(kW)	DEG2(kW)	DEG3(kW)	Converter (kW)	Dispatch	Cost/COE ($)	System/Ren Frac (%)
450	750	750	750	300	LF	0.534	7.70
450	750	750	750	300	CC	0.534	7.70
450	750	750	750	240	LF	0.535	7.18
450	750	750	750	240	CC	0.535	7.18
450	750	750	750	210	LF	0.537	6.73
450	750	750	750	210	CC	0.537	6.73
450	750	750	750	180	LF	0.539	6.14
450	750	750	750	180	CC	0.539	6.14
400	750	750	750	300	LF	0.535	6.97
400	750	750	750	300	CC	0.535	6.97
400	750	750	750	270	LF	0.535	6.89
400	750	750	750	270	CC	0.535	6.89
400	750	750	750	240	LF	0.536	6.69
400	750	750	750	240	CC	0.536	6.69
400	750	750	750	210	LF	0.537	6.34
400	750	750	750	210	CC	0.537	6.34
350	750	750	750	270	LF	0.537	6.12
350	750	750	750	270	CC	0.537	6.12
350	750	750	750	240	LF	0.537	6.05
350	750	750	750	240	CC	0.537	6.05
350	750	750	750	300	LF	0.537	6.13
350	750	750	750	300	CC	0.537	6.13
350	750	750	750	210	LF	0.537	5.85
350	750	750	750	210	CC	0.537	5.85

DG1	DG2	DG3	DG4	Dispatch	Cost/COE ($)
750	750	750		LF	0.550
750	750	750	750	LF	0.555
1000	1000	1000		LF	0.577
1000	1000	1000	1000	LF	0.583
1500	1500			LF	0.580
1500	1500	1500		LF	0.589
1500	1500	1500	1500	LF	0.598
2000	2000			LF	0.684
2000	2000	2000		LF	0.696

3.4 Result of Planning of PV-DEG Hybrid System

▪**Desroches Is.**

Image of 450 kW PV facility



3.4 Result of Planning of PV-DEG Hybrid System

▪**Curieuse Is.**

Current condition

Curieuse Island is one of the remote islands of the Seychelles Islands. It is located to the northwest of Praslin Island and has an area of 2.86 km^2 making it the second largest remote island in the Seychelles.

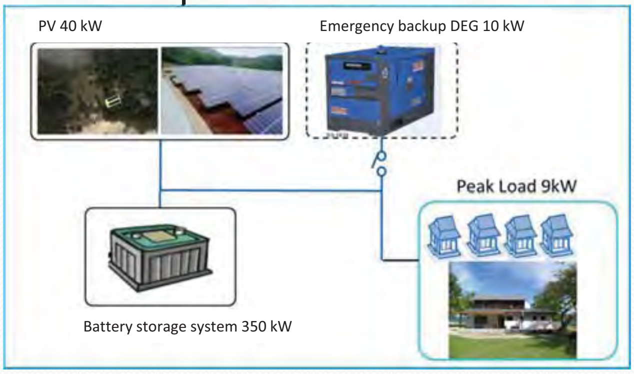
・ Generation equipment

1. 5.5 kVA diesel generator
2. 5 kVA gasoline generator
3. Normal feeding time: 17:00-6:00
4. Peak demand: approximately 7 kW
5. Gasoline price: 22 SCR/L (1.23 USD/L)

3.4 Result of Planning of PV-DEG Hybrid System

・Curieuse Is.

Future plan



Assuming a Peak load of 9 kW
System composition
・PV 40 kW
・Battery storage system 350 kWh
・PCS 10 kW
・Emergency backup DEG 10kW

Components			electicity tariff	Amount of power generation	excess of energy	PV gen. rate	cost
PV (kW)	CON (KW)	BTT (kWh)	$/kWh	kWh	%	%	$
40	10	350	1.16	69,290	40.2	100	280,000
40	15	350	1.17	69,290	40.2	100	282,500
40	20	350	1.18	69,290	40.2	100	285,000
50	10	300	1.19	86,612	52.3	100	280,000
25	25	350	1.19	69,290	40.2	100	287,500
50	15	300	1.20	86,612	52.3	100	282,500
40	30	350	1.20	69,290	40.2	100	290,000
50	20	300	1.20	86,612	52.3	100	285,000
40	35	350	1.21	69,290	40.2	100	292,500
40	10	400	1.21	69,290	40.2	100	305,000

3.4 Result of Planning of PV-DEG Hybrid System

・Curieuse Is.

Summary

- A simulation on the optimal combination with 10-50 kW PV, 10-50 kW CON, and 50-400 kWh BTT for PV deployment was conducted. The results showed that a system combining 40 kW of PV + 350 kWh of batteries + 10 kW CON is the best in terms of electric rates.
- The entire load for Curieuse Island and can be supplied with the PV in the system mentioned above. In addition, since Curieuse Island lacks a backup power supply in case the above system fails, installing a 10 kW diesel generator as emergency backup is recommended.

3.5 Optimizing operation of existing diesel gen set

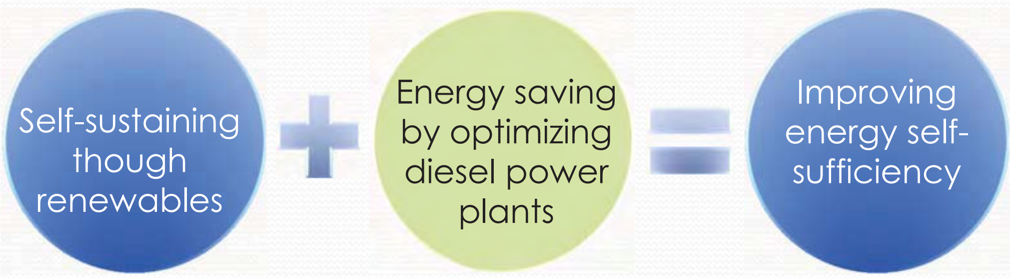
- Technical and economic study on the efficient use of diesel generators

3. Support areas for the project

3.5 Technical and economic study on the efficient use of diesel generators

- Position of this study on the project

In order to aim for improving energy self-sufficiency in Seychelles, in addition to the replacement of petroleum fuels with renewable energy, it is necessary to reduce fuel consumption through efficient operation of the existing power supply.



3. Support areas for the project

3.5 Technical and economic study on the efficient use of DEG

・ Position of this study on the project

Method of optimizing energy efficiency in power plant

① Proper maintenance to prevent worsening of fuel consumption characteristics **(management of each individual generator)**

② Application of economic load dispatch (EDC) operation to optimize fuel consumption **(management of power plant operation)**

→ EDC operation

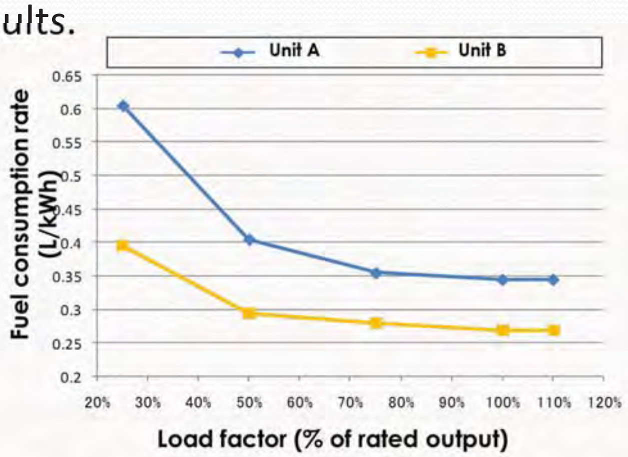
3. Support areas for the project

3.5 Technical and economic study on the efficient use of diesel generators

・ Overview of EDC operation

EDC (**E**conomic load **D**ispatching **C**ontrol)

Amid changes in demand, which generators (which have different fuel consumption characteristics) should be operated and at what output will lead to the most efficient operation is considered in advance, and the efficient operation of the generators is carried out based on the results.



Basic idea

- Each generator has different fuel consumption characteristics.

↓

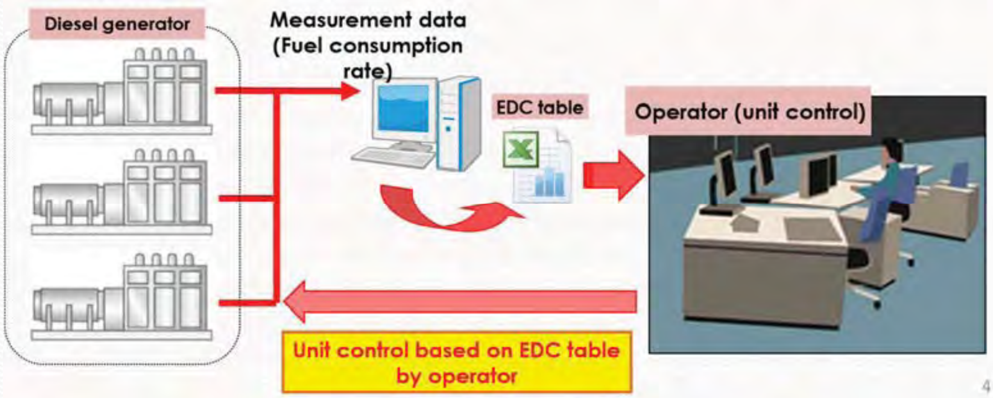
- Aim for the most efficient point for each generator.

3. Support areas for the project

3.5 Technical and economic study on the efficient use of DEG

・ Applicability in Seychelles

① Economic load dispatch calculation is carried out with a commercial PC software (Microsoft Excel) using the fuel consumption characteristics of each generator (fuel consumption rate).
② Based on the economic load dispatch calculation results, an economic load dispatch table for each combination of generators is prepared.
③ EDC operation based on the economic load dispatch table (EDC operation is performed by manual governor operation at the power plant)



3. Support areas for the project

3.5 Technical and economic study on the efficient use of DEG

・ Field survey for implementation

①Power plant assessment

Assessment items	MAHE	PRASLIN	LA DIGUE	DESROCHES	CURIEUSE
Existing power plant	YES	YES	NO Under sea cable to Praslin	YES	YES
Multiple generator operation	YES	YES	—	YES	NO Only 1 unit
Manual control for DEG output	YES	YES	—	NO Auto load sharing control	YES
Others	—	—	—	Will be replaced	—

⇩ ⇩

Plants selected for survey on EDC applicability

3. Support areas for the project

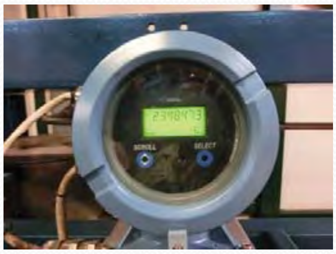
3.5 Technical and economic study on the efficient use of DEG

・ Field survey for implementation

②Power plant assessment （MAHE・PRASLIN）

To apply EDC operation, we conducted a survey on the following items.

- ✓ Specification of generators
- ✓ Operational status of generators
- ✓ Status of measurement equipment
- ✓ Structure of power plant maintenance
- ✓ Constraints on power plant operation



3. Support areas for the project

3.5 Technical and economic study on the efficient use of DEG

・ Field survey for implementation

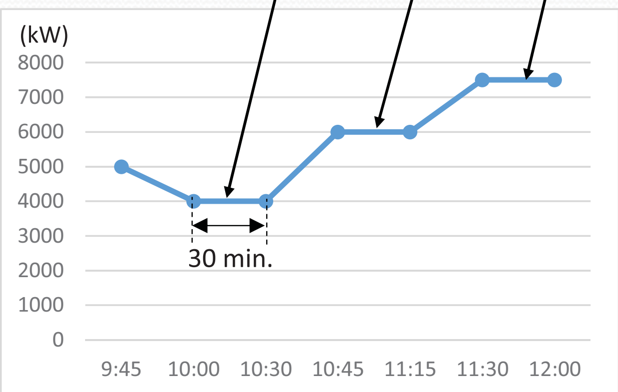
③ Collection of data required for implementation and confirmation of collection method

It is necessary to determine the fuel consumption characteristic of each generator for EDC implementation.

■Required Data: Fuel consumption rate at each output

■Measured item: Generated power (kWh), Fuel consumption (Liters)

Fuel consumption rate is measured at a constant output for a defined period of time to determine each generators efficiency (fuel consumption rate).



Fuel consumption measurement test
Procedure example

Fuel consumption measurement test
(Fuel flow meter measurement)

3. Support areas for the project

3.5 Technical and economic study on the efficient use of DEG

③Collection of data required for implementation and confirmation of collection method

Measurements on each DEG taken at Mahe PS. and Praslin PS. and results

Victoria C_B5

Rated output 8000 kW

KW	4000	6000	7500
%	50%	75%	94%
L/KWH	0.257	0.232	0.230

Victoria C_A4

Rated output 6348 kW

KW	5500	4500	3000
%	87%	71%	47%
L/KWH	0.238	0.239	0.249

Victoria C_A2

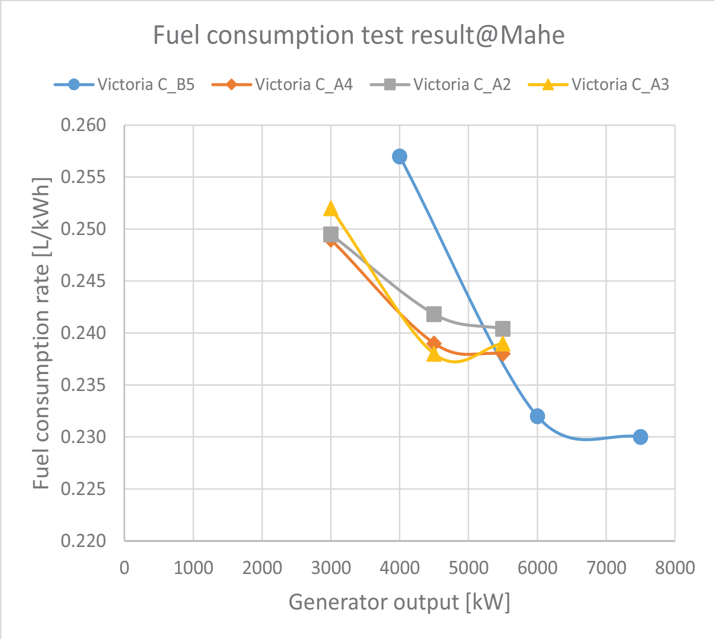
Rated output 6348 kW

KW	3000	4500	5500
%	47%	71%	87%
L/KWH	0.249	0.242	0.240

Victoria C_A3

Rated output 6348 kW

KW	3000	4500	5500
%	47%	71%	87%
L/KWH	0.252	0.238	0.239



3. Support areas for the project

3.5 Technical and economic study on the efficient use of DEG

③Collection of data required for implementation and confirmation of collection method

Measurements on each DEG taken at Mahe PS. and Praslin PS. and results

Praslin 6P

Rated output 1500 kW

KW	800	1040	1300
%	53%	69%	87%
L/KWH	0.282	0.275	0.271

Praslin 7P

Rated output 3000 kW

KW	1000	1700	2000
%	54%	73%	81%
L/KWH	0.2837	0.2729	0.2723

Praslin 4P

Rated output 670 kW

KW	548	444	296
%	82%	66%	44%
L/KWH	0.276	0.278	0.296

Praslin M6

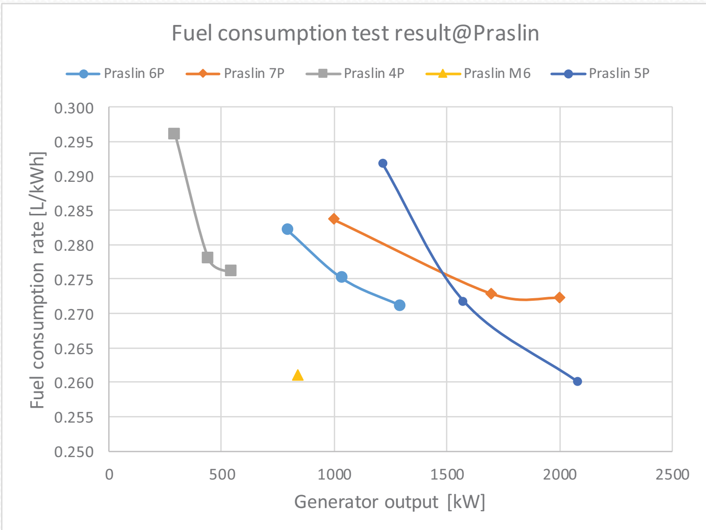
Rated output 1000 kW

KW	840		
%	84%		
L/KWH	0.261		

Praslin 5P

Rated output 3000 kW

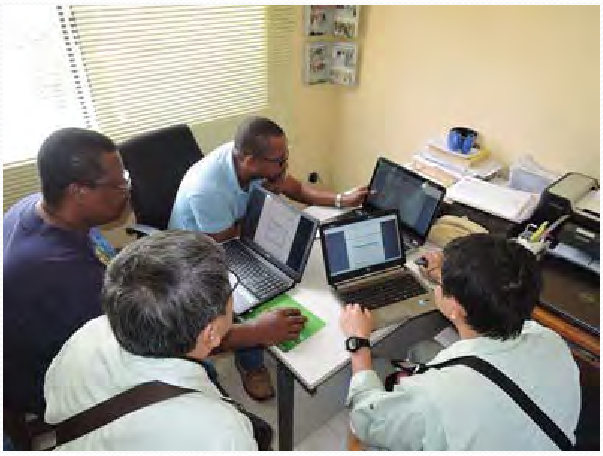
KW	2084	1576	1216
%	0.694667	0.525333	0.405333
L/KWH	0.260	0.272	0.292



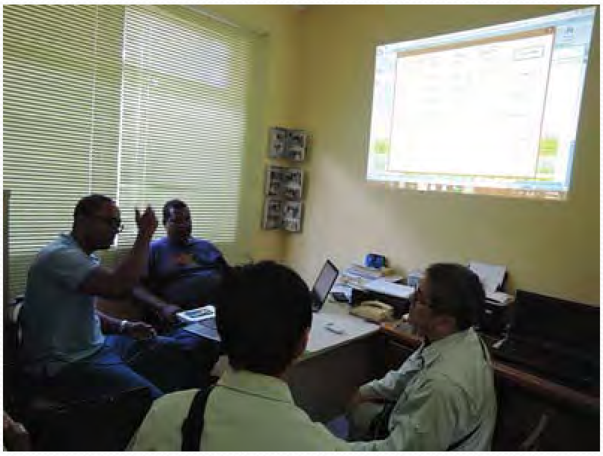
3.5 Technical and economic study on the efficient use of DEG

④ Confirmation of data collection method and EDC implementation method

We confirmed data collection method by conducting actual measurement tests. Also, we confirmed how to prepare an EDC table required for EDC operation using the measurement data.



Confirmation of how to implement EDC ①



Confirmation of how to implement EDC ②

3.5 Technical and economic study on the efficient use of DEG

・ Implementation effect (potential)

【Trial calculation conditions】

- ◆ Mahe Island Victoria C Power Plant was the target power plant.
- ◆ The target period was 11/1/2014 (Saturday) - 11/7/2014 (Friday) for a total of 7 days.
- ◆ Fuel consumption are not actual values, but instead calculated from the measured fuel consumption rates and actual generator output values.
- ◆ For the estimated fuel consumption after the application of EDC operation, we used fuel consumption when load is optimally shared for actual system loads.

01-Nov-14	Fuel consumption (ℓ)	Without EDC	190,972	05-Nov-14	Fuel consumption (ℓ)	Without EDC	221,058
		With EDC	190,275			With EDC	220,501
	Reduction	【ℓ】	697		Reduction	【ℓ】	557
		【%】	0.365%			【%】	0.252%
02-Nov-14	Fuel consumption (ℓ)	Without EDC	189,546	06-Nov-14	Fuel consumption (ℓ)	Without EDC	229,285
		With EDC	189,173			With EDC	228,872
	Reduction	【ℓ】	373		Reduction	【ℓ】	413
		【%】	0.197%			【%】	0.180%
03-Nov-14	Fuel consumption (ℓ)	Without EDC	217,722	07-Nov-14	Fuel consumption (ℓ)	Without EDC	219,332
		With EDC	217,268			With EDC	218,845
	Reduction	【ℓ】	454		Reduction	【ℓ】	487
		【%】	0.209%			【%】	0.222%
04-Nov-14	Fuel consumption (ℓ)	Without EDC	222,207	TOTAL	Fuel consumption (ℓ)	Without EDC	1,490,123
		With EDC	221,844			With EDC	1,486,777
	Reduction	【ℓ】	364		Reduction	【ℓ】	3,346
		【%】	0.164%			【%】	1.588%

3. Support areas for the project

3.5 Technical and economic study on the efficient use of DEG

- Future efforts for EDC implementation

① Continue measurement test on fuel consumption rate

Since efficiency of the generator is expected to constantly change due to conditions such as generator condition and weather conditions, it is necessary to accumulate and average the data through continuous measurement. Also, the condition of the generators can be determined by analyzing the accumulated data.

② Digitization of daily power generation records

In addition to paper-based daily power generation records, by digitizing them, changes in system load and other factors required for EDC operation can be accumulated.

③ Understanding system load in real time

There are no meters at Mahe and Praslin Island Power Plants which constantly display system load, so there is no way to know the ever-changing demand. This is lacking synchronism required to perform EDC operation, which optimizes load dispatch of generators for each demand portion.

3.6 Legal system related to renewables energy

- Grid Code
- Incentives for PV system

3.6 Legal system related to renewable energy

▪ Grid Code

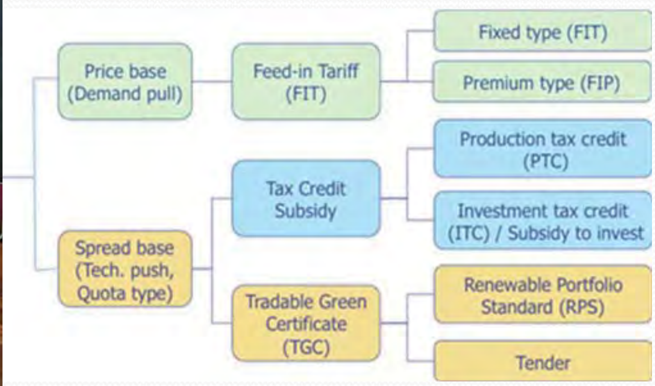
If a power generation system connected in a distributed manner to the power transmission and distribution system provides power to the grid side (reverse power flow), the failure of the distributed power system, as well as the amount and quality of the power generated by it, would affect the grid of the power company, and the consumers supplied with electricity from the same power company will also be affected. Therefore, regarding the installation and operation of distributed power sources, prescribed standards must be met, and the owner must make efforts to ensure the quality of the generated power for public safety. For these reasons, guidelines for grid connection were improved.

Grid Code contents

- Voltage management
- Protection coordination
- Islanding operation detection
- Power factor
- Targeted facility
- Harmonic wave

3.6 Legal system related to renewable energy

▪ Promotion and Dissemination



General explanation on FIT and their world trend were made, and the approach for Seychelles in this project was described. As output, how to design a FIT scheme was provided.
Issues, which Seychelles faces in this field, were analyzed, and the country's biggest issue is financial resources for supporting a scheme such as FIT.

3.6 Legal system related to renewable energy

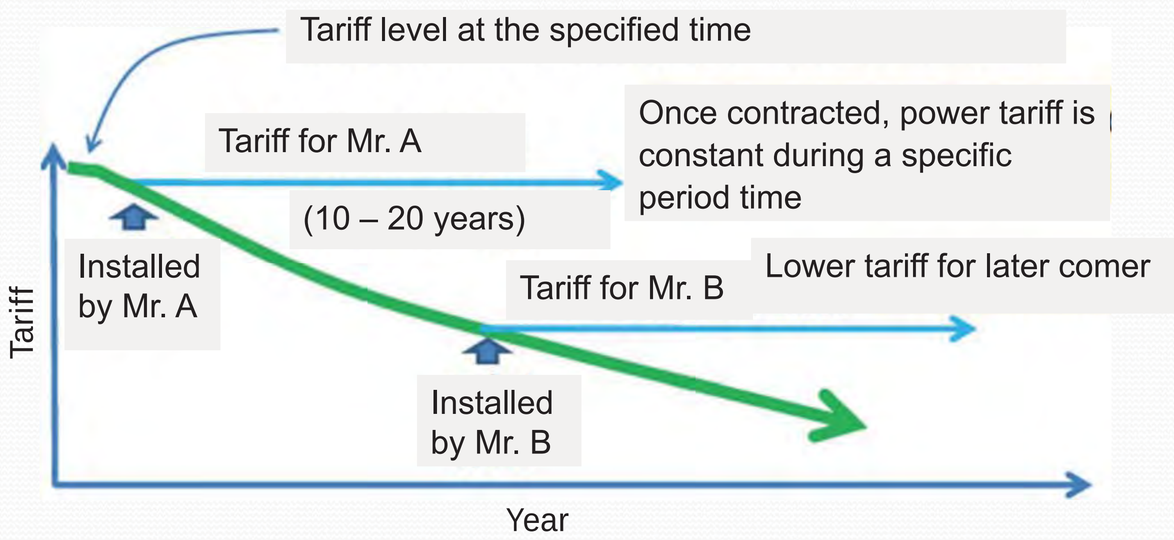
▪Incentives for PV system

<table>
<tr><th colspan="4">Type of Incentives</th></tr>
<tr><td rowspan="4">Investment</td><td rowspan="2">Tax Credit</td><td colspan="2">Production tax credit (PTC)</td></tr>
<tr><td colspan="2">Investment tax credit (ITC)</td></tr>
<tr><td colspan="3">Subsidy</td></tr>
<tr><td colspan="3">Low Interest Loan</td></tr>
<tr><td rowspan="5">Operation</td><td rowspan="3">Price base
(Demand pull)</td><td rowspan="2">Feed-in Tariff (FIT)</td><td>Fixed type (FIT)</td></tr>
<tr><td>Premium type (FIP)</td></tr>
<tr><td colspan="2">Net Metering (NEM)</td></tr>
<tr><td rowspan="2">Spread base
(Tech. push,
Quota type)</td><td>Quota Obligation</td><td>Renewable Portfolio Standard (RPS)</td></tr>
<tr><td colspan="2">Tender</td></tr>
</table>

- Can be combined / mixed

3.6 Legal system related to renewable energy

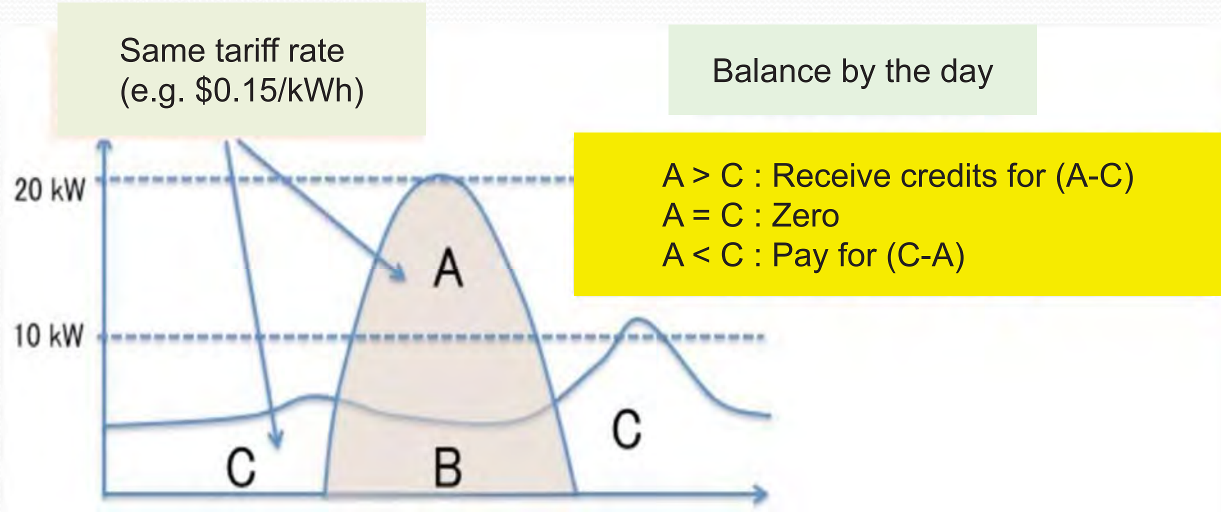
▪Mechanism of FIT



- On installation, tariff during a specific period of time is determined.
- Lowered tariff in later stage is not applied to already installed facilities.

3.6 Legal system related to renewable energy

Net Metering (NEM)



3.6 Legal system related to renewable energy

・FIT and NEM

	FIT	NEM
Merit	● Stipulate selling energy at fixed price for long period ● Can evaluate investment recovery ● Can sell surplus energy at fixed price ● Dissemination speed can be controlled by tariff. ● Can accelerate dissemination of RE	● Can set off generated and consumer energy ● Stipulate setoff, if agreement or act exists ● More simple ● Can hedge risk on soaring electricity price
Demerit	● Need contract ● More complex ● NEM is attractive, if electricity tariff is higher than FIT price ● Cannot hedge risks on soaring electricity price	● Change rules drastically by Clearing method of surplus energy ● Generally, not very profitable for surplus energy ● Longer payback period with lowering price of electricity

3.6 Legal system related to renewable energy
･Japanese case

- FIT was intiated in 2012. (after Fukushima)
  - 42 JPY (4.43 SCR, 0.34 USD) / kWh for PV, No total limit
  - Resource is avoided fuel cost + surcharge on tariff

  ⇒ Subdivision business of Mega-solar
  - No strict regulation: Elec. Business Act doesn't cover RE < 50kW
- Revised system in April 2014
  - 38 JPY JPY (4.01 SCR, 0.31 USD) / kWh for PV
  - Prohibited subdivision of mega-solar

  ⇒ In March, application of 27,000 MW PV received
- But, revision was too late.
  - From September 2014, 5 utilities refused new PV connection.
  - Unlimited curtailment of PV output w/o compensation

3.6 Legal system related to renewable energy
･Review History of FIT in Europe

- Steep drop in PV panel cost
  → Installed in large quantities → Increasing national burden

Germany (2000 -)
- 2000-01 - Maintained price - Cap 350MW (abolished in 2003)
- 2002-08 - Lowering mech. w/constant rate (5 to 6.5% annually)
- 2009 - - Lowering mech. w/variable rate 2009-: annually, 2012/1-: every half year, 2012/4-: every 4 months - Cap: 2.5GW
- 2012/4 – - Cap (accumulated): 52GW
- 2015 – - Tendering for PV installed on ground (3 times a year)

Spain (1998 -)
- 1998 - - Same price for later installation; 2004 - - Annually revised price by formula
- 2009 - - Lowering mech. w/ constant rate revised every quarter - Cap (Annual)
- 2012/1 - - Stopped
- 2013/7 - - Repeal FIT - Move to new scheme

France (2002 -)
- 2002/7 - - Maintained price; 2006/7, Revised price
- 2010 - - Adjusted price based on insolation condition at site
- 2011/3 – - Lowering mech. w/ constant rate revised every quarter - Cap (Annual)
- Combine FIT with Tendering
- Tendering for over 100kW

Italy (2005 -)
- 2005 – Maintained price
- 2009 – Lowering mechanism with constant rate 2009-: Yearly, 2011/1-: Every 4 months, 2011/6-: Every 6 months
- Cap 350MW → 1.2GW → 3.5GW
- 2011/6 Cap: 23GW
- 2012/8 Cap: 6.7 billion Euro annually
- 2013/7 – - Stopped by accumu-lated cap

UK (2010 -)
- 2010/4 – - Maintained price; 2012 – - Lowering mechanism.
- 2012/3 – - Lowering mech. w/ constant rate revised every quarter
- 2014 – - Tendering for over 5MW

3.6 Legal system related to renewable energy

▪Discussion on NEM in USA

- Demand charge
  - Contract capacity is determined based on max demand in a certain period.
- Grid access charge
  - Usage charge of utility's distribution line to access/connect with grid
- Standby charge
  - Charge to keep supply power for cloudy day and nighttime
- Installed capacity charge
  - Basic charge based on capacity of installed PV

3.6 Legal system related to renewable energy

▪Incentives for PV system

Avoidable Cost

- Decreased utility's cost by PV installation

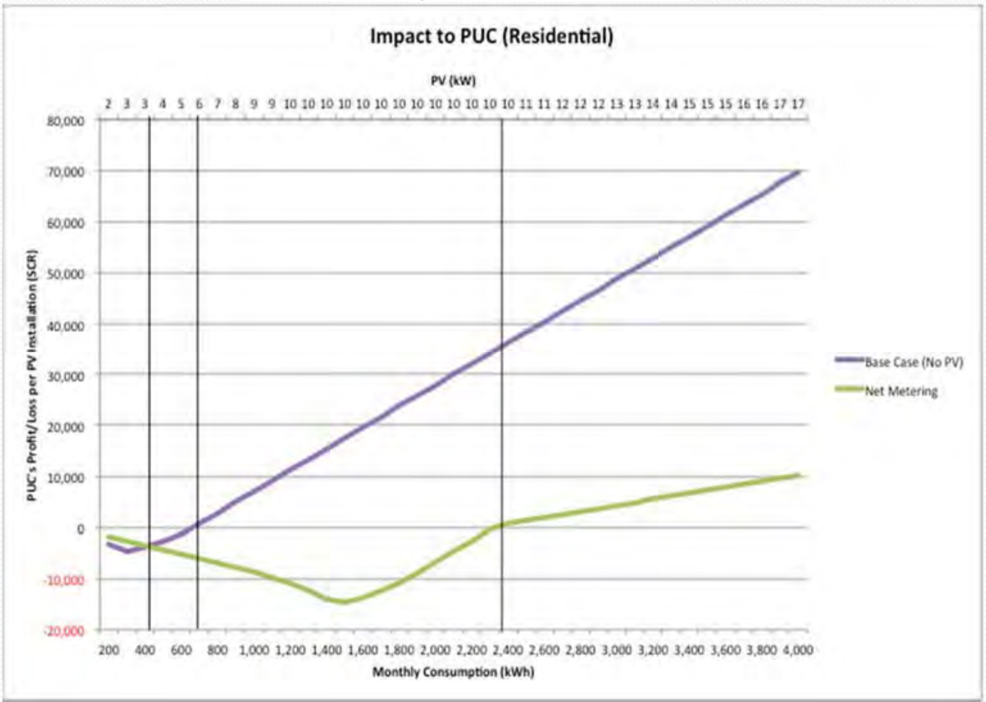
- Very controversial issue
  - Fuel only?
  - May be: lube oil, fuel transportation cost, …
  - NG?: distribution cost, # of employee, …

- Can reduced fuel cost improve Utility's P/L?
  - Reduced fuel is just a fuel cost down in Loss.
  - Not a profit

3.6 Legal system related to renewable energy

▪Incentives for PV system

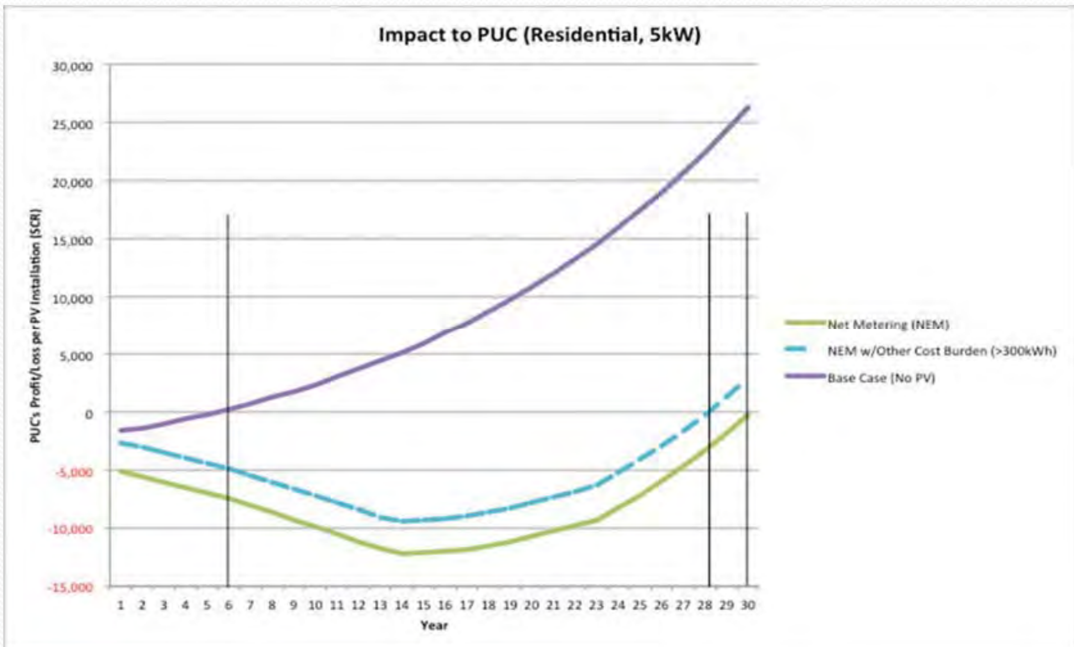
NEM: Seychelles Case



3.6 Legal system related to renewable energy

▪Incentives for PV system

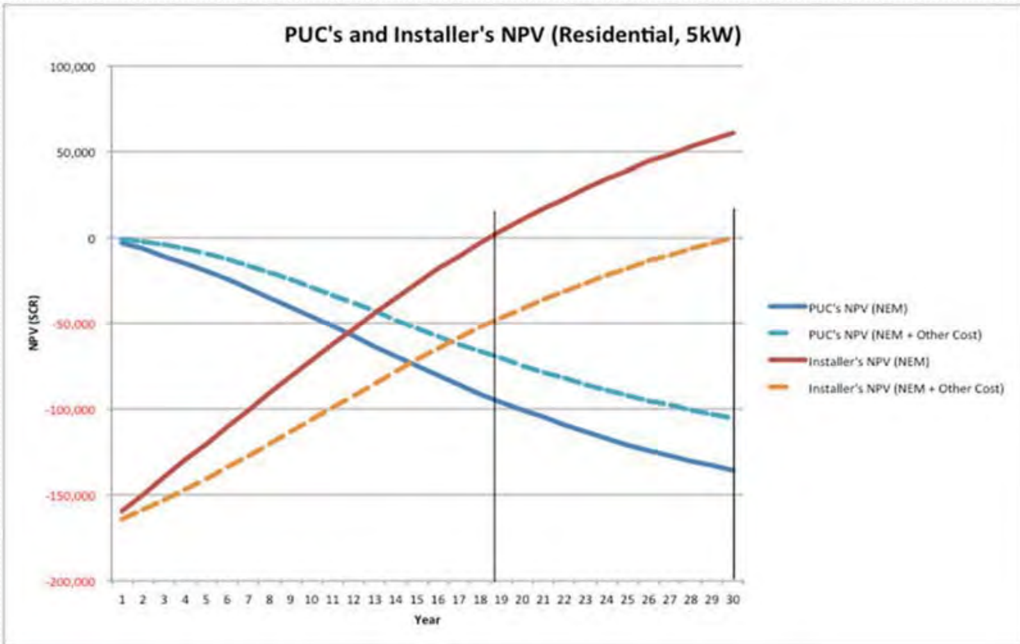
NEM: Seychelles Case, Domestic 5kW - Profit/Loss -



3.6 Legal system related to renewable energy

▪Incentives for PV system

NEM: Seychelles Case, Domestic 5kW
- NPV -

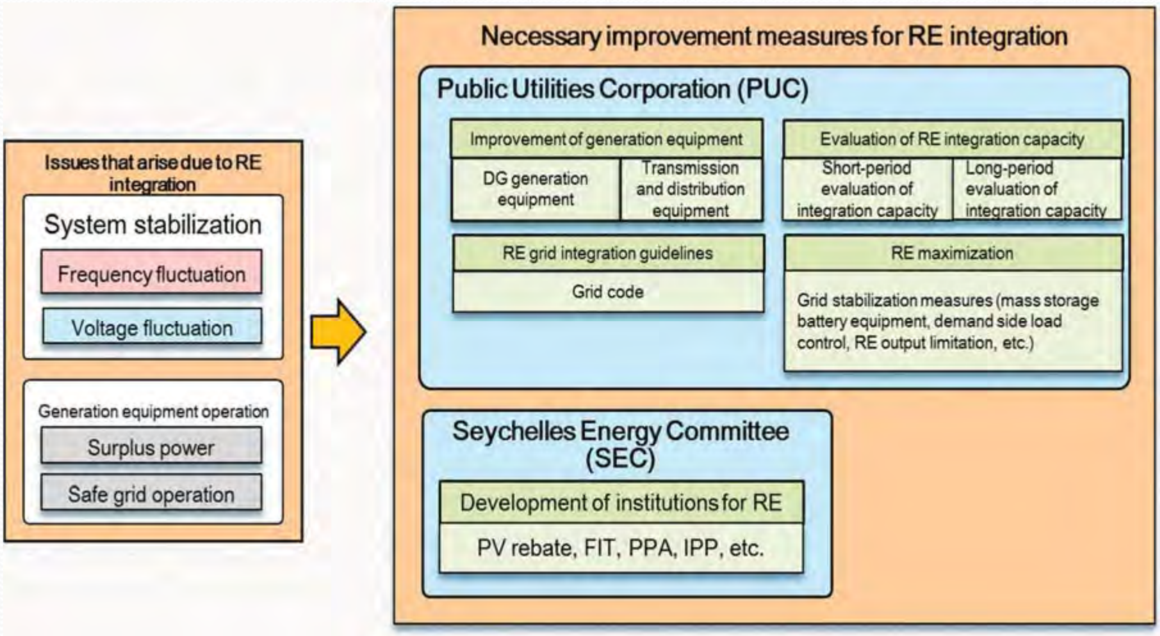


3.6 Legal system related to renewable energy

- Both FIT and NEM have issues.
  - Hard to maintain FIT price in long term
  - Network access charge … Fairness between PV owner and non-owner
  - Financial resource
- Plan
  - Review current situations and select better scheme with cap
  - What is avoided cost?
  - Estimate economic effect on utility and PV owner side in NPV
- Do [Implementation] → Check
  - Monitor PV penetration and analyze impact to utility
- Act
  - Revise scheme periodically based on the evaluation

4. Master Plan for Seychelles

4. Master Plan for RE implementation in Seychelles
Basic items for establishing a master plan



4. Master Plan for RE implementation in Seychelles

Improvements in Power Equipment to avoid issues in RE implementation

DG Power Generation

- Low Load Operation Capacity (50% → 40~30%)
- Adjustment of Governors of Diesel Generators
- Introduction of Low Load Diesel Generators

→ **Solutions in**

- Excess of Energy
- Frequency fluctuations

Transmission & Distribution

Network analysis → (Impedance map / modelling)
- Voltage and current flow analysis
- Active and reactive power analysis
- RE grid connections analysis

↓

Improvements Network
- Proper settings of protection relays
- Selection of the appropriate transmission cables
- Optimization of the network, etc.

→ **Solutions in**

- Over Voltage
- Prevent sudden blackout due to fluctuations in RE generation

Improvements in Power Equipment to avoid issues in RE implementation

Transmission & Distribution

Implementation of measurement equipment
- Normal time (SCADA equipment･few minutes order)
- Accident time (System phenomenon observation instrument ･few second order)
- Oscilloscope instrument (μs order)

↓

Data gathering
- Active power, Reactive power, Voltage, Frequency, Current,
- Normal time, Accident time circumstances

↓

Specifications
- Impedance map
- System modelling

→

System analysis
- Current flow calculations
- Failure calculations
- Frequency response calculations.
- Stability, etc.

↓

Extraction of challenges
- Overload
- Preservation of the voltage
- Frequency fluctuation
- Status of protection relays

↓

Measures for Renewable Energy
- Proper settings of Protection relays
- Expansion of new transmission lines
- Installation of new substations

↓

Solutions in

- Over Voltage
- Prevention of sudden blackout due to fluctuations in RE generation

4. Master Plan for RE implementation in Seychelles

● Calculation of the Max. Amount of RE Implementable

Study on short-term fluctuation

- Simulation software
- Algebraic method

→ **Solutions in**

Frequency deviation from Tolerance values

Study on Long-term fluctuation

- Simulation using software (Homer, DIgSILENT power factory, Ret screen, etc.)

↓

- Countermeasures plan to balance between demand and generation (batteries storage, flywheels, etc.)

→ **Solutions in**

Excess of Energy = operation of diesel generators below of the set minimum output limit.

4. Master Plan for RE implementation in Seychelles

● RE Connection Guideline

● Grid Code Requirements

Grid parameters

- Frequency & voltage

Power Quality :

- DC injection
- Flicker
- Harmonics
- Surge withstand capability
- Power factor

Others

Harmonization of technical standards among and within countries

Safety and isolation

- Safe intentional islanding operation
- Isolation device
- Operation during utility system outage
- Control of faults when in grid-connected mode

Protection requirement

- Voltage regulation
- Frequency disturbance
- Unintentional islanding detection
- Fault ride through
- Disconnection
- Re-connection and synchronization
- Grounding
- Short circuit capacity

↓

Solutions in

Safety Operation of the Power System

4. Master Plan for RE implementation in Seychelles

● Maximization Method

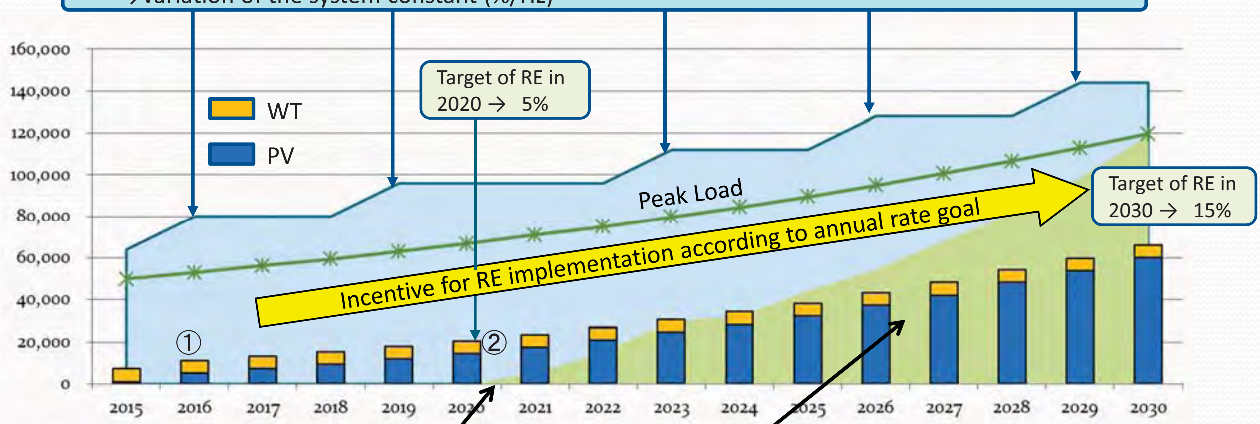
Power system stabilization

- EMS (Energy Management System)
- Grid stabilization using network available load, such us water facilities pump, fishing port ice makers, etc .
- Controlling of customers PV power conditioner.

4. Master Plan for RE implementation in Seychelles

Short period constraint → calculation of the maximum amount of RE using Algebraic method) ①

■ Implementation of Diesel Generator to secure operational reserve for renewable energy.
→variation of the system constant (%/Hz)



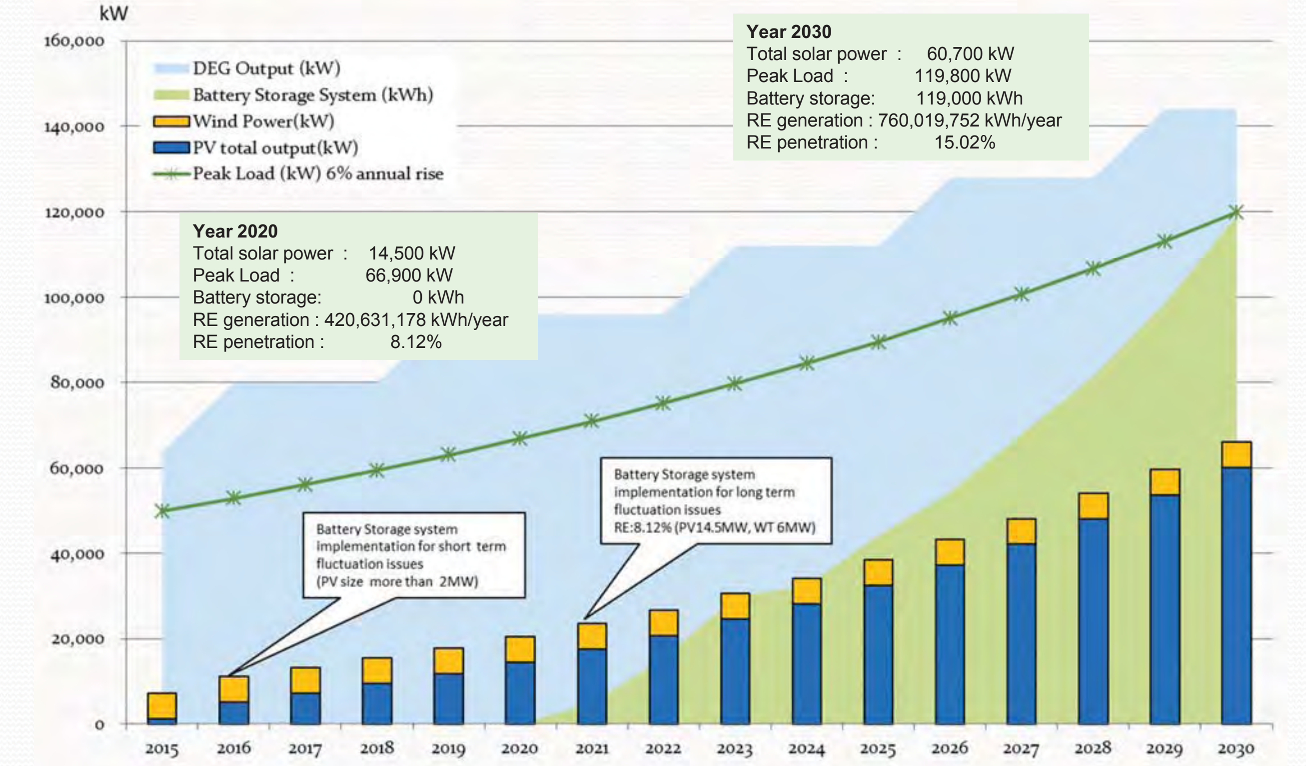
Long period constraint → calculation of RE integration capacity without the use of Battery storage system ②

Long period constraint → calculation of Battery storage system implementation amount using Homer software

Power system stabilization study and implementation (EMS, smart inverters, use of network available load, etc)

EDC operation with periodical measurement on fuel consumption rate (L/kWh) to update the EDC tables

4. Master Plan for RE implementation in Seychelles Mahe Is. (peak load 6% annual rise)



4. Master Plan for RE implementation in Seychelles Mahe Is. (6% peak load year increment)

item / Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Diesel Generators total Output(kW)	64,000	80,000	80,000	80,000	96,000	96,000	96,000	96,000	112,000	112,000	112,000	128,000	128,000	128,000	144,000	144,000
Domestic PV	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Lagoon PV		4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
PUC / PV			2,000	4,300	6,600	9,300	12,300	15,500	19,300	23,000	27,300	32,000	37,000	42,800	48,700	55,500
Total Solar Power(kW)	1,200	5,200	7,200	9,500	11,800	14,500	17,500	20,700	24,500	28,200	32,500	37,200	42,200	48,000	53,900	60,700
Wind Power(kW)	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
TOTAL RE (kW)	7,200	11,200	13,200	15,500	17,800	20,500	23,500	26,700	30,500	34,200	38,500	43,200	48,200	54,000	59,900	66,700
Battery Storage System (kWh)	0	0	0	0	0	0	5,100	15,300	29,920	32,300	44,200	54,400	68,000	81,600	98,600	119,000
PCS(kW)	0	0	2,000	4,300	6,600	9,300	17,400	30,800	49,220	55,300	71,500	86,400	105,000	124,400	147,300	174,500
Peak Load (kW) 6% annual rise	50,000	53,000	56,200	59,500	63,100	66,900	71,000	75,200	79,700	84,500	89,500	95,000	100,600	106,600	113,000	119,800
Power Generation (kWh/year)	313,103,521	331,889,096	352,152,331	373,646,560	396,442,529	420,631,178	446,286,602	473,491,536	502,392,897	532,981,138	565,457,396	599,916,511	636,448,257	#########	716,360,944	760,019,752
RE total power generation(kWh)	11,114,917	18,042,695	21,506,584	25,316,874	29,473,551	34,149,800	39,345,639	44,887,849	51,469,249	57,877,459	65,324,795	73,464,919	82,124,835	92,169,967	102,388,479	114,165,663
Re penetration (%)	3.55	5.44	6.11	6.78	7.43	8.12	8.82	9.48	10.24	10.86	11.55	12.25	12.90	13.65	14.29	15.02
COE (USD/kWh)	0.2343	0.2325	0.2334	0.2344	0.2370	0.2363	0.2354	0.2329	0.2319	0.2332	0.2333	0.2342	0.2345	0.2336	0.2346	0.2344
Excess Electricity (kWh/year)	2.40	2.10	4.40	4.20	4.30	4.20	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.30	0.70	0.90
Capacity Shortage (kWh/year)	47,612.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

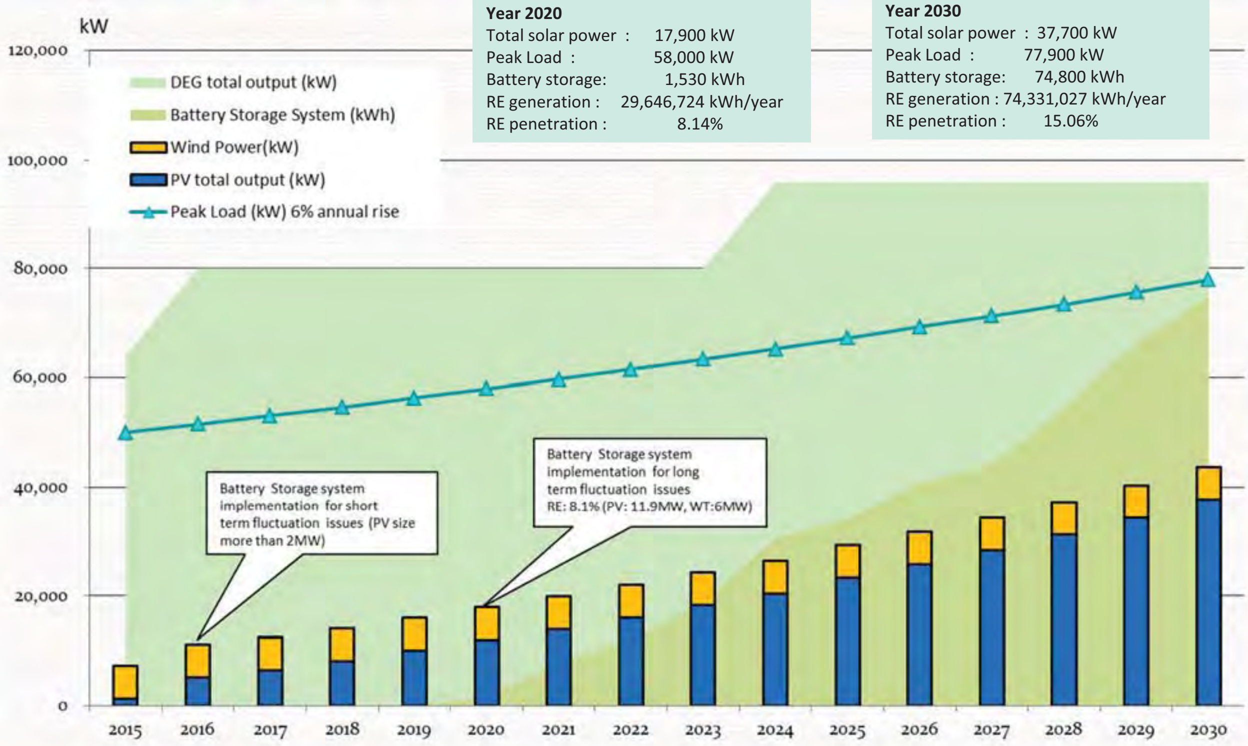
Year 2020
Total solar power : 14,500 kW
Peak Load : 66,900 kW
Battery storage: 0 kWh
RE generation : 420,631,178 kWh/year
RE penetration : 8.12%

Year 2030
Total solar power : 60,700 kW
Peak Load : 119,800 kW
Battery storage: 119,000 kWh
RE generation : 760,019,752 kWh/year
RE penetration : 15.02%

4. Master Plan for RE implementation in Seychelles Mahe Is. (peak load 3% annual rise)

Year 2020
Total solar power : 17,900 kW
Peak Load : 58,000 kW
Battery storage: 1,530 kWh
RE generation : 29,646,724 kWh/year
RE penetration : 8.14%

Year 2030
Total solar power : 37,700 kW
Peak Load : 77,900 kW
Battery storage: 74,800 kWh
RE generation : 74,331,027 kWh/year
RE penetration : 15.06%



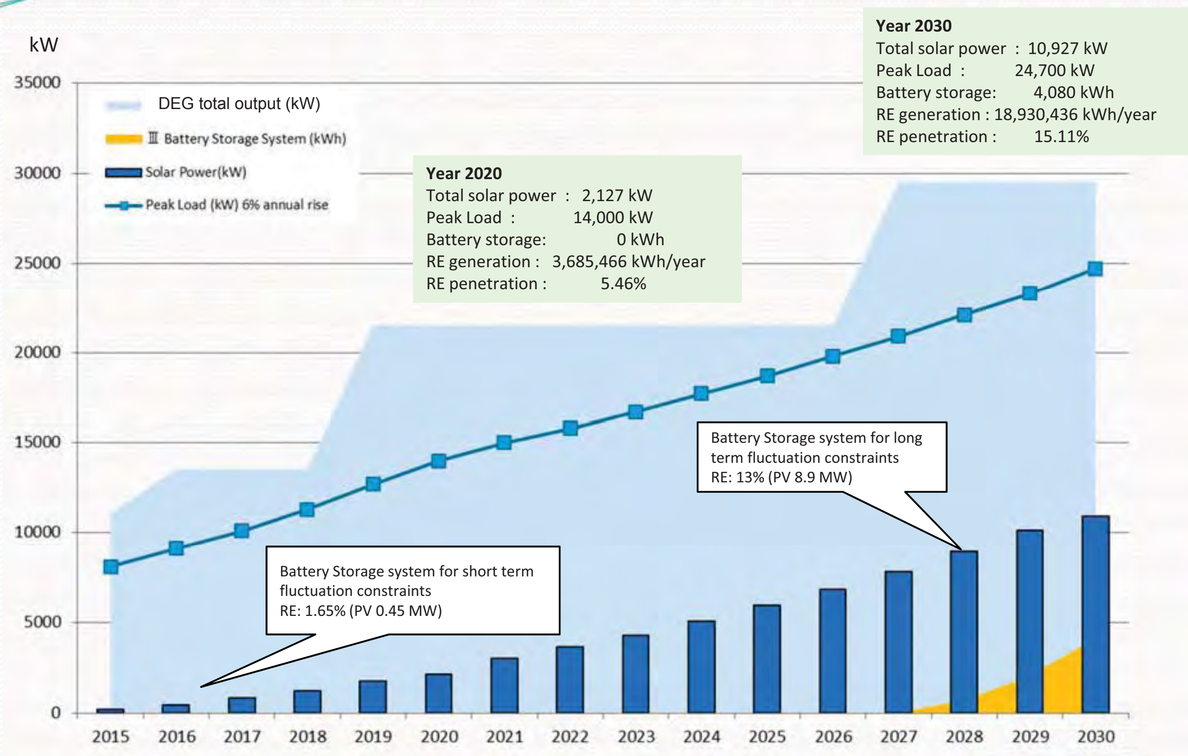
4. Master Plan for RE implementation in Seychelles Mahe Is. (peak load 3% annual rise)

item / year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Diesel generators total output (kW)	64,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	96,000	96,000	96,000	96,000	96,000	96,000	96,000
Domestic PV	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Lagoon PV	0	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
PUC PV	0	0	1,300	2,800	4,800	6,700	8,700	10,800	13,200	15,300	17,900	20,500	23,300	26,100	29,000	32,500
Total Solar Power(kW)	1,200	5,200	6,500	8,000	10,000	11,900	13,900	16,000	18,400	20,500	23,100	25,700	28,500	31,300	34,200	37,700
Wind Power(kW)	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
TOTAL RE (kW)	7,200	11,200	12,500	14,000	16,000	17,900	19,900	22,000	24,400	26,500	29,100	31,700	34,500	37,300	40,200	43,700
Battery Storage System(kWh)	0	0	0	0	0	1,530	7,990	11,900	18,700	30,600	34,000	40,800	44,200	57,800	66,300	74,800
PCS(kW)	0	0	1,300	2,800	4,800	8,230	16,690	22,700	31,900	45,900	51,900	61,300	67,500	83,900	95,300	107,300
Peak Load (kW) 6% annual rise	50,000	51,500	53,050	54,600	56,300	58,000	59,700	61,500	63,300	65,200	67,200	69,200	71,300	73,400	75,600	77,900
Power Generation (kWh/year)	313,103,529	322,494,520	332,395,650	342,636,291	353,230,987	364,132,081	375,367,389	386,949,738	398,920,843	411,179,794	423,890,284	436,965,722	450,457,911	464,344,306	478,646,563	493,474,007
RE total power generation(kWh)	11,114,917	18,042,695	20,294,228	23,065,348	26,356,043	29,646,724	33,110,624	36,747,705	40,904,407	44,541,433	49,044,539	53,547,615	58,397,051	63,246,595	68,269,091	74,331,027
Re penetration (%)	3.55	5.59	6.11	6.73	7.46	8.14	8.82	9.50	10.25	10.83	11.57	12.25	12.96	13.62	14.26	15.06
COE (USD/kWh)	0.2344	0.2327	0.2332	0.2338	0.2345	0.2350	0.2344	0.2343	0.2329	0.2326	0.2311	0.2319	0.2319	0.2337	0.2337	0.2329
Excess Electricity (kWh/year)	2.4	2.1	4.3	4.10	4.2	0.00	0.00	0.00	0.00	0.00	0.00	0	0.1	0.1	0.2	0.40
Capacity Shortage (kWh/year)	47,612.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0	0	0.00	0.00

Year 2020
Total solar power : 11,900 kW
Peak Load : 58,000 kW
Battery storage: 1,530 kWh
RE generation : 29,646,724 kWh/year
RE penetration : 8.14%

Year 2030
Total solar power : 37,700 kW
Peak Load : 77,900 kW
Battery storage: 74,800 kWh
RE generation : 74,331,027 kWh/year
RE penetration : 15.06%

4. Master Plan for RE implementation in Seychelles Praslin Is. + La Digue Is. (peak load 6% annual rise)



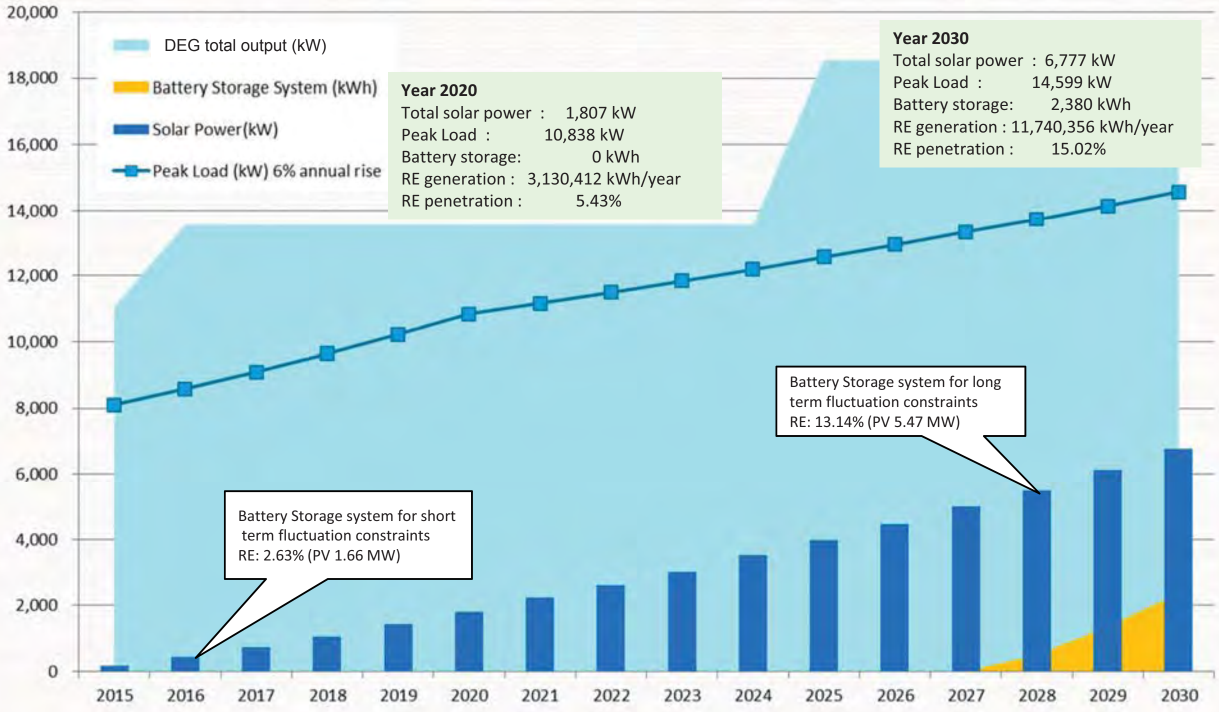
4. Master Plan for RE implementation in Seychelles Praslin Is. + La Digue Is. (peak load 6% annual rise)

item / year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Diesel generators total output (kW)	11,050	13,550	13,550	13,550	21,550	21,550	21,550	21,550	21,550	21,550	21,550	21,550	29,550	29,550	29,550	29,550
Existing PV (kW)	177	177	177	177	177	177	177	177	177	177	177	177	177	177	177	177
PUC PV (kW)	0	280	640	1,050	1,600	1,950	2,800	3,450	4,100	4,900	5,750	6,650	7,650	8,750	9,950	10,750
Total Solar Power(kW)	177	457	817	1,227	1,777	2,127	2,977	3,627	4,277	5,077	5,927	6,827	7,827	8,927	10,127	10,927
Battery Storage System(kWh)	0	0	0	0	0	0	0	0	0	0	0	0	0	680	2,040	4,080
PCS(kW)	0	457	640	1,050	1,600	1,950	2,800	3,450	4,100	4,900	5,750	6,650	7,650	9,430	11,990	14,830
Peak Load (kW) 6% annual rise	8,100	9,100	10,100	11,300	12,700	14,000	15,000	15,800	16,700	17,700	18,700	19,800	20,900	22,100	23,300	24,700
Power Generation (kWh/year)	42,872,548	48,001,823	53,746,282	60,175,496	67,380,419	67,441,036	79,808,100	84,429,391	89,309,297	94,484,999	99,954,476	105,736,388	111,856,175	118,333,823	125,181,685	125,320,125
RE total power generation(kWh)	307,324	792,390	1,416,048	2,126,325	3,079,139	3,685,466	5,157,990	6,284,044	7,410,082	8,795,994	10,268,531	11,827,657	13,560,038	15,465,678	17,544,542	18,930,436
Re penetration (%)	0.72	1.65	2.63	3.53	4.57	5.46	6.46	7.44	8.30	9.31	10.27	11.19	12.12	13.07	14.02	15.11
COE (USD/kWh)	0.2641	0.2682	0.2663	0.2667	0.2733	0.2725	0.2706	0.2694	0.2683	0.2672	0.2661	0.2651	0.2687	0.2681	0.2682	0.2693
Excess Electricity (kWh/year)	0.2	0.5	0.5	0.50	0.6	0.50	0.80	0.80	0.90	0.90	0.90	0.9	0.9	0.1	0.1	0.10
Capacity Shortage (kWh/year)	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0	0	0.00	0.00

Year 2020
Total solar power : 2,127 kW
Peak Load : 14,000 kW
Battery storage: 0 kWh
RE generation : 3,685,466 kWh/year
RE penetration : 5.46%

Year 2030
Total solar power : 10,927 kW
Peak Load : 24,700 kW
Battery storage: 4,080 kWh
RE generation : 18,930,436 kWh/year
RE penetration : 15.11%

4. Master Plan for RE implementation in Seychelles
Praslin Is. + La Digue Is. (peak load 3% annual rise)



4. Master Plan for RE implementation in Seychelles
Praslin Is. + La Digue Is. (peak load 3% annual rise)

item / Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Diesel generators total output (kW)	11,050	13,550	13,550	13,550	13,550	13,550	13,550	13,550	13,550	13,550	21,550	21,550	21,550	21,550	21,550	21,550
Existing PV (kW)	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00
PUC PV	0.00	260	550	870	1,250	1,630	2,050	2,450	2,850	3,350	3,800	4,300	4,820	5,300	5,950	6,600
Total Solar Power(kW)	177	437	727	1,047	1,427	1,807	2,227	2,627	3,027	3,527	3,977	4,477	4,997	5,477	6,127	6,777
Battery Storage System(kWh)	0	0	0	0	0	0	0	0	0	0	0	0	0	510	1,360	2,380
PCS(kW)	0	260	550	870	1,250	1,630	2,050	2,450	2,850	3,350	3,800	4,300	7,650	5,810	7,310	8,980
Peak Load (kW) 3% annual rise	8,100	8,586	9,101	9,647	10,225	10,838	11,163	11,497	11,841	12,196	12,561	12,937	13,325	13,724	14,135	14,559
Power Generation (kWh/year)	42,872,548	45,487,690	48,260,002	51,201,133	54,325,537	57,633,815	59,422,656	61,259,426	63,149,523	65,111,914	67,120,720	69,197,778	71,336,731	73,547,377	75,816,927	78,168,754
RE total power generation(kWh)	306,632	757,050	1,259,441	1,813,806	2,472,111	3,130,412	3,858,011	4,550,967	5,243,927	6,110,123	6,889,687	7,755,867	8,656,728	9,661,499	10,614,324	11,740,356
Re penetration (%)	0.72	1.66	2.61	3.54	4.55	5.43	6.49	7.43	8.30	9.38	10.26	11.21	12.14	13.14	14.00	15.02
COE (USD/kWh)	0.2641	0.2669	0.2662	0.2654	0.2647	0.2640	0.2631	0.2623	0.2617	0.2620	0.2659	0.2650	0.2629	0.2628	0.2633	0.2639
Excess Electricity (kWh/year)	0.20	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.00	0.00	0.00
Capacity Shortage (kWh/year)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Year 2020
Total solar power : 1,807 kW
Peak Load : 10,838 kW
Battery storage: 0 kWh
RE generation : 3,130,412 kWh/year
RE penetration : 5.43%

Year 2030
Total solar power : 6,777 kW
Peak Load : 14,599 kW
Battery storage: 2,380 kWh
RE generation : 11,740,356 kWh/year
RE penetration : 15.02%

Thank you for your attention.












Okinawa Enetech Co., Inc.