



République Tunisienne
Ministère de l'Enseignement Supérieur et de la Recherche Scientifique
Université de Tunis El Manar
Faculté des sciences de Tunis



Mastère professionnel Energies Renouvelables, Technologies et Applications

ÉLABORATION D'UN PLAN DE DÉVELOPPEMENT D'UN PROJET SOLAIRE PHOTOVOLTAÏQUE DE 1MW

Réalisé au sein :



par : Ala eddine LASSOUED

Encadrante académique : Mme Jouda KHABTHANI

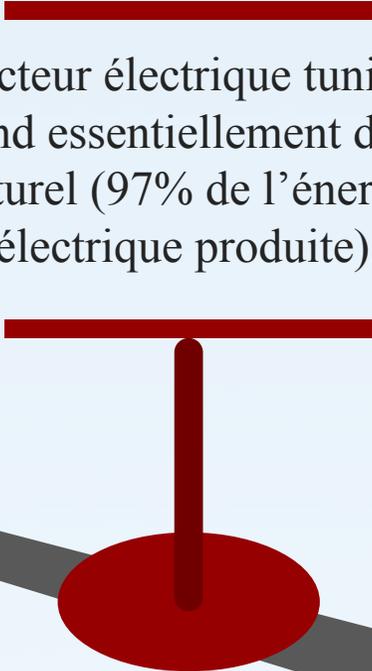
Encadrant professionnel : M. Adel Dhouib

Année Universitaire : 2019/2020

Introduction



Défis : stratégiques,
économiques, sociaux et
environnementaux.



le secteur électrique tunisien,
dépend essentiellement du gaz
naturel (97% de l'énergie
électrique produite).



L'objectif est la
satisfaction des besoins
énergétiques du pays.

Plan

Problématique

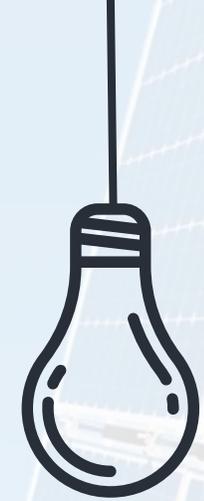
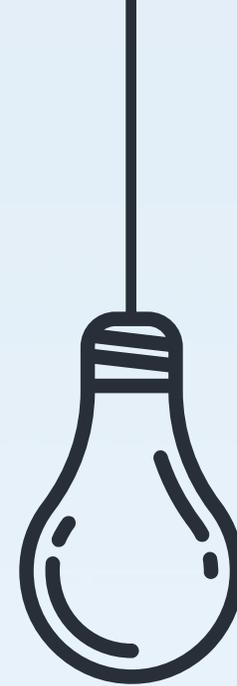
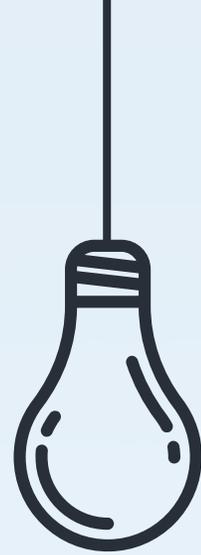
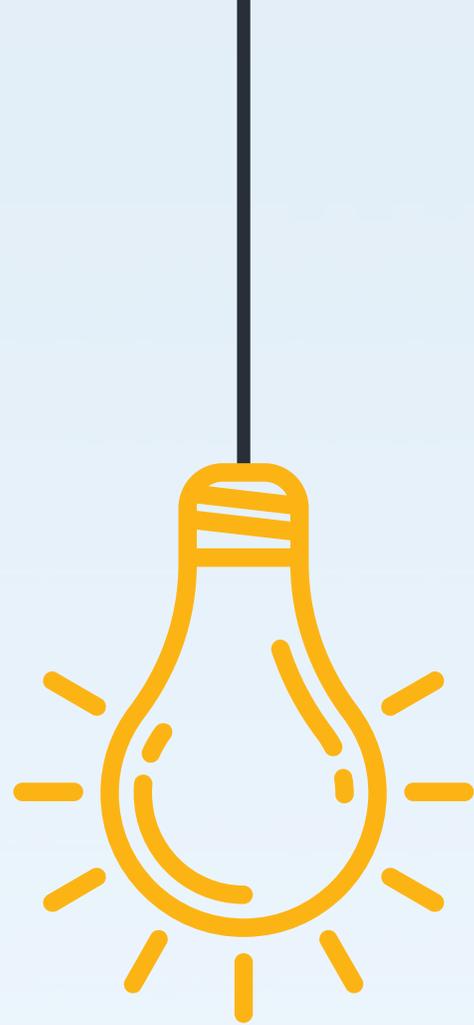
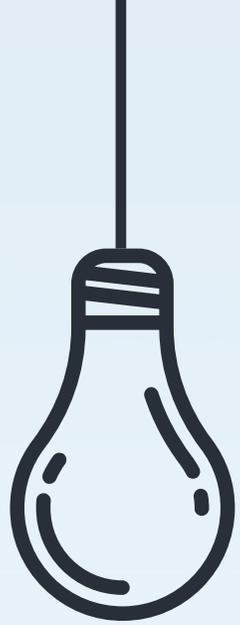
Organisme d'accueil

Justification du choix du site

Simulation et résultats

Etude économique

Conclusion



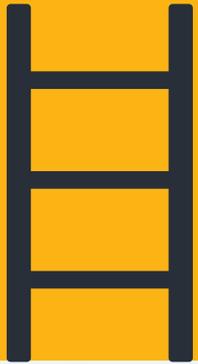
Problématique

Problématique

Déclin des ressources
d'énergie primaire (7% par an).

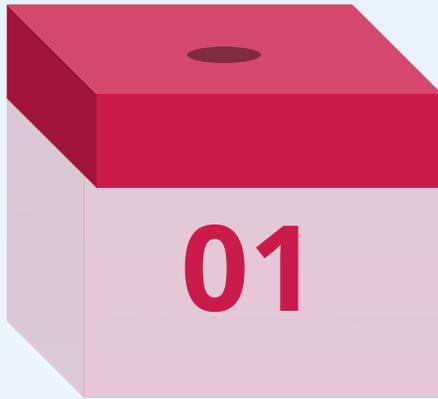
l'article 12 de la loi n°2015-12 du 11 mai
2015 et le chapitre 2 du décret n°2016-1123
qui s'applique aux projets de production d'
électricité à partir des énergies éolienne et
solaire photovoltaïque.

Réalisation d'une centrale solaire
photovoltaïque dont la puissance est
égale à un (1) mégawatt crête

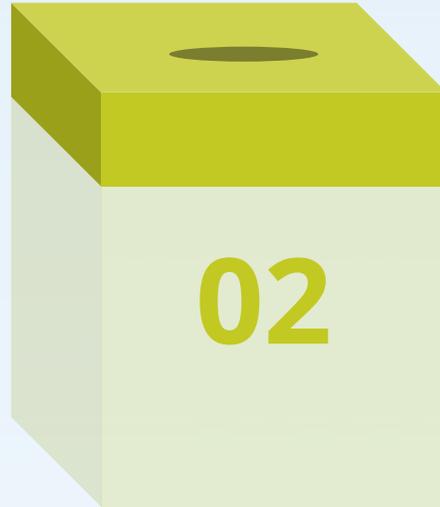


Problématique

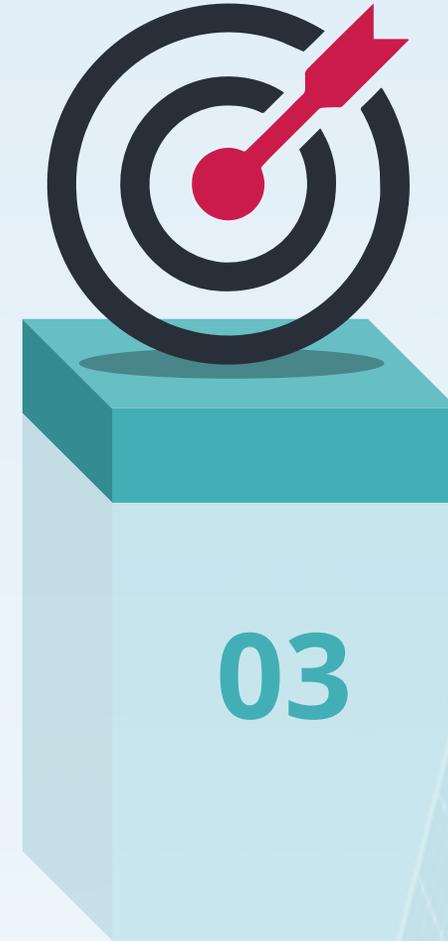
Objectifs à réaliser



Choix du site



**Dimensionnement
de la centrale
photovoltaïque**



Analyse économique

Organisme d'accueil



Organisme d'accueil



01

Gestion et pilotage de projets renouvelables (Éolien et solaire)

02

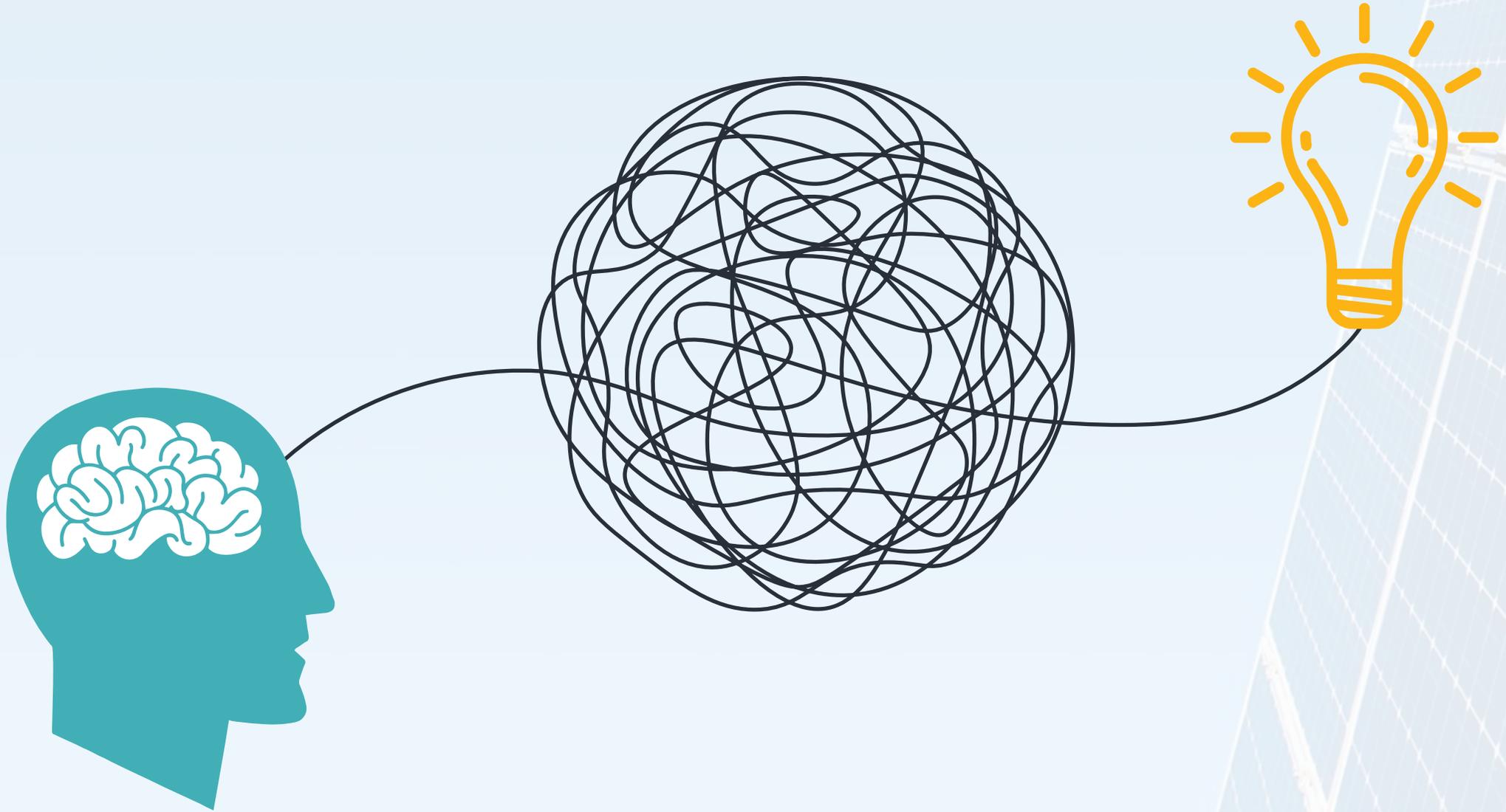
Réalisation de projets solaire photovoltaïques clé en main pour le compte d'industriels, agriculteurs et secteur tertiaires

03

Développement et implémentation de projets de valorisation de déchets en bioénergie.



Choix du site



Choix du site

Potentiel solaire



L'accessibilité



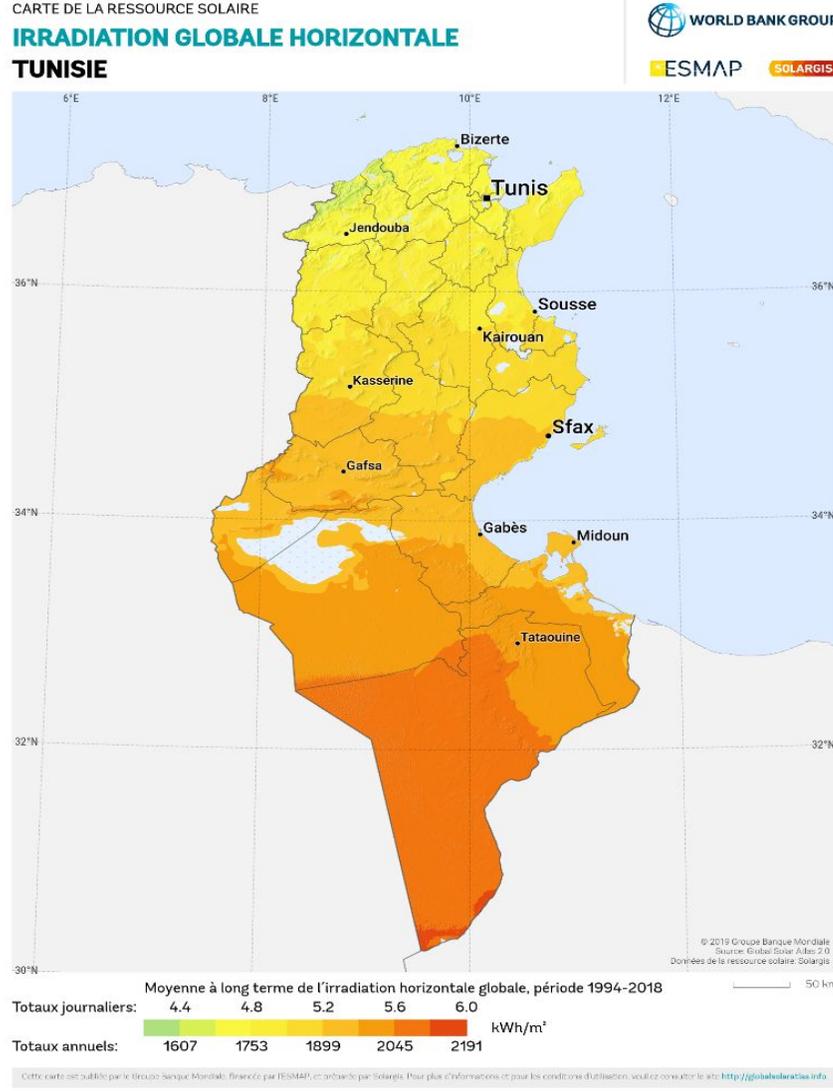
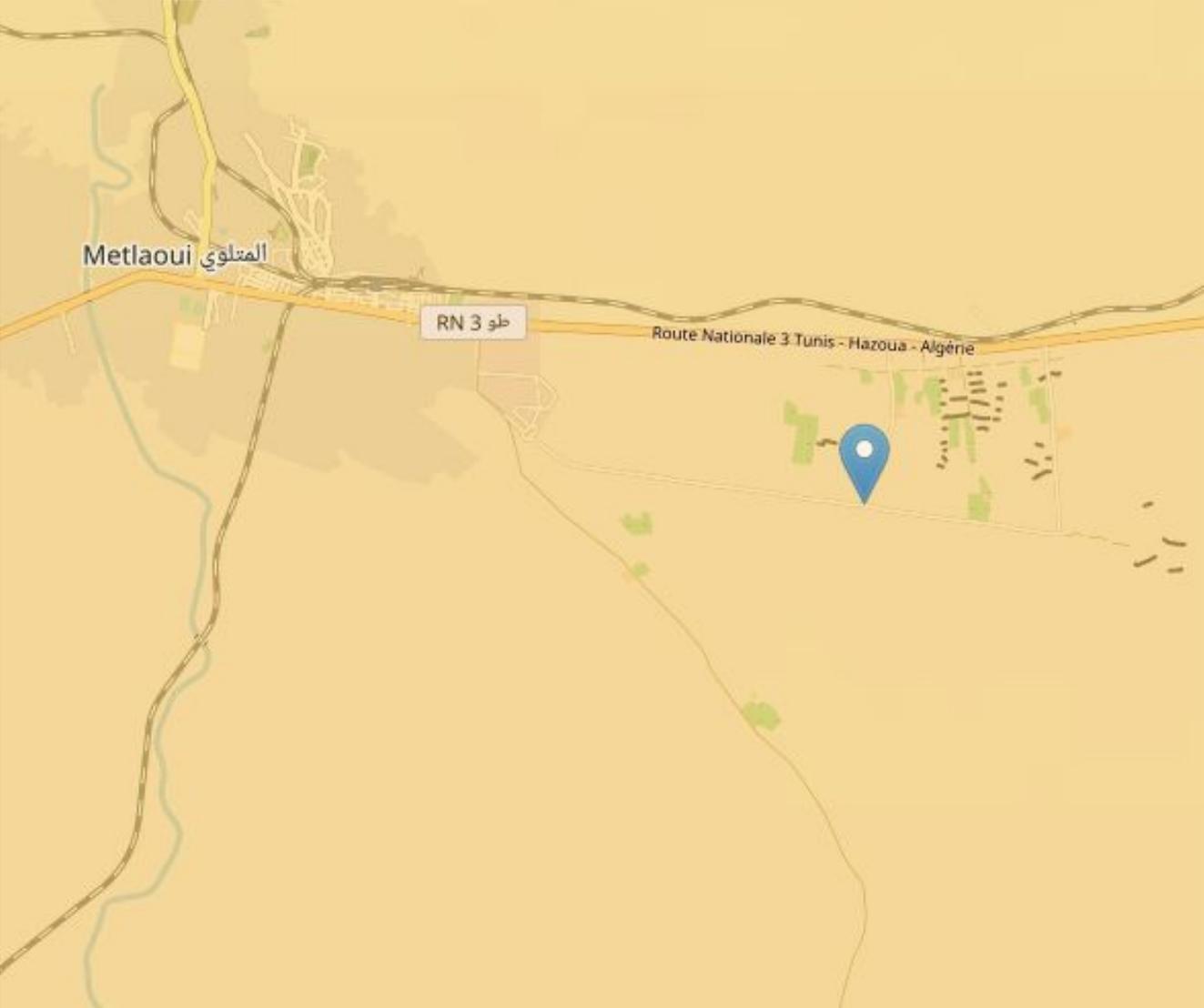
04

Règlementation et
Considérations
environnementales

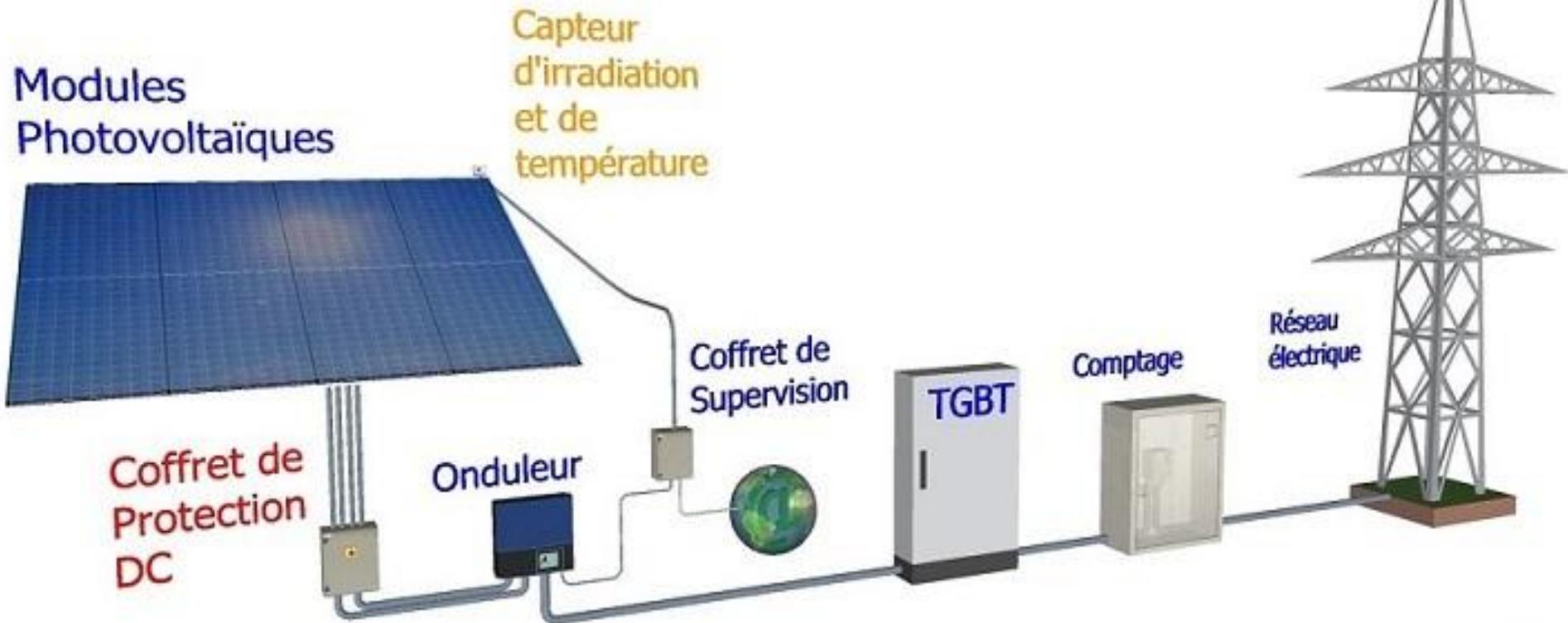
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La raccordabilité
au réseau

Choix du site

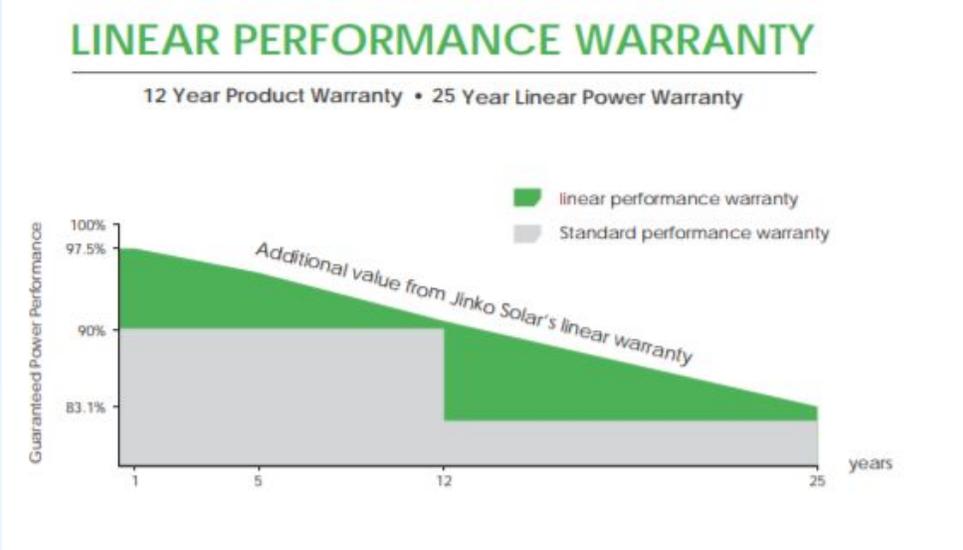
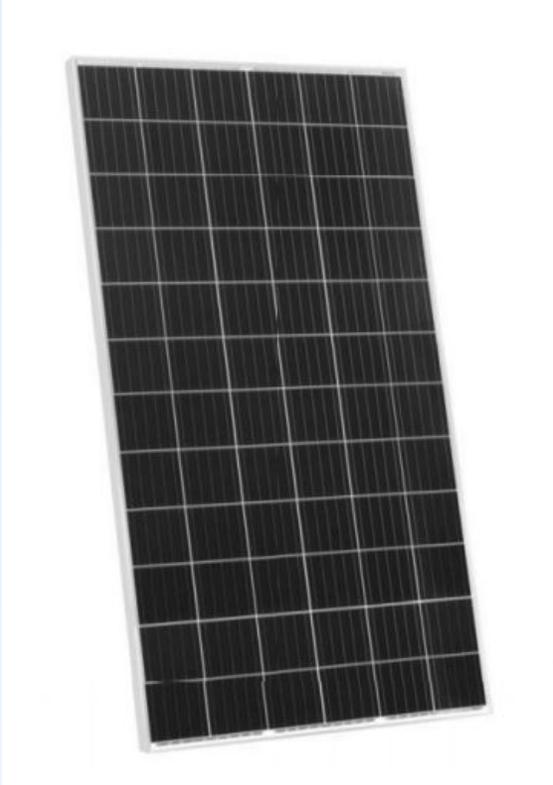


Choix du site



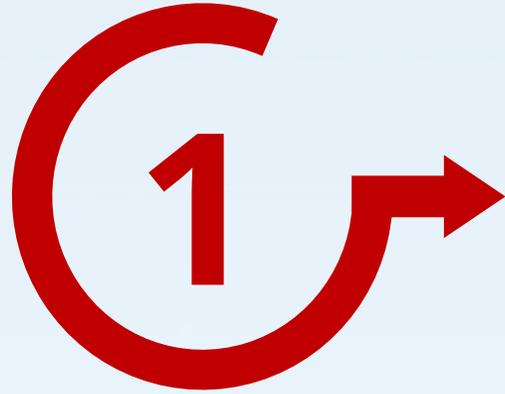
Choix du site

Choix du module PV



Choix du site

Choix d'onduleur



la protection



Les pertes / le rendement

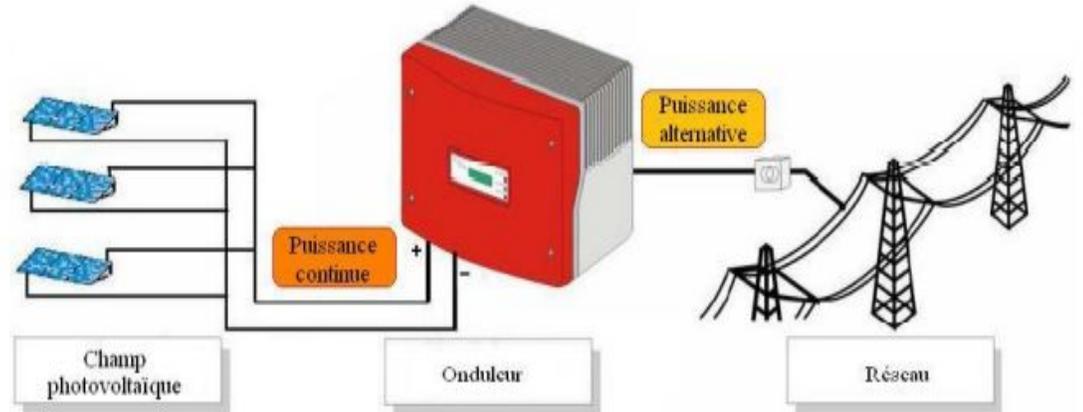
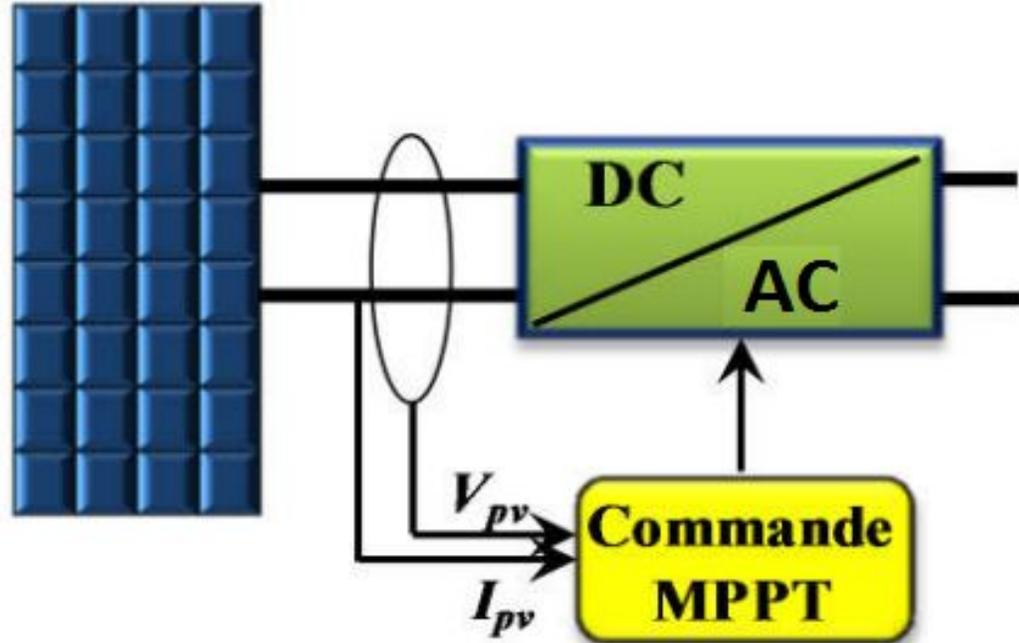


Le coût

SUNGROW

Choix du site

Panneau PV

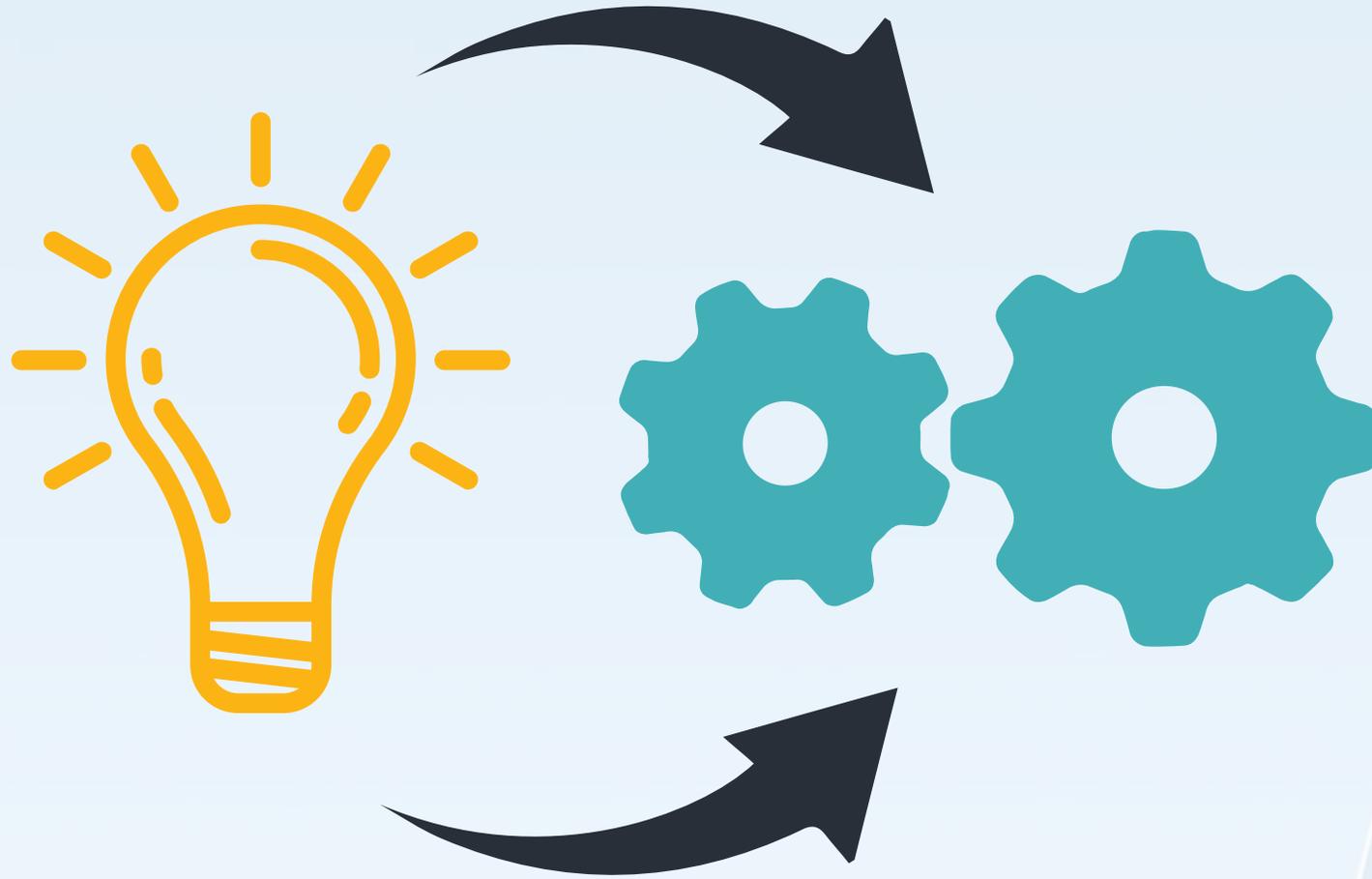


$$\eta = \frac{\text{Puissance en sortie}}{\text{Puissance en entrée}} = \frac{P_{AC}}{P_{DC}}$$



Fonctionnement d'onduleur





Simulation et résultats

Simulation et résultats

SAM 2020.2.29: C:\Users\DELL\Desktop\1MWc PPA (Metloui 5)\1 MWc PPA (Metloui5).sam

File Add 1 MW PPA (Metlaoui 5) Help

Photovoltaic, Single owner

Location and Resource

Module

Inverter

System Design

Shading and Layout

Losses

Grid Limits

Lifetime and Degradation

System Costs

Financial Parameters

Revenue

Incentives

Depreciation

Simulate >

Parametrics Stochastic

P50 / P90 Macros

+ Albedo - Sky Diffuse Model - Irradiance Data (Advanced)

Download Weather Files

The NSRDB is a database of thousands of weather files that you can download and add to your solar resource library. Download a default typical-year (TMY) file for most long-term cash flow analyses, or choose files to download for single-year or P50/P90 analyses. See Help for details.

One location Multiple locations 60-minute 30-minute

Type a location name, street address, or lat,lon in decimal degrees Download files for all years (P50/P90)

[For locations not covered by the NSRDB, click here to go to the SAM website Weather Page for links to other data sources.](#)

Weather Data Information

The following information describes the data in the highlighted weather file from the Solar Resource library above. This is the file SAM will use when you click Simulate.

Weather file:

-Header Data from Weather File-

Latitude	<input type="text" value="34.3"/> DD	Station ID	<input type="text" value="unknown"/>
Longitude	<input type="text" value="8.458"/> DD	Data Source	<input type="text" value="ECMWF/ERA"/>
Time zone	<input type="text" value="GMT 1"/>	For NSRDB data, the latitude and longitude shown here from the weather file header are the coordinates of the NSRDB grid cell and may be different from the values in the file name, which are the coordinates of the requested location.	
Elevation	<input type="text" value="178"/> m		

-Annual Averages Calculated from Weather File Data-

Global horizontal	<input type="text" value="5.70"/> kWh/m ² /day	-Optional Data	
Direct normal (beam)	<input type="text" value="6.40"/> kWh/m ² /day	Maximum snow depth	<input type="text" value="NaN"/> cm
Diffuse horizontal	<input type="text" value="1.71"/> kWh/m ² /day	Annual albedo	<input type="text" value="-999"/>
Average temperature	<input type="text" value="21.4"/> °C	*NaN indicates missing data.	
Average wind speed	<input type="text" value="4.0"/> m/s		

Simulation et résultats

SAM 2020.2.29: C:\Users\DELL\Desktop\1MWc PPA (Metloui 5)\1 MWc PPA (Metloui5).sam

File Add 1 MW PPA (Metlaoui 5) Help

Photovoltaic, Single owner

CEC Performance Model with Module Database

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P50 / P90 Macros

Filter: Name

Name	Manufacturer	Technology	Bifacial	STC	PTC	A_c	Length	Width	N_s	I_sc_ref	V_oc_ref	I_mp_ref	V_mp_ref	z
Jinko Solar Co., Ltd JKM400M-72BL	Jinko Solar Co., Ltd	Mono-c-Si	0	400.32	369.6	1.92			72	10.36	49.8	9.6	41.7	C
Jinko Solar Co., Ltd JKM400M-72HL	Jinko Solar Co., Ltd	Mono-c-Si	0	400.32	370	1.96			144	10.36	49.8	9.6	41.7	C
Jinko Solar Co., Ltd JKM400M-72H...	Jinko Solar Co., Ltd	Mono-c-Si	0	400.32	371.4	1.96			144	10.36	49.8	9.6	41.7	C
Jinko Solar Co., Ltd JKM400M-72L	Jinko Solar Co., Ltd	Mono-c-Si	0	400.32	368.2	1.92			72	10.36	49.8	9.6	41.7	C
Jinko Solar Co., Ltd JKM400M-72L-V	Jinko Solar Co., Ltd	Mono-c-Si	0	400.32	368.6	1.92			72	10.36	49.8	9.6	41.7	C
Jinko Solar Co., Ltd JKMS400M-72L...	Jinko Solar Co., Ltd	Mono-c-Si	0	400.32	368.2	1.92			72	10.36	49.8	9.6	41.7	C
Jinko Solar Co., Ltd JKMS400M-72L...	Jinko Solar Co., Ltd	Mono-c-Si	0	400.32	368.6	1.92			72	10.36	49.8	9.6	41.7	C
Jinko Solar Co., Ltd JKM405M-72HL	Jinko Solar Co., Ltd	Mono-c-Si	0	405.3	374.7	1.96			144	10.48	50.1	9.65	42	C

Module Characteristics at Reference Conditions

Reference conditions: Total Irradiance = 1000 W/m², Cell temp = 25 C

Jinko Solar Co. Ltd JKM400M-72L-V

Nominal efficiency: 20.85 %

Maximum power (Pmp): 400.320 Wdc

Max power voltage (Vmp): 41.7 Vdc

Max power current (Imp): 9.6 Adc

Open circuit voltage (Voc): 49.8 Vdc

Short circuit current (Isc): 10.4 Adc

Temperature coefficients

Temperature coefficient of Pmp: -0.402 %/°C

Temperature coefficient of Voc: -0.300 V/°C

Temperature coefficient of Isc: 0.050 %/°C

Temperature coefficient of Vmp: -1.609 W/°C

Temperature coefficient of Imp: -0.149 V/°C

Temperature coefficient of Voc: 0.005 A/°C

Bifacial Specifications

Module is bifacial

Transmission fraction: 1 0-1

Bifaciality: 0.665 0-1

Ground clearance height: 1.5 m

Temperature Correction

Nominal operating cell temperature (NOCT) method

NOCT Method Parameters

Mounting standoff: Ground level mounted

16:38 13/08/2020

Simulation et résultats

SAM 2020.2.29: C:\Users\DELL\Desktop\1MWc PPA (Metloui 5)\1 MWc PPA (Metloui5).sam

File Add 1 MW PPA (Metlaoui 5) Help

Photovoltaic, Single owner

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Simulate >

Parametrics Stochastic

P50 / P90 Macros

0 10 20 30 40 50

Module Voltage (Volts)

Module is bifacial

Transmission fraction 0-1

Bifaciality 0-1

Ground clearance height m

Temperature Correction

Nominal operating cell temperature (NOCT) method

Heat transfer method

See Help for more information about CEC cell temperature models.

NOCT Method Parameters

Mounting standoff

Array height

Heat Transfer Method Parameters

Mounting configuration

Heat transfer dimensions

Mounting structure orientation

Module width m

Module length m

Rows of modules in array

Columns of modules in array

Temperature behind the module °C

Space between module back and roof surface m

Physical Characteristics

Material Module area m² Number of cells

Additional Parameters

T_noct °C I_L_ref A R_s Ohm

A_ref V I_o_ref A R_sh_ref Ohm

The model assumes a reference bandgap voltage $E_{g_ref} = 1.121$ eV, and temperature coefficient for bandgap of -0.0002677 eV/K.

References

For more information about the CEC module model inputs, see Help. For a detailed description of the model, see Gilman (2015), De Soto (2004), and Neises (2011) on the SAM website's Performance Documentation page:

[Performance Model Documentation page on SAM website](#)

Je suis Cortana. Posez-moi une question.

16:41 13/08/2020

Simulation et résultats

SAM 2020.2.29: C:\Users\DELL\Desktop\1MWc PPA (Metloui 5)\1 MWc PPA (Metloui5).sam

File Add 1 MW PPA (Metlaoui 5) Help

Photovoltaic, Single owner

Inverter CEC Database

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Filter: Name

Name	Paco	Pdco	Pso	Pnt	Vac	Vdcmx	Vdco	Mppt_high	Mppt_low	C0	C1	C2	C3
Sungrow Power Supply Co - Ltd : SG1000...	10...	1033038.5	7066.0...	300	0	800	630	800	570	-3.23E-08	0.000021	0.001095	0.001191
Sungrow Power Supply Co - Ltd : SG100K...	10...	105314.3...	681.89...	30.3	480	480	380	480	300	-3.04E-07	0.000023	0.000502	-0.00045
Sungrow Power Supply Co - Ltd : SG100K...	10...	104464.5	476.79...	30	480	480	350	480	300	-2.83E-07	0.000044	0.000319	0.00163
Sungrow Power Supply Co - Ltd : SG125...	12...	127404.3...	93.234...	37.5	600	1200	945	1200	860	-8.41E-08	0.00002	0.00546	0.003088
Sungrow Power Supply Co - Ltd : SG2500...	25...	2542502.5	3912.4...	750	550	1200	900	1200	800	-3.86E-09	4.99E-06	0.000279	-0.00049

Efficiency Curve and Characteristics

Sungrow Power Supply Co - Ltd : SG125HV [600V]

Number of MPPT inputs: CEC weighted efficiency: %
European weighted efficiency: %

-Datasheet Parameters-

Maximum AC power	<input type="text" value="125000"/>	Wac
Maximum DC power	<input type="text" value="127404"/>	Wdc
Power use during operation	<input type="text" value="93.2348"/>	Wdc
Power use at night	<input type="text" value="37.5"/>	Wac
Nominal AC voltage	<input type="text" value="600"/>	Vac
Maximum DC voltage	<input type="text" value="1200"/>	Vdc
Maximum DC current	<input type="text" value="134.819"/>	Adc
Minimum MPPT DC voltage	<input type="text" value="860"/>	Vdc
Nominal DC voltage	<input type="text" value="945"/>	Vdc
Maximum MPPT DC voltage	<input type="text" value="1200"/>	Vdc

-Sandia Coefficients-

C0	<input type="text" value="-8.41e-08"/>	1/Wac
C1	<input type="text" value="2e-05"/>	1/Vdc
C2	<input type="text" value="0.00546"/>	1/Vdc
C3	<input type="text" value="0.003088"/>	1/Vdc

Note: If you are modeling a system with microinverters or DC power optimizers, see the Losses page to adjust the system losses accordingly.

-CEC Information-

CEC name: CEC type: CEC date:

Simulate >

Parametrics Stochastic

P50 / P90 Macros

Je suis Cortana. Posez-moi une question.

15:15 15/08/2020

Simulation et résultats

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File Add 1 MW PPA (Metlaoui 5) Help

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Simulate >

Parametrics Stochastic

P50 / P90 Macros

AC Sizing

Number of inverters: 7

DC to AC ratio: 1.14

Desired array size: 1000 kWdc

Desired DC to AC Ratio: 1.2

Estimate Subarray 1 configuration

Sizing Summary

Nameplate DC capacity	999.199 kWdc	Number of modules	2,496
Total AC capacity	875.000 kWac	Number of strings	104
Total inverter DC capacity	891.830 kWdc	Total module area	4,792.3 m ²

DC Sizing and Configuration

To model a system with one array, specify properties for Subarray 1 and disable Subarrays 2, 3, and 4. To model a system with up to four subarrays connected in parallel to a single bank of inverters, for each subarray, check Enable and specify a number of strings and other properties.

	Subarray 1	Subarray 2	Subarray 3	Subarray 4
Electrical Configuration	(always enabled)	<input type="checkbox"/> Enable	<input type="checkbox"/> Enable	<input type="checkbox"/> Enable
Modules per string in subarray	24			
Strings in parallel in subarray	104			
Number of modules in subarray	2,496			
String Voc at reference conditions (V)	1,195.2			
String Vmp at reference conditions (V)	1,000.8			

Tracking & Orientation

Azimuth
N = 0
W 270
E 90
S 180

Tilt
90 Vert.
0 Horiz.

Fixed
 1 Axis
 2 Axis
 Azimuth Axis
 Seasonal Tilt

Tilt=latitude

Tilt (deg): 30
Azimuth (deg): 180

Je suis Cortana. Posez-moi une question.

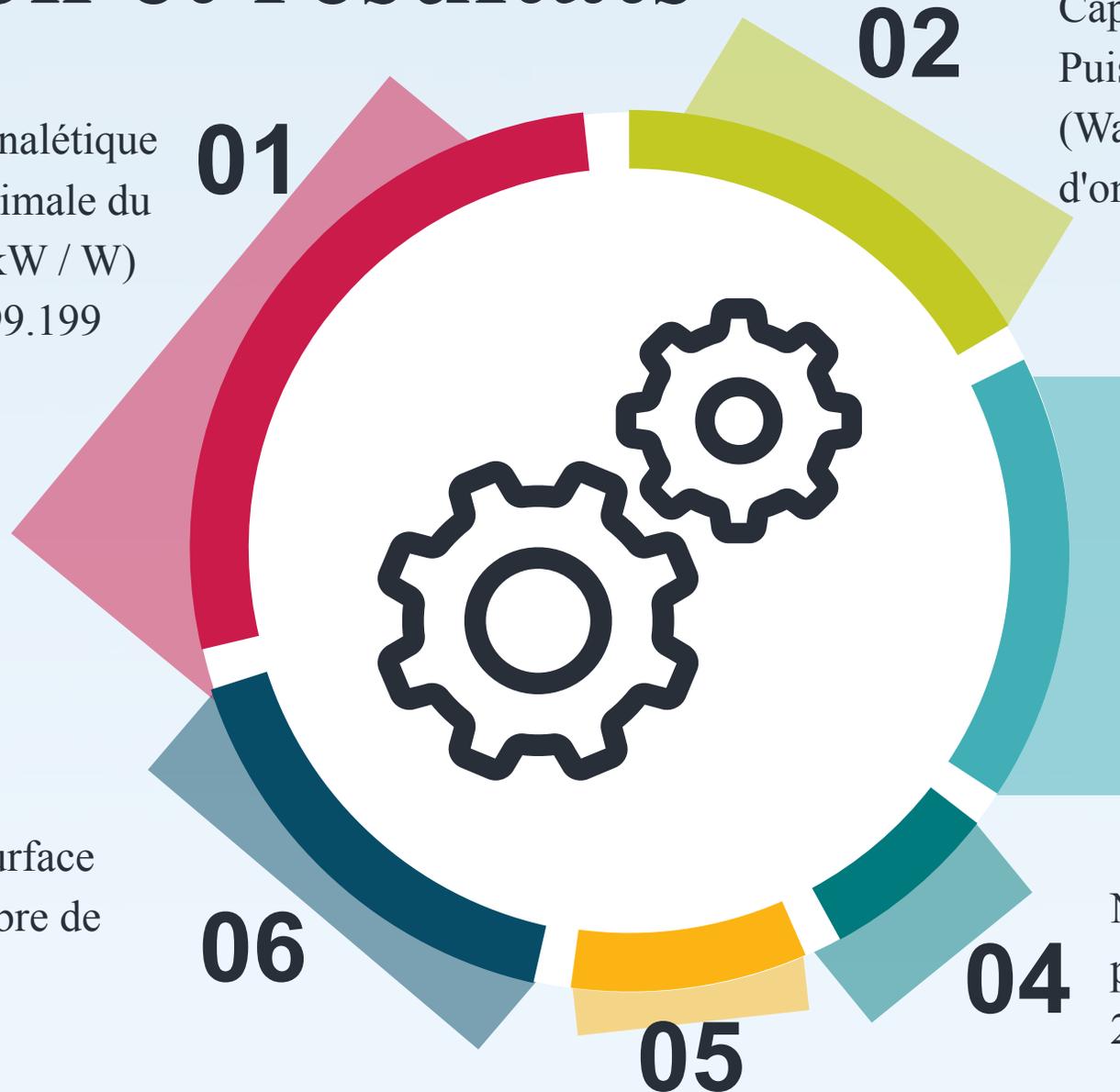
15:34
15/08/2020

Simulation et résultats

Capacité de la plaque signalétique (kWdc) = Puissance maximale du module (Wdc) \times 0,001 (kW / W) \times Total des modules = 999.199 kWdc .

Surface totale (m²) = Surface du module (m²) \times Nombre de modules = 4,792.3 m².

Nombre total de chaînes : Le nombre de chaînes de modules dans le rang = 104 chaînes.



Capacité totale de l'onduleur (kWac) = Puissance AC maximale de l'onduleur (Wac) \times 0,001 (kW / W) \times Nombre d'onduleurs = 875.000 kWac.

Capacité totale de l'onduleur (kWdc) = Puissance d'entrée DC maximale de l'onduleur (Wdc) \times 0,001 (kW / W) \times Nombre d'onduleurs = 891.830 kWdc.

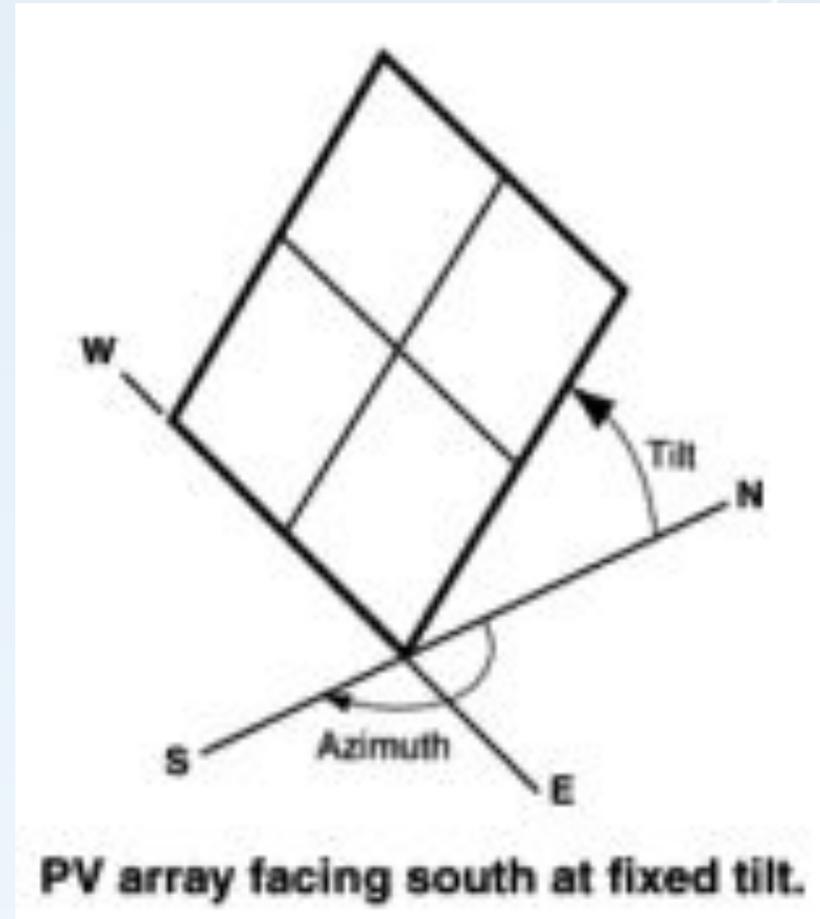
Nombre total de modules = modules par chaîne \times chaînes en parallèle = 2,496 modules.

Simulation et résultats



Suivi et orientation :

- Inclinaison : 30°
- Azimut : 180°
- Taux de couverture du sol (GCR) : 0.3



Simulation et résultats

External Shading

External shading is shading of beam and diffuse incident irradiance by nearby objects such as trees and buildings. Shading losses apply in addition to any soiling losses on the Losses page.

-3D Shade Calculator - Automatically generate shade data from a drawing of the array and shading objects. **-Shade Loss Tables** - Edit and import shade data. Data may be entered by hand, imported from shade analysis software and devices, or generated by the 3D shade calculator.

Open 3D shade calculator... Subarray 1 Edit shading... Subarray 2 Edit shading... Subarray 3 Edit shading... Subarray 4 Edit shading...

Self Shading for Fixed Subarrays and One-axis Trackers

Self shading is shading of modules in the array by modules in a neighboring row.

Self shading: None None None None

Array Dimensions for Self Shading, Snow Losses, and Bifacial Modules

The product of number of modules along side and bottom and number of rows should be equal to the number of modules in subarray.

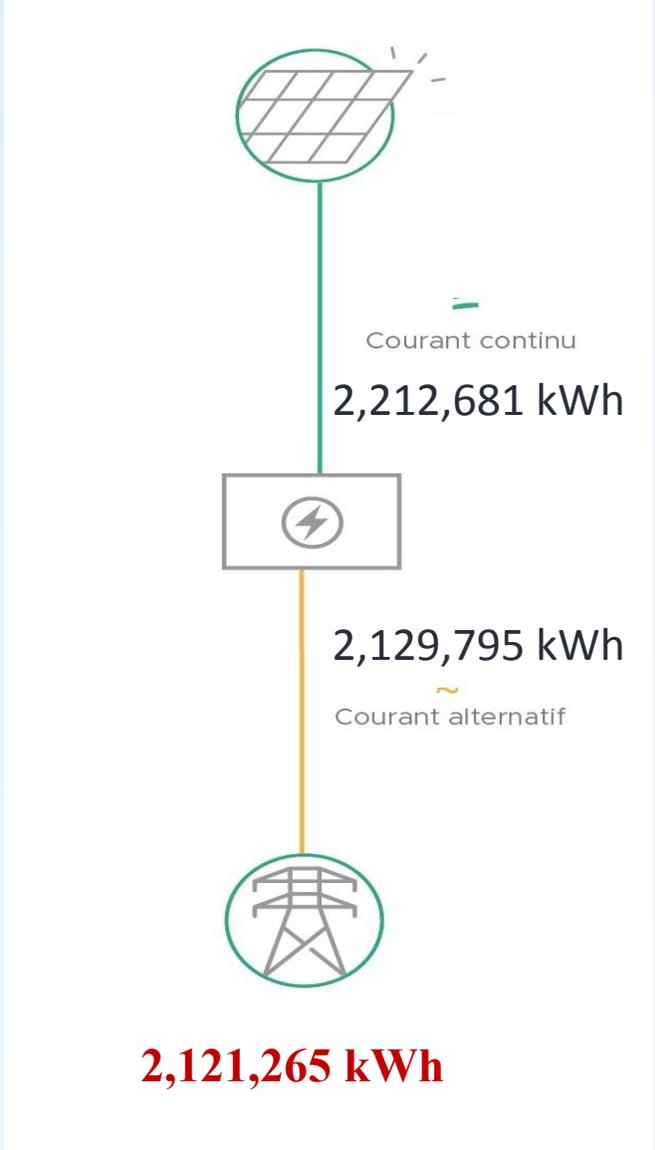
	Subarray 1	Subarray 2	Subarray 3	Subarray 4
Module orientation	Portrait	Portrait	Portrait	Portrait
Number of modules along side of row	2	2	2	2
Number of modules along bottom of row	48	9	9	9
-Calculated System Layout-				
Number of rows	26	0	0	0
Modules in subarray from System Design page	2,496	0	0	0
Length of side (m)	3.61331	3.61331	3.61331	3.61331
GCR from System Design page	0.3	0.3	0.3	0.3
Row spacing estimate (m)	12.0444	12.0444	12.0444	12.0444

Module aspect ratio: 1.7
row spacing = length of side + GCR
module orientation (portrait)
number of rows

Dimensions de la section pour l'auto-ombrage, les pertes de neige et les modules bifaciaux :

- Orientation du module : portrait
- Nombre de modules le long de la rangée : 2
- Nombre de modules en bas de rangée : 48

Simulation et résultats



Les pertes

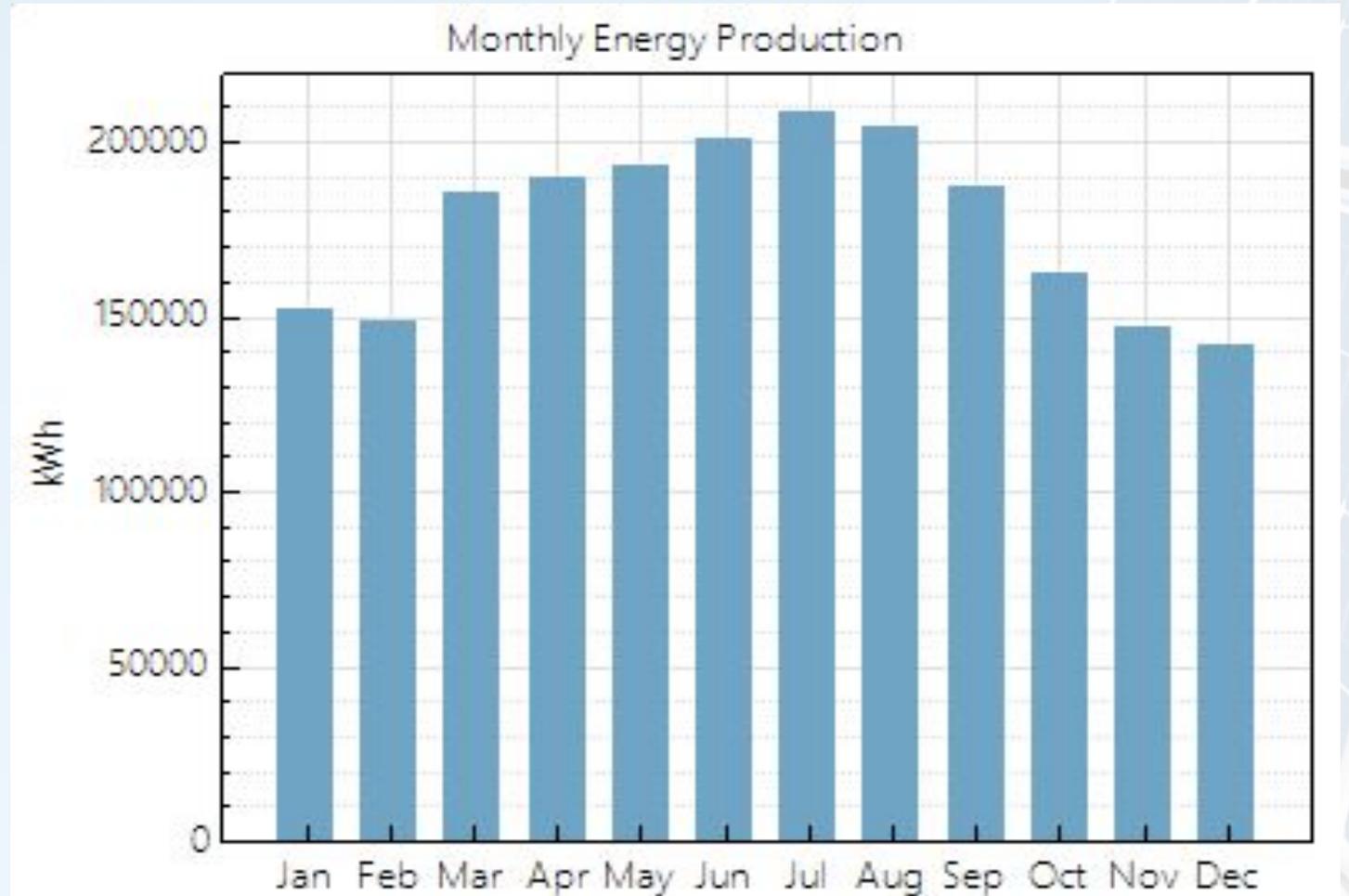


Nominal DC energy (kWh) 2,436,042	Snow -0 %
	Module deviation from STC -6.835 %
	Inverter MPPT clipping -0.023 %
	Module mismatch -1 %
	Diodes and connections -0.5 %
	DC wiring -1 %
	Tracking error -0 %
	Nameplate -0 %
	DC power optimizer -0 %
	DC availability and curtail -0 %
	DC Lifetime daily losses-) -0 %
Net DC energy (kWh) 2,212,681	Inverter power clipping -1.929 %
	Inverter power consumption -0.04 %
	Inverter nighttime consumption -0.057 %
	Inverter efficiency -1.753 %
Gross AC energy (kWh) 2,129,795	AC wiring -0.4 %
	AC Lifetime daily losses- year one -0 %
	Transformer loss -0 %
	AC Availability and curtailment -0 %
Annual energy (kWh) 2,121,265	

Simulation et résultats



1 MWc a permis de produire 2121265 kWh = 2121,265 MWh au cours de l'année pour l'adresse Metlaoui 5 – Gafsa.

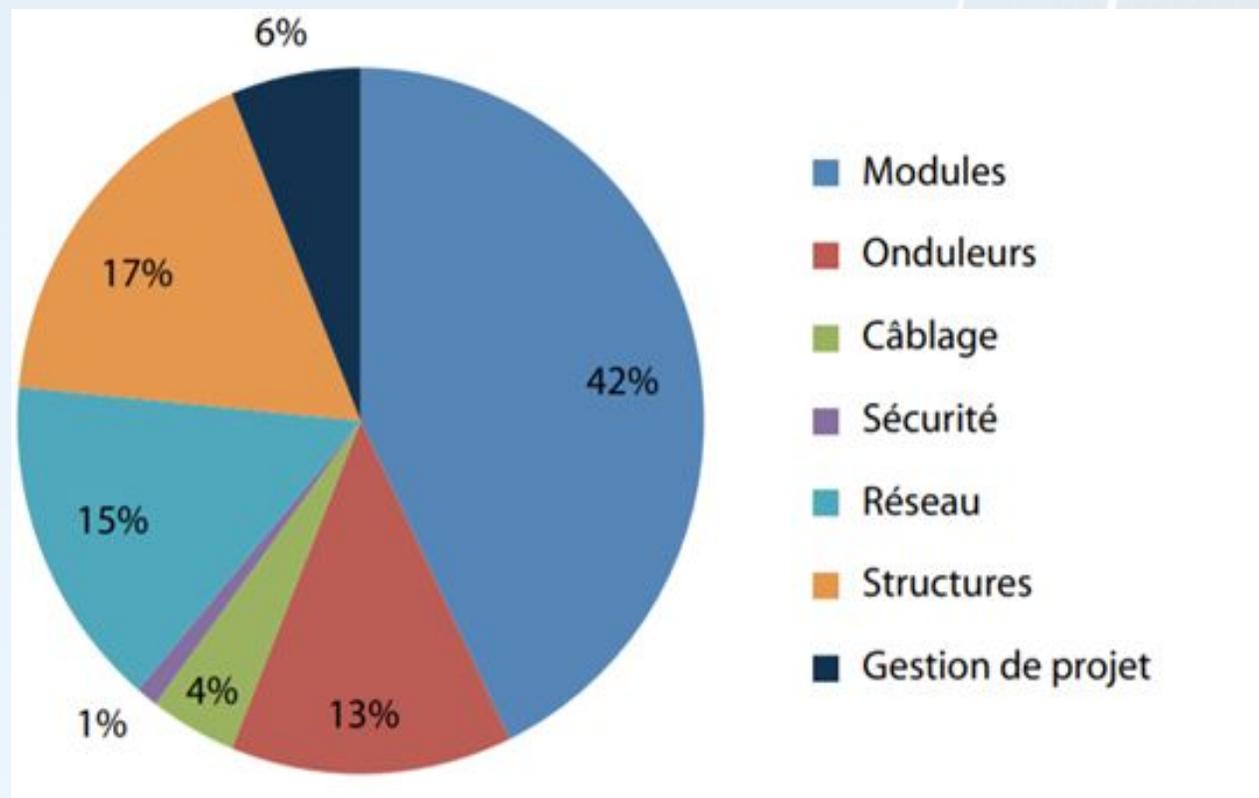




Etude économique

Etude économique

- Les Coûts d'investissement
- Les dépenses d'exploitation et de maintenance



Etude économique

SAM 2020.2.29: C:\Users\DELL\Desktop\1MWc PPA (Metloui 5)\1 MWc PPA (Metloui5).sam

File Add 1 MW PPA (Metlaoui 5) Help

Photovoltaic, Single owner

- Location and Resource
- Module
- Inverter
- System Design
- Shading and Layout
- Losses
- Grid Limits
- Lifetime and Degradation
- System Costs**
- Financial Parameters
- Revenue
- Incentives
- Depreciation

Simulate > Parametrics Stochastic P50 / P90 Macros

Direct Capital Costs

Module	2,496 units	0.4 kWdc/unit	999.2 kWdc	0.82 \$/Wdc	\$ 819,342.94
Inverter	7 units	125.0 kWac/unit	875.0 kWac	0.21 \$/Wdc	\$ 209,831.73
			\$	\$/Wdc	\$/m ²
Balance of system equipment			0.00	0.47	\$ 469,623.41
Installation labor			0.00	0.38	\$ 379,695.53
Installer margin and overhead			0.00	0.21	\$ 209,831.73
Subtotal					\$ 2,088,325.38
-Contingency					
			Contingency	0 % of subtotal	\$ 0.00
Total direct cost					\$ 2,088,325.38
	% of direct cost		\$/Wdc	\$	
Permitting and environmental studies	0		0.00	20,000.00	\$ 20,000.00
Engineering and developer overhead	0		0.01	0.00	\$ 9,991.99
Grid interconnection	0		0.00	6,000.00	\$ 6,000.00
-Land Costs					
Land area	3.947 acres				
Land purchase	\$ 0/acre	0	0.00	10,000.00	\$ 10,000.00
Land prep. & transmission	\$ 0/acre	0	0.01	0.00	\$ 9,991.99
-Sales Tax					
Sales tax basis, percent of direct cost	100 %	Sales tax rate	24.0 %		\$ 501,198.09
Total indirect cost					\$ 557,182.06
Total installed cost	\$ 2,645,507.50				
Total installed cost per capacity	\$ 2.65/Wdc				



Etude économique

SAM 2020.2.29: C:\Users\DELL\Desktop\1MWc PPA (Metloui 5)\1 MWc PPA (Metloui5).sam

File Add 1 MW PPA (Metloui 5) Help

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Simulate > Parametrics Stochastic P50 / P90 Macros

-Contingency- Subtotal \$ 2,088,325.38
 Contingency 0 % of subtotal \$ 0.00
Total direct cost \$ 2,088,325.38

Indirect Capital Costs

	% of direct cost	\$/Wdc	\$
Permitting and environmental studies	0	0.00	20,000.00
Engineering and developer overhead	0	0.01	0.00
Grid interconnection	0	0.00	6,000.00

-Land Costs-

Land area 3.947 acres

Land purchase	\$ 0/acre	0	0.00	10,000.00	\$ 10,000.00
Land prep. & transmission	\$ 0/acre	0	0.01	0.00	\$ 9,991.99

-Sales Tax-

Sales tax basis, percent of direct cost 100 % Sales tax rate 24.0 % \$ 501,198.09

Total indirect cost \$ 557,182.06

Total Installed Cost

The total installed cost is the sum of the direct and indirect costs. Note that it does not include any financing costs from the Financial Parameters page.

Total installed cost \$ 2,645,507.50
 Total installed cost per capacity \$ 2.65/Wdc

Operation and Maintenance Costs

	First year cost	Escalation rate (above inflation)
Fixed annual cost	Value 26500 \$/yr	0 %
Fixed cost by capacity	Value 0 \$/kW-yr	0 %
Variable cost by generation	Value 0 \$/MWh	0 %

In Value mode, SAM applies both inflation and escalation to the first year cost to calculate out-year costs. In Schedule mode, neither inflation nor escalation applies. See Help for details.

Etude économique

Énergie annuelle (année 1)	2121265 kWh
Valeur actuelle nette (VAN)	1,750,458 dt
Taux de rendement interne (TRI)	17.37%
Année TRI est atteint	20
TRI en fin de projet	17.37%
Coût en capital net	2,645,508 dt

An illustration of a piggy bank and three coins. The piggy bank is orange and positioned at the bottom right. Above it are three green coins with white dollar signs, arranged in a cluster.

Conclusion

Maitriser le logiciel SAM.

Maitriser les étapes d'étude de pré faisabilité.

Le projet peut être exploiter ultérieurement pour la réalisations des installations photovoltaïques.



Merci

POUR

Attention

Votre