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REGIONE SICILIA

PROVINCIA DI TRAPANI

COMUNE DI ALCAMO

LOCALITÀ MONTELEONE

Oggetto:

PROGETTO DEFINITIVO PER LA COSTRUZIONE E L'ESERCIZIO DI UN IMPIANTO AGRO-FOTOVOLTAICO AVENTE POTENZA DI PICCO PARI A 25.01 MW E POTENZA DI IMMISSIONE 22.37 MW E RELATIVE OPERE DI CONNESSIONE

Sezione:

SEZIONE A - RELAZIONI GENERALI

Elaborato:

STIMA DI PRODUCIBILITA'

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ORDINE DEGLI INGEGNERI DELLA PROVINCIA DI TRAPANI
DOTT. ING. BOTTONE ANTONIO
SEZIONE A
17385

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1 PREMESSA

IL PRESENTE ELABORATO È RIFERITO AL PROGETTO PER LA COSTRUZIONE E L'ESERCIZIO DI UN IMPIANTO AGRO-FOTOVOLTAICO, SITO IN ALCAMO (TP), LOCALITÀ MONTELEONE.

In particolare, l'impianto in progetto ha una potenza installata pari a 25,01 MW e una potenza nominale di 22,37 MW e presenta la seguente configurazione:

1. Un generatore fotovoltaico suddiviso in 11 sottocampi, costituiti da moduli fotovoltaici bifacciali aventi potenza unitaria pari a 710 Wp cadauno ed installati su strutture ad inseguimento solare mono-assiali (tracker);
2. Una stazione integrata per la conversione e trasformazione dell'energia elettrica detta *"Power Station"* per ogni sottocampo dell'impianto;
3. Una Cabina di Raccolta e Misura;
4. Elettrodotto interno in cavo interrato per l'interconnessione delle Power Station di cui al punto 2, con la Cabina di Raccolta e Misura;
5. Elettrodotto esterno in cavo interrato per l'interconnessione della Cabina di Raccolta e Misura in antenna a 36 kV con una nuova stazione elettrica di trasformazione (SE) della RTN a 220/36 kV, da inserire in entra - esce sulla linea RTN a 220 kV "Partinico - Partanna";

Titolare dell'iniziativa proposta è la società E-Way 8 S.R.L., avente sede legale in Piazza di San Lorenzo in Lucina, 4 – 00186 Roma (RM), P.IVA 16771051006

2 INTRODUZIONE

Il presente documento costituisce la relazione di stima di producibilità energetica dell'impianto agro-fotovoltaico proposto.

Tale stima è stata ottenuta caratterizzando l'impianto all'interno del **software per sistemi fotovoltaici PVSyst**.

Il progetto prevede l'installazione di **35224 moduli fotovoltaici** di marca Mysolar, modello GOLD N-Type e potenza pari a **710 W** (marca e modello del pannello sono stati scelti in via del tutto preliminare e possono essere adeguati o ridefiniti in una fase avanzata del progetto). I moduli sono installati su strutture atte a garantire la massima captazione di irraggiamento seguendo il percorso solare e consentendo, di conseguenza, ai moduli di essere sempre nella posizione ottimale di lavoro. Tali strutture sono dette "tracker" o "inseguitori solari", proprio per questa loro caratteristica funzionale.

I moduli vengono alloggiati in numero di 28 per ogni tracker in modo tale da far coincidere la singola struttura con la stringa elettrica, l'unità minima elettrica di impianto. I tracker/stringhe vengono quindi a loro volta raccolti in quadri di stringhe o "combiner box", i quali semplificano il collegamento con le Power Station, sede dei principali componenti elettrici quali inverter, trasformatore, quadri di misura e controllo, protezioni principali.

La struttura elettrica dell'impianto è chiaramente esposta ed approfondita nell'apposita documentazione dello schema unifilare.

Si vuole evidenziare il ricorso ad un ulteriore sistema di efficientamento produttivo del campo fotovoltaico: il sistema di Back Tracking, il quale consente di ridurre le perdite per auto-ombreggiamento, cioè le perdite da ombreggiamento indotto dai tracker stessi alle file retrostanti. Ciò avviene per mezzo di un sistema logico-adattivo che gestisce contemporaneamente piccoli gruppi di tracker, al fine di ottimizzare dunque le prestazioni del campo FV.

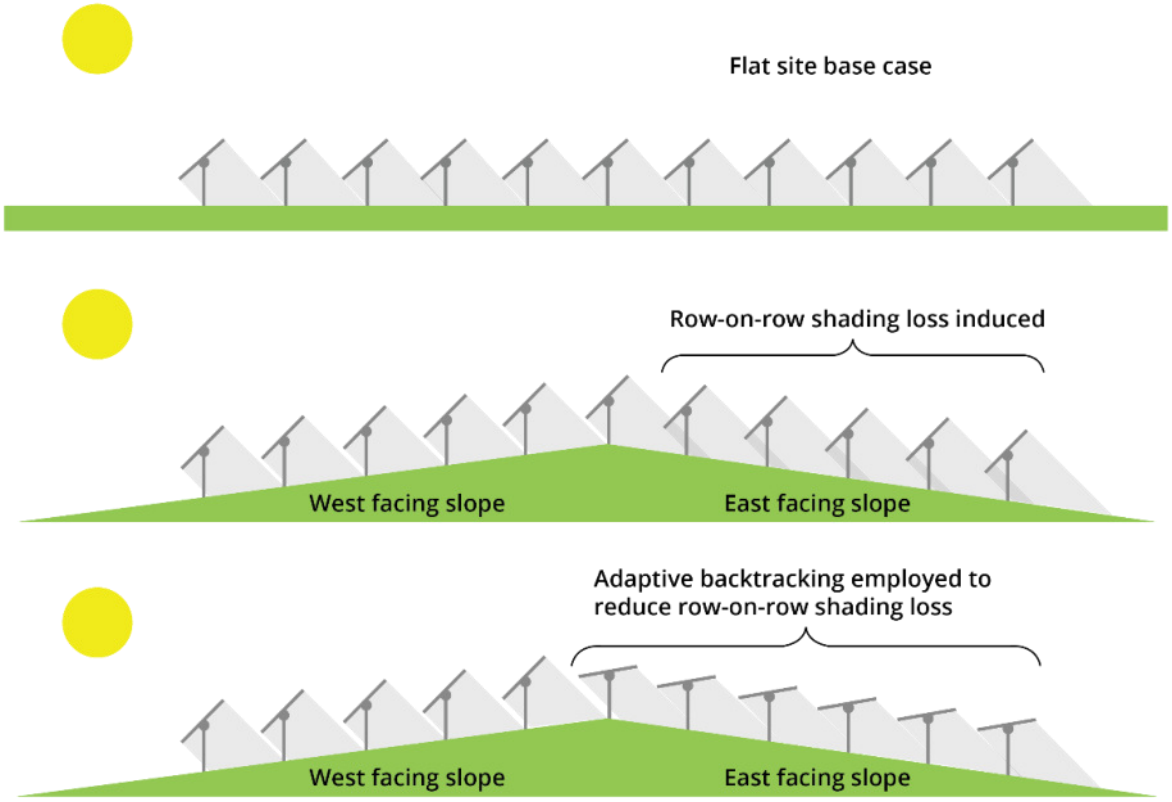

Figura 1: Schema funzionamento Back-Tracking

3 DATI CLIMATICI

Il **PVGIS – PhotoVoltaic Geographical Information System** è un sistema sviluppato dal JRC (Joint Research Centre) della Commissione Europea a partire dal 2001. Gli obiettivi principali del progetto sono:

- La ricerca scientifica ai fini della valutazione della risorsa energetica solare;
- Effettuare studi sui miglioramenti di performance dei sistemi fotovoltaici;
- La diffusione di conoscenze e dati riguardanti l'irraggiamento solare e le performance fotovoltaiche ad esso collegate.

Ad oggi la copertura territoriale dei database PVGIS riguarda la totalità dell'Europa e dell'Africa e gran parte dell'Asia e dell'America.

Il PVGIS consente un accesso libero e gratuito ad una grande serie di dati:

- Potenziale fotovoltaico per diverse tecnologie e configurazioni di impianto, sia questo un impianto stand-alone che connesso alla rete;
- Dati di temperatura e radiazione solare, sia in forma di medie mensili che di profili giornalieri;
- Serie storiche dei valori orari di radiazione solare e performance FV;
- Dati TMY – Typical Metereological Year per 9 differenti parametri climatici;
- Mappe stampabili dell'irraggiamento solare e della potenzialità fotovoltaica.

L'attendibilità dei dati PVGIS è internazionalmente riconosciuta, questi possono essere dunque utilizzati per l'elaborazione statistica della stima di radiazione solare del sito in progetto.

Si riportano di seguito i dati metereologici assunti:

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	71.0	34.55	11.08	102.2	95.1	133.0	127.6	0.897
February	79.6	40.26	9.10	110.2	103.7	145.8	139.9	0.912
March	145.0	53.88	11.04	201.8	192.3	262.1	238.9	0.851
April	180.1	63.93	14.77	243.3	234.0	304.9	292.6	0.864
May	224.5	68.21	18.60	296.2	285.3	359.8	345.4	0.838
June	223.1	69.71	23.77	289.5	278.9	351.2	315.7	0.784
July	246.3	62.50	28.25	329.4	318.2	392.2	376.6	0.822
August	204.4	63.43	26.93	276.0	265.6	339.9	326.4	0.850
September	150.2	56.50	22.33	207.0	198.3	266.0	255.4	0.887
October	114.7	45.40	17.11	163.3	155.1	212.8	189.2	0.832
November	79.3	33.14	14.90	116.8	109.0	150.5	144.5	0.889
December	72.4	31.63	11.01	110.0	101.4	141.7	136.1	0.889
Year	1790.7	623.17	17.46	2445.6	2336.9	3060.1	2888.2	0.849

Tabella 1: Dati metereologici di irraggiamento per il sito di progetto

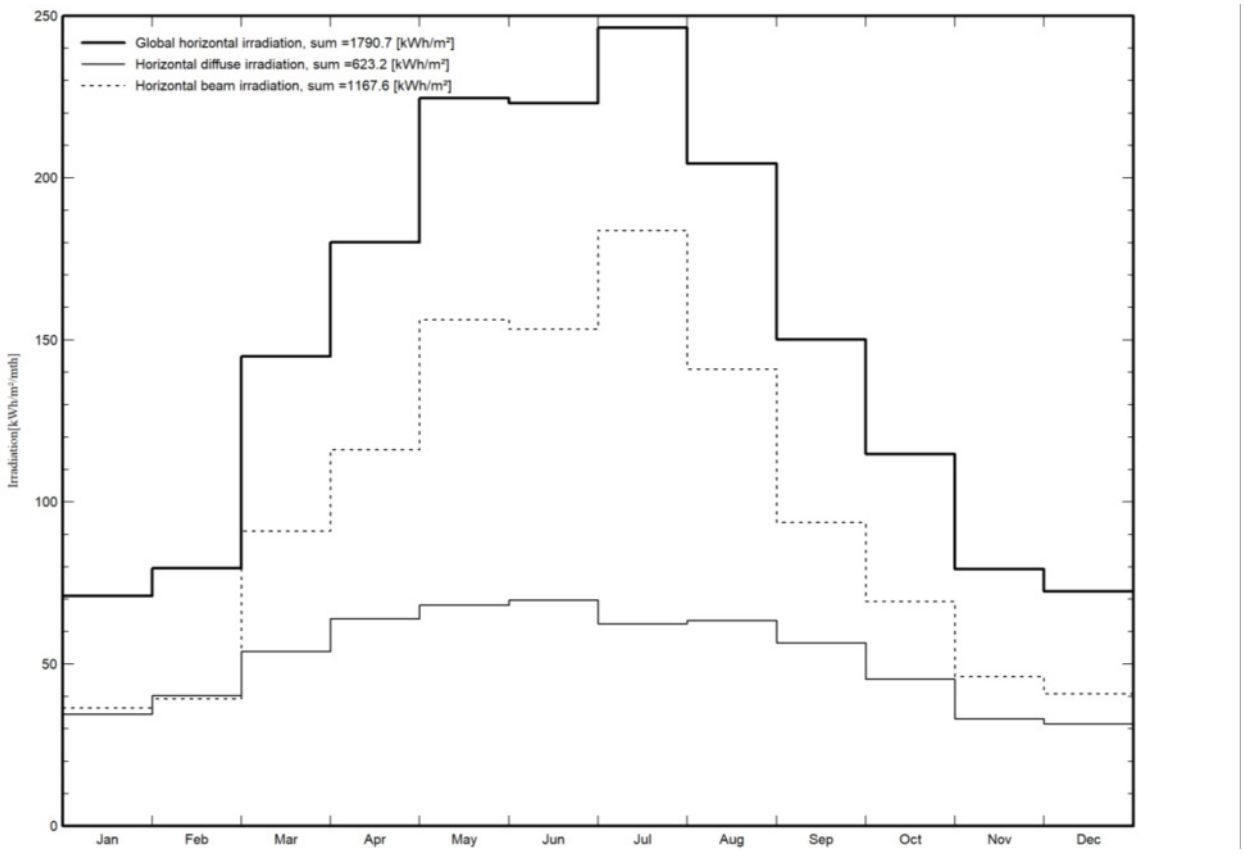

Figura 2: Meteo per Casa Valdibella - Typical Metereological Year

4 RISULTATI

I risultati completi dell’analisi di producibilità svolta sono mostrati nei report allegati alla presente relazione.

Si riportano qui, brevemente, i risultati complessivi di produzione dell’impianto:

POTENZA DI PICCO (MWp)	25,01
POTENZA AC (MW_{AC})	22,37
ENERGIA PRODOTTA P50 (MWh/anno)	52578
PRODUZIONE SPECIFICA P50 (kWh/kWp/anno)	2103
ENERGIA PRODOTTA P90 (MWh/anno)	50502
PRODUZIONE SPECIFICA P90 (kWh/kWp/anno)	2020

Tabella 2: Principali caratteristiche di potenza installata ed energia prodotta

I valori tabellati rappresentano:

- Potenza di picco: essa è la potenza installata d’impianto intesa come somma complessiva della potenza dei pannelli che lo costituiscono;
- Potenza AC: intesa come potenza nominale d’impianto, che nel progetto in esame coincide con la potenza complessiva degli inverter costituenti il campo fotovoltaico;
- Energia prodotta P50: rappresenta il valore di energia prodotta in un anno che ha la probabilità del 50% di essere superata;
- Produzione specifica P50: rappresenta il valore di produzione specifica in un anno che ha la probabilità del 50% di essere superato;
- Energia prodotta P90: rappresenta il valore di energia prodotta in un anno che ha la probabilità del 90% di essere superata;
- Produzione specifica P90: rappresenta il valore di produzione specifica in un anno che ha la probabilità del 90% di essere superato.

I valori P90 e P50 sono risultati da un’analisi probabilistico/statistica. Questo approccio presuppone che, nell'arco di diversi anni di funzionamento, la distribuzione delle rese annuali segua una legge che si assume essere la distribuzione gaussiana (o "normale"). Essa è funzione di due parametri, ossia il valore medio e la deviazione standard (denominata sigma o RMS) principalmente funzione dell’incertezza e della variabilità dei dati meteo.

Altri risultati legati all’analisi di producibilità dell’impianto sono consultabili nei documenti in allegato.

5 RICADUTE AMBIENTALI DEL PROGETTO

Un utile indicatore per definire il risparmio di combustibile derivante dall'utilizzo di fonti energetiche rinnovabili è il **Life Cycle Emissions (LCE).** Esso rappresenta le potenziali emissioni di CO_2 associate a un dato componente installativo o ammontare energetico nell'arco di tutto il ciclo di vita dell'impianto, e può comprendere le fasi di produzione, messa in opera, gestione, dismissione, ecc. Nel calcolare tale parametro si può ricorrere alle **T.E.P.** ossia le **Tonnellate Equivalenti di Petrolio** necessarie per la realizzazione di 1 MWh di energia da fonte rinnovabile fotovoltaica, ovvero alla **Grey Energy** intesa come l'energia impiegata per la produzione di un componente seguito da un fattore di conversione per trasformare l'energia in un valore LCE.

Il LCE è un parametro fondamentale per il calcolo del **bilancio di emissione del carbonio totale** per un impianto PV. Quest'ultimo rappresenta la differenza tra le emissioni di CO_2 risparmiate e prodotte, e dipende da 4 fattori chiave:

- Energia immessa in rete (E Grid): la produzione energetica, o rendimento energetico, dell'impianto PV per il primo anno (può essere stimato anche per gli anni successivi al 1°);
- Ciclo di vita del sistema (Project lifetime): è la durata di vita dell'impianto PV data in anni;
- LCE della rete (LCE Grid): è dato in gCO_2/kWh e rappresenta l'ammontare medio di emissioni di CO_2 per unità di Energia elettrica prodotta dalla rete;
- LCE dell'impianto PV (LCE System): è dato in gCO_2/kWh e rappresenta l'ammontare medio di emissioni di CO_2 causate dalla costruzione e messa in opera dell'impianto fotovoltaico.

Emissioni generate	584093 tCO_2
Emissioni risparmiate	667222,8 tCO_2
Produzione annuale	52578 MWh/yr
LCE di rete	423 gCO_2/kWh
Ciclo di vita d'impianto	30 anni
Degradazione annuale stimata	1,0 %

Tabella 3: Bilancio di emissione di CO_2

Di seguito si riporta un'equazione utile al calcolo del bilancio di carbonio totale dell'impianto:

$$\text{E Grid} \bullet \text{Project lifetime} \bullet \text{LCE Grid} - \text{LCE System} = \text{Carbon balance}$$

I valori dei termini dell'equazione sono di seguito specificati:

$$52578\ MWh\ \bullet 30\ \text{years}\ \bullet 423\ \frac{\text{gCO2}}{\text{kWh}} - 584093\ tCO2 = 667222\ tCO2$$

Il calcolo dei valori di LCE inoltre, dipende dalle categorie per le quali viene calcolato e da scelte progettuali. Nel calcolo appena descritto le categorie sono suddivisibili in 3 macro: **produzione dei moduli PV, bilancio del sistema impianto (BoS: Balance of System) ed eventuali apporti aggiuntivi (manutenzione, dismissione, ecc.)**. Naturalmente è preferibile utilizzare valori di LCE messi direttamente a disposizione dal produttore o dal fornitore o ricorrendo a banche dati riconosciute (ECOINVENT, Carbon Trust, ecc). Tali valori del LCE sono ottenuti a partire da:

- Caratteristiche e quantità di moduli impiegati;
- modalità di spostamento dei moduli che generalmente sono il trasporto via mare e via terra. Per il progetto in esame è stato previsto che il paese di produzione sia la Cina, regione contraddistinta per essere tra i principali produttori di pannelli;
- caratteristiche e quantità degli elementi di supporto dei pannelli, dei fabbricati quali cabine di raccolta e misura, delle strutture per ospitare inverter, trasformatori, combiner box, ed altri elementi elettromeccanici dell'impianto;
- Caratteristiche e quantità degli inverter, dei cavi e di tutti quegli elementi essenziali per il funzionamento del sistema impianto (Balance of System);
- apporti aggiuntivi dati dalle operazioni di manutenzione (generalmente considerata nulla perché di piccola entità) e dismissione (riciclaggio, smaltimento, rinaturalizzazione dell'area d'impianto, ecc). Per il progetto in esame non sono stati considerati apporti aggiuntivi in quanto considerati non significativi o in seguito alla consultazione dei vari database scientifici riconosciuti a livello internazionale, non sono stati ritrovati valori utili alla definizione esatta della loro entità.

Altri risultati legati al bilancio sulle emissioni di Carbonio dell'impianto sono consultabili nei documenti in allegato.

6 ALLEGATI

Version 7.4.2

PVsyst - Simulation report

Grid-Connected System

Project: Alcamo_Monteleone_Project

Variant: 08_Alcamo_Monteleone_CTR_VIG_7.5m_SottocampoA

Tracking system with backtracking

System power: 1392 kWp

Casa Valdibella - Italy

Author

E-Way Finance S.p.A. (Italy)

PVsyst V7.4.2
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Project summary

Geographical Site
Casa Valdibella
Italy

Situation

Latitude	37.93 °N
Longitude	13.00 °E
Altitude	250 m
Time zone	UTC+1

Project settings

Albedo	0.20

Meteo data
Casa Valdibella
PVGIS api TMY

System summary

Grid-Connected System

Tracking system with backtracking

PV Field Orientation
Orientation

Tracking plane, tilted axis	
Avg axis tilt	5.1 °
Avg axis azim.	0 °

Tracking algorithm

Irradiance optimization	
Backtracking activated	
Wind stow	
Wind Speed threshold	12 m/s
Wind stow position	0 °

Near Shadings
According to strings : Fast (table)

Electrical effect	80 %
Diffuse shading	Automatic

System information

PV Array

Nb. of modules	1960 units
Pnom total	1392 kWp

Inverters

Nb. of units	1 unit
Pnom total	1169 kWac
Pnom ratio	1.190

User's needs
Unlimited load (grid)

Results summary

Produced Energy	2888.20 MWh/year	Specific production	2075 kWh/kWp/year	Perf. Ratio PR	84.86 %

Table of contents

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General parameters

Grid-Connected System

Tracking system with backtracking

PV Field Orientation

Orientation

Tracking plane, tilted axis	
Avg axis tilt	5.1 °
Avg axis azim.	0 °

Tracking algorithm

Irradiance optimization	
Backtracking activated	
Wind stow	
Wind Speed threshold	12 m/s
Wind stow position	0 °

Backtracking array

Nb. of trackers	79 units

Sizes

Tracker Spacing	7.50 m
Collector width	2.38 m
Ground Cov. Ratio (GCR)	31.8 %
Phi min / max.	-/+ 45.0 °

Backtracking strategy

Phi limits for BT	-/+ 79.9 °
Backtracking pitch	7.50 m
Backtracking width	2.38 m

Models used

Transposition	Perez
Diffuse	Imported
Circumsolar	separate

Horizon

Average Height	4.1 °

Near Shadings

According to strings : Fast (table)	
Electrical effect	80 %
Diffuse shading	Automatic

User's needs

Unlimited load (grid)

Bifacial system

Model: 2D Calculation
unlimited trackers

Bifacial model geometry

Tracker Spacing	7.50 m
Tracker width	2.38 m
GCR	31.8 %
Axis height above ground	3.05 m

Bifacial model definitions

Ground albedo	0.20
Bifaciality factor	80 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

PV Array Characteristics

PV module

Manufacturer	Mysolar
Model	Mysolar GOLD N-Type HJT BIFACIAL MS710N-HJTGB
(Custom parameters definition)	
Unit Nom. Power	710 Wp
Number of PV modules	1960 units
Nominal (STC)	1392 kWp
Modules	70 Strings x 28 In series

At operating cond. (50°C)

Pmpp	1301 kWp
U mpp	1104 V
I mpp	1179 A

Inverter

Manufacturer	Ingeteam
Model	INGECON SUN 1170TL B450 IP54 H1000
(Custom parameters definition)	
Unit Nom. Power	1169 kWac
Number of inverters	1 unit
Total power	1169 kWac
Operating voltage	645-1300 V
Pnom ratio (DC:AC)	1.19

Total PV power

Nominal (STC)	1392 kWp
Total	1960 modules
Module area	6088 m²

Total inverter power

Total power	1169 kWac
Number of inverters	1 unit
Pnom ratio	1.19

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Array losses

Array Soiling Losses
Loss Fraction 1.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 29.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 0.69 mΩ
Loss Fraction 0.1 % at STC

LID - Light Induced Degradation
Loss Fraction 1.0 %

Module Quality Loss
Loss Fraction -0.2 %

Module mismatch losses
Loss Fraction 1.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.2 %

IAM loss factor
Incidence effect (IAM): Fresnel smooth glass, n = 1.526

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.998	0.981	0.948	0.862	0.776	0.636	0.403	0.000

Spectral correction
FirstSolar model
Precipitable water estimated from relative humidity

Coefficient Set	C0	C1	C2	C3	C4	C5
Monocrystalline Si	0,85914	-0,02088	-0,0058853	0,12029	0,026814	-0,001781

System losses

Unavailability of the system
Time fraction 1.5 %
5.5 days,
3 periods

Auxiliaries loss
constant (fans) 2.00 kW
292.0 kW from Power thresh.

AC wiring losses

Inv. output line up to MV transfo
Inverter voltage 450 Vac tri
Loss Fraction 0.02 % at STC
Inverter: INGECON SUN 1170TL B450 IP54 H1000
Wire section (1 Inv.) Copper 1 x 3 x 1200 mm²
Wires length 2 m

MV line up to Injection
MV Voltage 36 kV
Wires Copper 3 x 6 mm²
Length 1700 m
Loss Fraction 0.56 % at STC

AC losses in transformers

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AC losses in transformers

MV transfo

Medium voltage	36 kV
Transformer parameters	
Nominal power at STC	1.36 MVA
Iron Loss (24/24 Connexion)	1.36 kVA
Iron loss fraction	0.10 % at STC
Copper loss	13.59 kVA
Copper loss fraction	1.00 % at STC
Coils equivalent resistance	3 x 1.49 mΩ

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Horizon definition

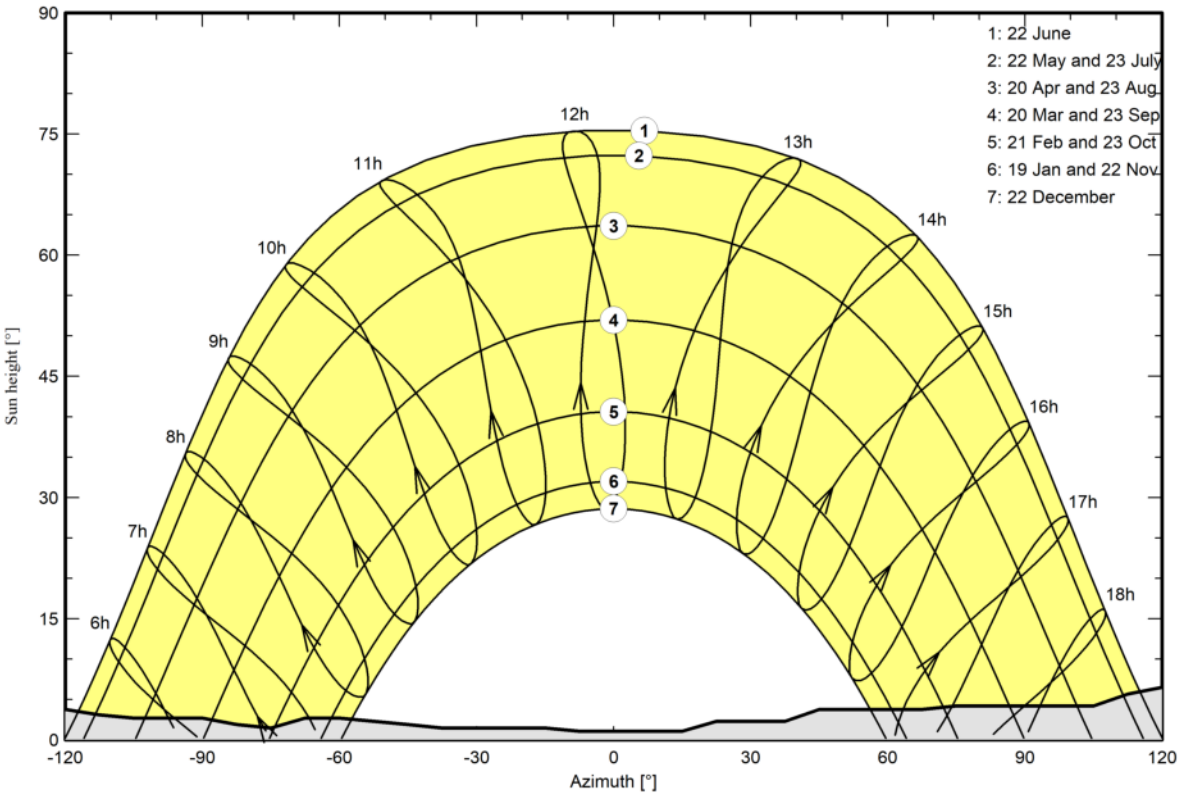
Horizon from PVGIS website API, Lat=37°55'53", Long=13°0'14", Alt=221m

Average Height	4.1 °	Albedo Factor	0.77
Diffuse Factor	0.96	Albedo Fraction	100 %

Horizon profile

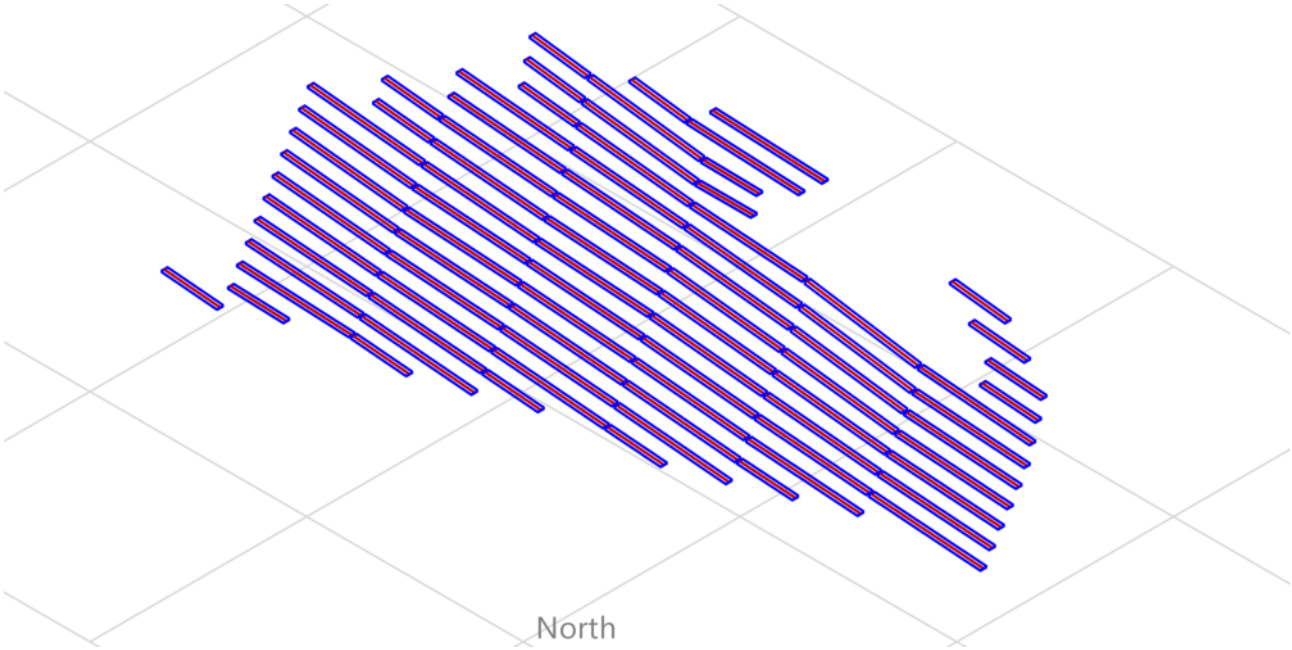
Azimuth [°]	-180	-173	-165	-158	-150	-143	-135	-128	-120	-113	-105	-90	-83
Height [°]	8.0	6.1	5.3	5.3	5.7	5.7	3.4	3.8	3.8	3.1	2.7	2.7	1.9
Azimuth [°]	-75	-68	-60	-53	-45	-38	-15	-8	15	23	38	45	68
Height [°]	1.5	2.7	2.7	2.3	1.9	1.5	1.5	1.1	1.1	2.3	2.3	3.8	3.8
Azimuth [°]	75	105	113	120	128	135	143	150	158	165	173	180	
Height [°]	4.2	4.2	5.7	6.5	7.6	8.4	8.8	8.8	7.6	8.4	8.8	8.0	

Sun Paths (Height / Azimuth diagram)



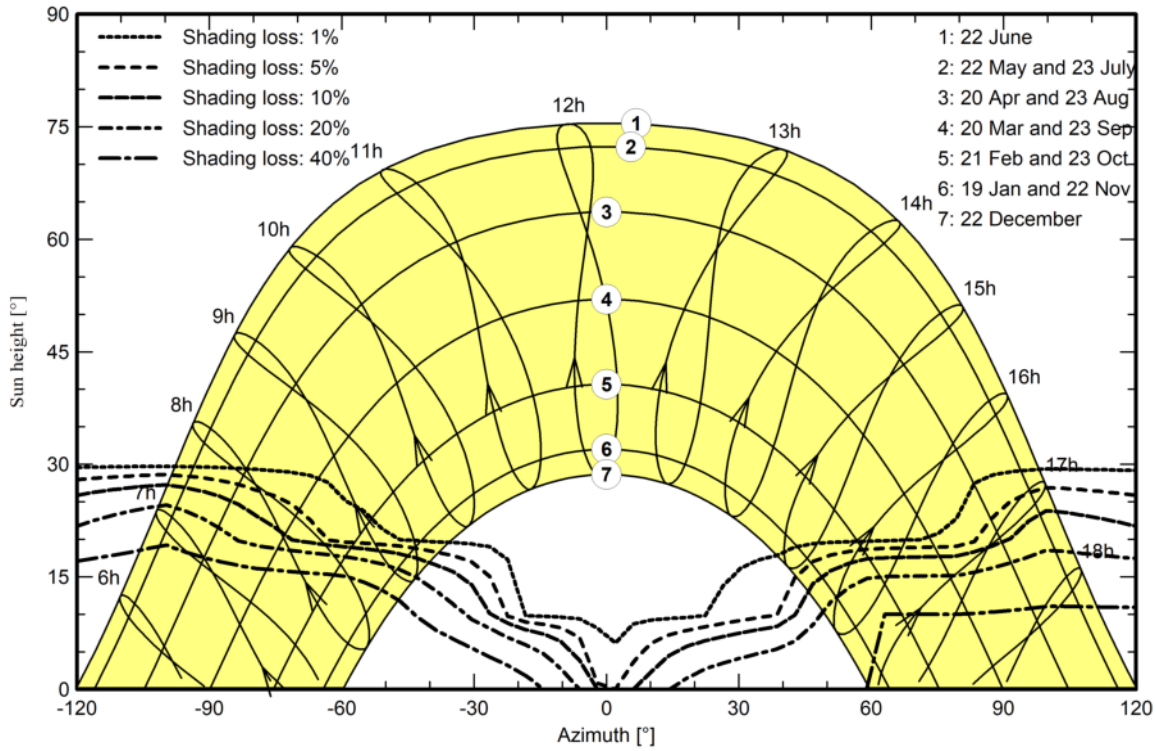
Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram

Orientation #1



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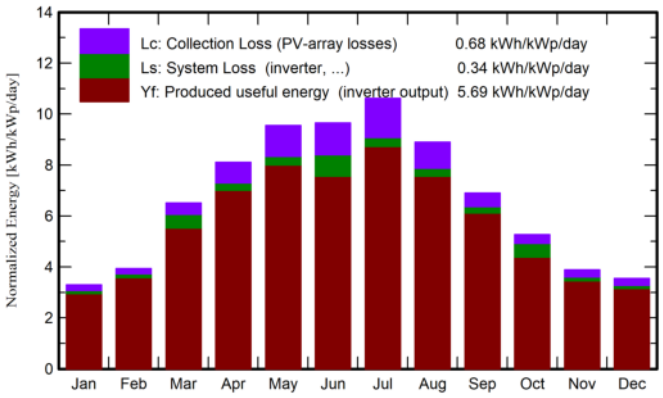
Main results

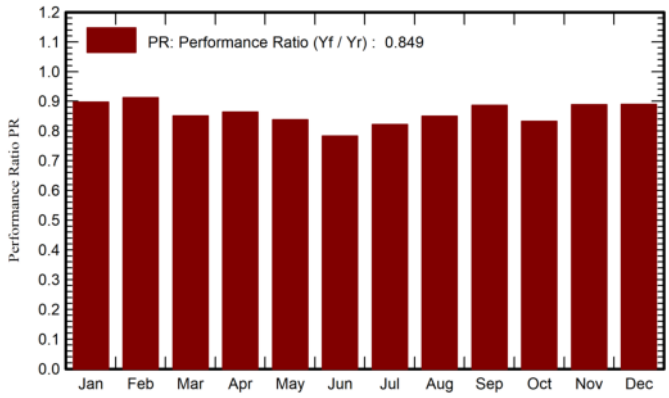
System Production

Produced Energy (P50)	2888.20 MWh/year	Specific production (P50)	2075 kWh/kWp/year	Perf. Ratio PR	84.86 %
Produced Energy (P90)	2774.05 MWh/year	Specific production (P90)	1993 kWh/kWp/year		
Produced Energy (P95)	2741.93 MWh/year	Specific production (P95)	1970 kWh/kWp/year		

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	71.0	34.55	11.08	102.2	95.1	133.0	127.6	0.897
February	79.6	40.26	9.10	110.2	103.7	145.8	139.9	0.912
March	145.0	53.88	11.04	201.8	192.3	262.1	238.9	0.851
April	180.1	63.93	14.77	243.3	234.0	304.9	292.6	0.864
May	224.5	68.21	18.60	296.2	285.3	359.8	345.4	0.838
June	223.1	69.71	23.77	289.5	278.9	351.2	315.7	0.784
July	246.3	62.50	28.25	329.4	318.2	392.2	376.6	0.822
August	204.4	63.43	26.93	276.0	265.6	339.9	326.4	0.850
September	150.2	56.50	22.33	207.0	198.3	266.0	255.4	0.887
October	114.7	45.40	17.11	163.3	155.1	212.8	189.2	0.832
November	79.3	33.14	14.90	116.8	109.0	150.5	144.5	0.889
December	72.4	31.63	11.01	110.0	101.4	141.7	136.1	0.889
Year	1790.7	623.17	17.46	2445.6	2336.9	3060.1	2888.2	0.849

Legends

GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

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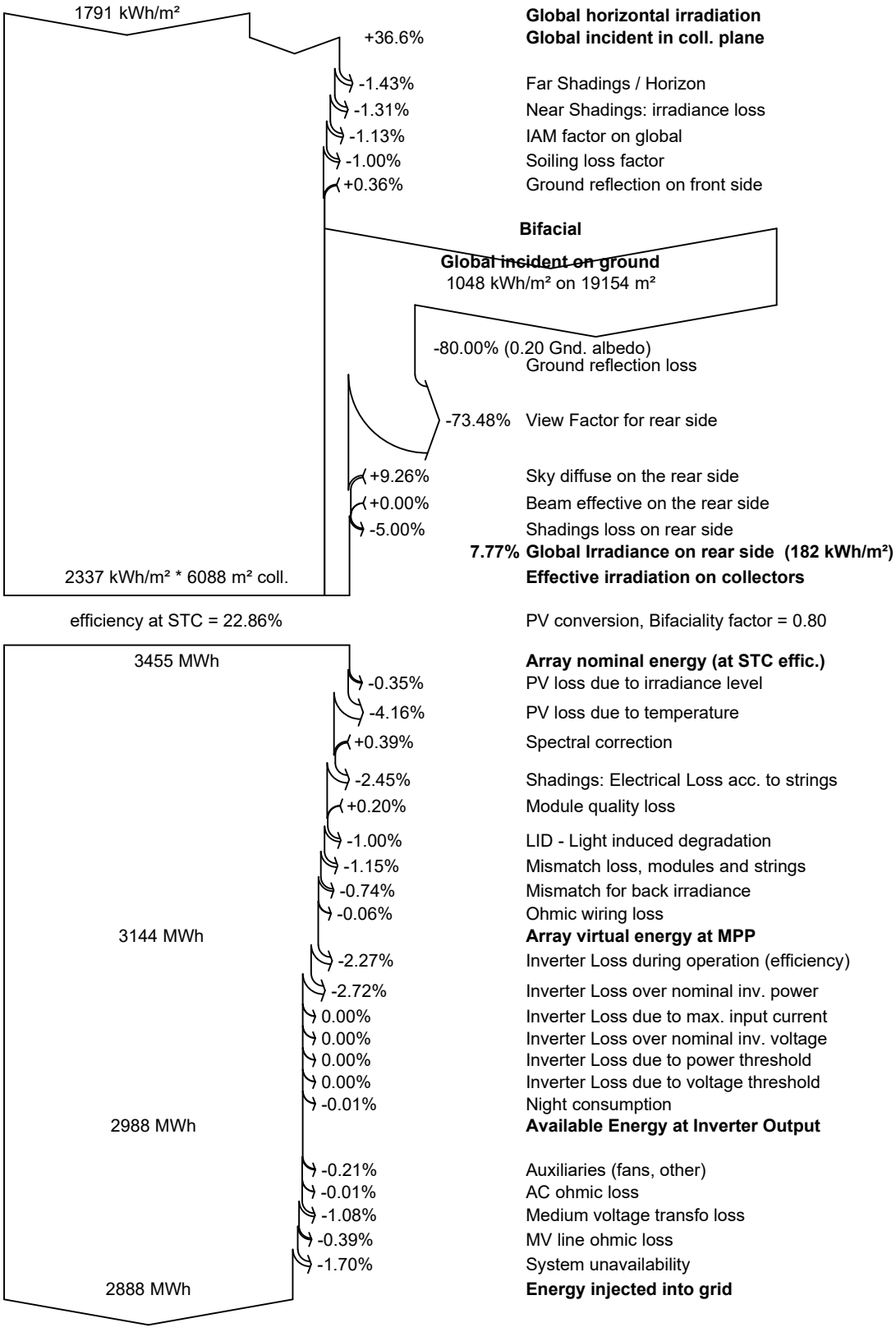
VC2, Simulation date:
17/10/23 17:48
with v7.4.2

Loss diagram



PVsyst V7.4.2
VC2, Simulation date:
17/10/23 17:48
with v7.4.2

P50 - P90 evaluation

Meteo data

Source	PVGIS api TMY
Kind	TMY, multi-year
Year-to-year variability(Variance)	2.5 %
Specified Deviation	
Climate change	0.0 %

Simulation and parameters uncertainties

PV module modelling/parameters	1.0 %
Inverter efficiency uncertainty	0.5 %
Soiling and mismatch uncertainties	1.0 %
Degradation uncertainty	1.0 %

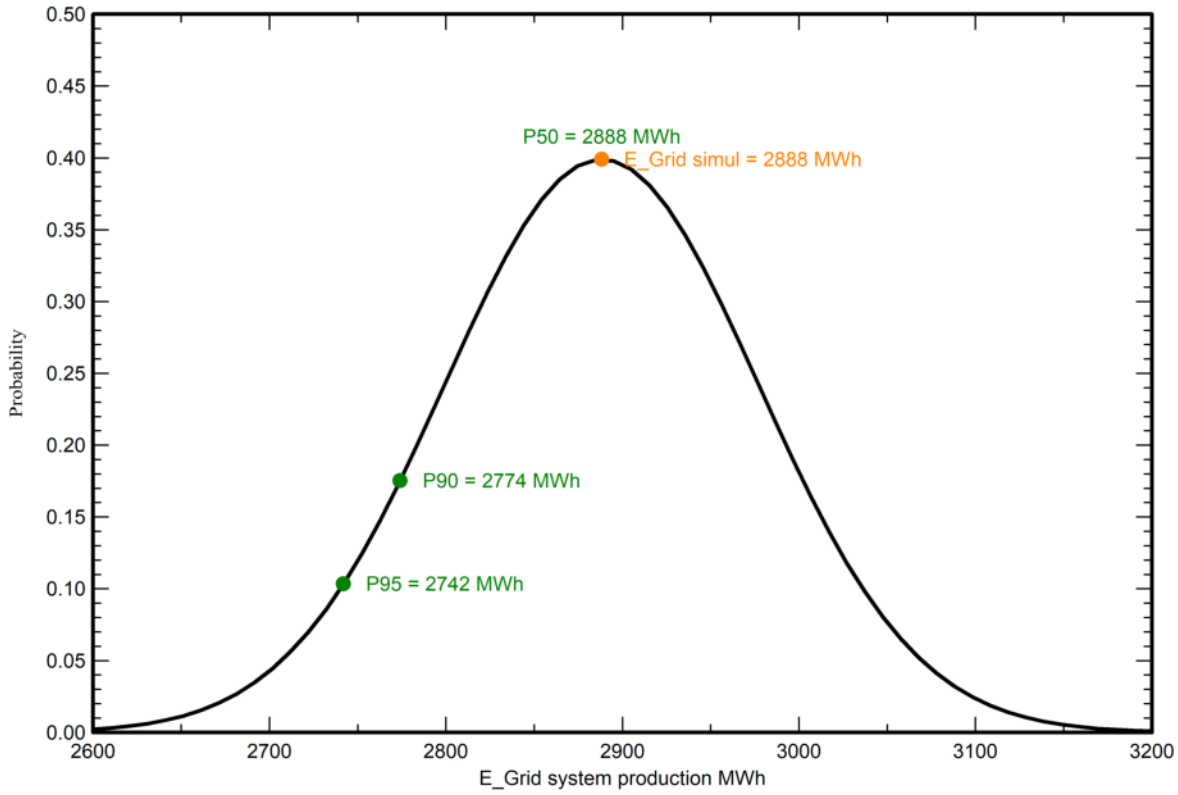
Global variability (meteo + system)

Variability (Quadratic sum)	3.1 %

Annual production probability

Variability	89 MWh
P50	2888 MWh
P90	2774 MWh
P95	2742 MWh

Probability distribution



CO_2 Emission Balance

Total: 29221.9 tCO_2

Generated emissions

Total: 2579.13 tCO_2

Source: Detailed calculation from table below

Replaced Emissions

Total: 36651.2 tCO_2

System production: 2888.20 MWh/yr

Grid Lifecycle Emissions: 423 gCO_2/kWh

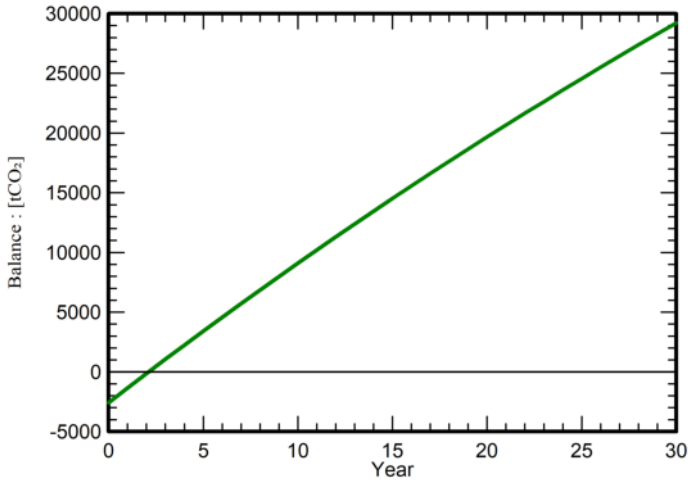
Source: IEA List

Country: Italy

Lifetime: 30 years

Annual degradation: 1.0 %

Saved CO_2 Emission vs. Time



System Lifecycle Emissions Details

Item	LCE	Quantity	Subtotal
			[$kgCO_2$]
Modules	1713 kgCO2/kWp	1392 kWp	2383421
Transport1	35.0 gCO2/km	15100 km	40191
Transport2	59.7 gCO2/km	1350 km	6129
Supports	2.82 kgCO2/kg	40600 kg	114549
Concrete	177 kgCO2/m³	45.0 m³	7965
Inverters	280 kgCO2/units	1.00 units	280
Wiring	14.8 kgCO2/m	1800 m	26591

Version 7.4.2

PVsyst - Simulation report

Grid-Connected System

Project: Alcamo_Monteleone_Project

Variant: 08_Alcamo_Monteleone_CTR_VIG_7.5m_SottocampoB-J

Tracking system with backtracking

System power: 21.89 MWp

Casa Valdibella - Italy

Author

E-Way Finance S.p.A. (Italy)

PVsyst V7.4.2
VC7, Simulation date:
18/10/23 12:47
with v7.4.2

Project summary

Geographical Site
Casa Valdibella
Italy

Situation

Latitude	37.92 °N
Longitude	12.99 °E
Altitude	196 m
Time zone	UTC+1

Project settings

Albedo	0.20

Meteo data
Casa Valdibella
PVGIS api TMY

System summary

Grid-Connected System

Tracking system with backtracking

PV Field Orientation

Orientation	
Tracking plane, horizontal N-S axis	
Avg axis azim.	0 °

Tracking algorithm

Irradiance optimization	
Backtracking activated	
Wind stow	
Wind Speed threshold	12 m/s
Wind stow position	0 °

Near Shadings

According to strings : Fast (table)	
Electrical effect	80 %
Diffuse shading	Automatic

System information

PV Array		**Inverters**	
Nb. of modules	30828 units	Nb. of units	13 units
Pnom total	21.89 MWp	Pnom total	19.64 MWac
		Pnom ratio	1.114

User's needs
Unlimited load (grid)

Results summary

Produced Energy	46027.86 MWh/year	Specific production	2103 kWh/kWp/year	Perf. Ratio PR	87.10 %

Table of contents

General parameters

Grid-Connected System — **Tracking system with backtracking**

PV Field Orientation

Orientation

Tracking plane, horizontal N-S axis	
Avg axis azim.	0 °

Tracking algorithm

Irradiance optimization	
Backtracking activated	
Wind stow	
Wind Speed threshold	12 m/s
Wind stow position	0 °

Backtracking array

Nb. of trackers	1212 units

Sizes

Tracker Spacing	7.50 m
Collector width	2.38 m
Ground Cov. Ratio (GCR)	31.8 %
Phi min / max.	-/+ 45.0 °

Backtracking strategy

Phi limits for BT	-/+ 79.9 °
Backtracking pitch	7.50 m
Backtracking width	2.38 m

Models used

Transposition	Perez
Diffuse	Imported
Circumsolar	separate

Horizon

Average Height	4.1 °

Near Shadings

According to strings : Fast (table)	
Electrical effect	80 %
Diffuse shading	Automatic

User's needs

Unlimited load (grid)

Bifacial system

Model: 2D Calculation
unlimited trackers

Bifacial model geometry

Tracker Spacing	7.50 m
Tracker width	2.38 m
GCR	31.8 %
Axis height above ground	3.05 m

Bifacial model definitions

Ground albedo	0.20
Bifaciality factor	80 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

PV Array Characteristics

PV module

Manufacturer	Mysolar
Model	Mysolar GOLD N-Type HJT BIFACIAL MS710N-HJTGB
(Custom parameters definition)	
Unit Nom. Power	710 Wp
Number of PV modules	11928 units
Nominal (STC)	8469 kWp

Inverter

Manufacturer	Ingeteam
Model	INGECON SUN 1560TL B600 IP54 H1000
(Custom parameters definition)	
Unit Nom. Power	1559 kWac
Number of inverters	5 units
Total power	7795 kWac

Array #1 - sottocampo B

Number of PV modules	2464 units
Nominal (STC)	1749 kWp
Modules	88 Strings x 28 In series
At operating cond. (50°C)	
Pmpp	1636 kWp
U mpp	1104 V
I mpp	1482 A

Number of inverters	1 unit
Total power	1559 kWac
Operating voltage	853-1300 V
Pnom ratio (DC:AC)	1.12

PV Array Characteristics

Array #8 - sottocampo I

Number of PV modules	7140 units	Number of inverters	3 units
Nominal (STC)	5069 kWp	Total power	4677 kWac
Modules	255 Strings x 28 In series		
At operating cond. (50°C)		Operating voltage	853-1300 V
Pmpp	4740 kWp	Pnom ratio (DC:AC)	1.08
U mpp	1104 V		
I mpp	4293 A		

Array #9 - sottocampo J

Number of PV modules	2324 units	Number of inverters	1 unit
Nominal (STC)	1650 kWp	Total power	1559 kWac
Modules	83 Strings x 28 In series		
At operating cond. (50°C)		Operating voltage	853-1300 V
Pmpp	1543 kWp	Pnom ratio (DC:AC)	1.06
U mpp	1104 V		
I mpp	1397 A		

PV module

Manufacturer	Mysolar
Model	Mysolar GOLD N-Type HJT BIFACIAL MS710N-HJTGB
(Custom parameters definition)	
Unit Nom. Power	710 Wp
Number of PV modules	7840 units
Nominal (STC)	5566 kWp

Inverter

Manufacturer	Ingeteam
Model	INGECON SUN 1170TL B450 IP54 H1000
(Custom parameters definition)	
Unit Nom. Power	1169 kWac
Number of inverters	4 units
Total power	4676 kWac

Array #2 - sottocampo C

Number of PV modules	2044 units	Number of inverters	1 unit
Nominal (STC)	1451 kWp	Total power	1169 kWac
Modules	73 Strings x 28 In series		
At operating cond. (50°C)		Operating voltage	645-1300 V
Pmpp	1357 kWp	Pnom ratio (DC:AC)	1.24
U mpp	1104 V		
I mpp	1229 A		

Array #4 - sottocampo E

Number of PV modules	3836 units	Number of inverters	2 units
Nominal (STC)	2724 kWp	Total power	2338 kWac
Modules	137 Strings x 28 In series		
At operating cond. (50°C)		Operating voltage	645-1300 V
Pmpp	2547 kWp	Pnom ratio (DC:AC)	1.16
U mpp	1104 V		
I mpp	2307 A		

Array #6 - sottocampo G

Number of PV modules	1960 units	Number of inverters	1 unit
Nominal (STC)	1392 kWp	Total power	1169 kWac
Modules	70 Strings x 28 In series		
At operating cond. (50°C)		Operating voltage	645-1300 V
Pmpp	1301 kWp	Pnom ratio (DC:AC)	1.19
U mpp	1104 V		
I mpp	1179 A		

PV Array Characteristics

PV module

Manufacturer	Mysolar
Model	Mysolar GOLD N-Type HJT BIFACIAL MS710N-HJTGB
(Custom parameters definition)	
Unit Nom. Power	710 Wp
Number of PV modules	11060 units
Nominal (STC)	7853 kWp

Inverter

Manufacturer	Ingeteam
Model	INGECON SUN 1800TL B690 IP54 H1000
(Custom parameters definition)	
Unit Nom. Power	1793 kWac
Number of inverters	4 units
Total power	7172 kWac

Array #3 - sottocampo D

Number of PV modules	2912 units	Number of inverters	1 unit
Nominal (STC)	2068 kWp	Total power	1793 kWac
Modules	104 Strings x 28 In series		
At operating cond. (50°C)		Operating voltage	978-1300 V
Pmpp	1933 kWp	Pnom ratio (DC:AC)	1.15
U mpp	1104 V		
I mpp	1751 A		

Array #5 - sottocampo F

Number of PV modules	3052 units	Number of inverters	1 unit
Nominal (STC)	2167 kWp	Total power	1793 kWac
Modules	109 Strings x 28 In series		
At operating cond. (50°C)		Operating voltage	978-1300 V
Pmpp	2026 kWp	Pnom ratio (DC:AC)	1.21
U mpp	1104 V		
I mpp	1835 A		

Array #7 - sottocampo H

Number of PV modules	5096 units	Number of inverters	2 units
Nominal (STC)	3618 kWp	Total power	3586 kWac
Modules	182 Strings x 28 In series		
At operating cond. (50°C)		Operating voltage	978-1300 V
Pmpp	3383 kWp	Pnom ratio (DC:AC)	1.01
U mpp	1104 V		
I mpp	3064 A		

Total PV power

Nominal (STC)	21888 kWp
Total	30828 modules
Module area	95763 m²

Total inverter power

Total power	19643 kWac
Number of inverters	13 units
Pnom ratio	1.11

Array losses

Array Soiling Losses
Loss Fraction 1.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 29.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

LID - Light Induced Degradation
Loss Fraction 1.0 %

Module Quality Loss
Loss Fraction -0.2 %

Module mismatch losses
Loss Fraction 1.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.2 %

IAM loss factor
Incidence effect (IAM): Fresnel smooth glass, n = 1.526

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.998	0.981	0.948	0.862	0.776	0.636	0.403	0.000

Array losses

Spectral correction

FirstSolar model

Precipitable water estimated from relative humidity

Coefficient Set	C0	C1	C2	C3	C4	C5
Monocrystalline Si	0,85914	-0,02088	-0,0058853	0,12029	0,026814	-0,001781

DC wiring losses

Global wiring resistance 0.065 mΩ
Loss Fraction 0.1 % at STC

Array #1 - sottocampo B
Global array res. 0.58 mΩ
Loss Fraction 0.1 % at STC

Array #2 - sottocampo C
Global array res. 0.69 mΩ
Loss Fraction 0.1 % at STC

Array #3 - sottocampo D
Global array res. 0.50 mΩ
Loss Fraction 0.1 % at STC

Array #4 - sottocampo E
Global array res. 0.49 mΩ
Loss Fraction 0.1 % at STC

Array #5 - sottocampo F
Global array res. 0.50 mΩ
Loss Fraction 0.1 % at STC

Array #6 - sottocampo G
Global array res. 0.69 mΩ
Loss Fraction 0.1 % at STC

Array #7 - sottocampo H
Global array res. 0.64 mΩ
Loss Fraction 0.2 % at STC

Array #8 - sottocampo I
Global array res. 0.63 mΩ
Loss Fraction 0.2 % at STC

Array #9 - sottocampo J
Global array res. 0.68 mΩ
Loss Fraction 0.1 % at STC

System losses

Unavailability of the system
Time fraction 1.5 %
5.5 days,
3 periods

Auxiliaries loss
constant (fans) 24.0 kW
4774.0 kW from Power thresh.

AC wiring losses

Inv. output line up to MV transfo

Inverter voltage 600 Vac tri
Loss Fraction 0.35 % at STC

Inverters: INGECON SUN 1560TL B600 IP54 H1000, INGECON SUN 1170TL B450 IP54 H1000, INGECON SUN 1800TL B690 IP54 H1000
Wire section (13 Inv.) Copper 13 x 3 x 1200 mm²
Average wires length 40 m

MV line up to Injection

MV Voltage 36 kV
Wires Copper 3 x 185 mm²
Length 840 m
Loss Fraction 0.14 % at STC

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AC losses in transformers

MV transfo

Medium voltage	36 kV
Transformer parameters	
Nominal power at STC	21.47 MVA
Iron Loss (24/24 Connexion)	22.75 kVA
Iron loss fraction	0.11 % at STC
Copper loss	214.88 kVA
Copper loss fraction	1.00 % at STC
Coils equivalent resistance	3 x 0.17 mΩ

Horizon definition

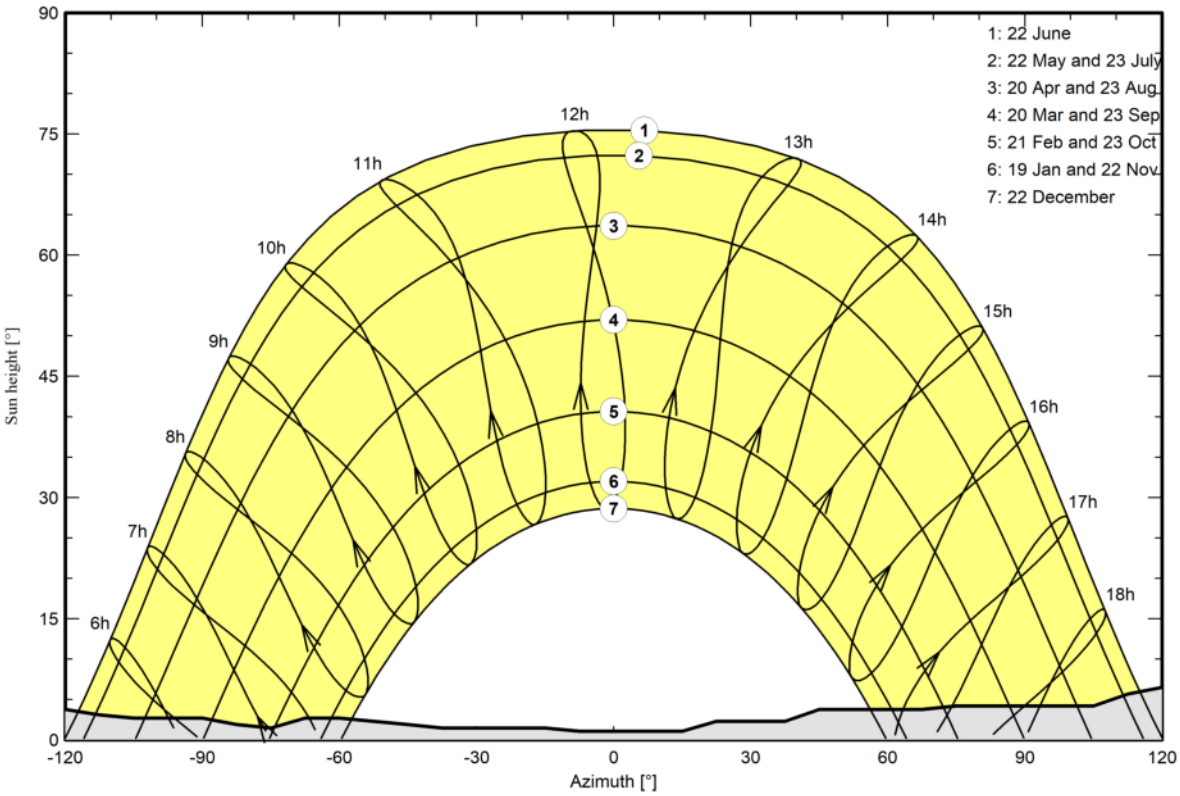
Horizon from PVGIS website API, Lat=37°55'53", Long=13°0'14", Alt=221m

Average Height	4.1 °	Albedo Factor	0.77
Diffuse Factor	0.96	Albedo Fraction	100 %

Horizon profile

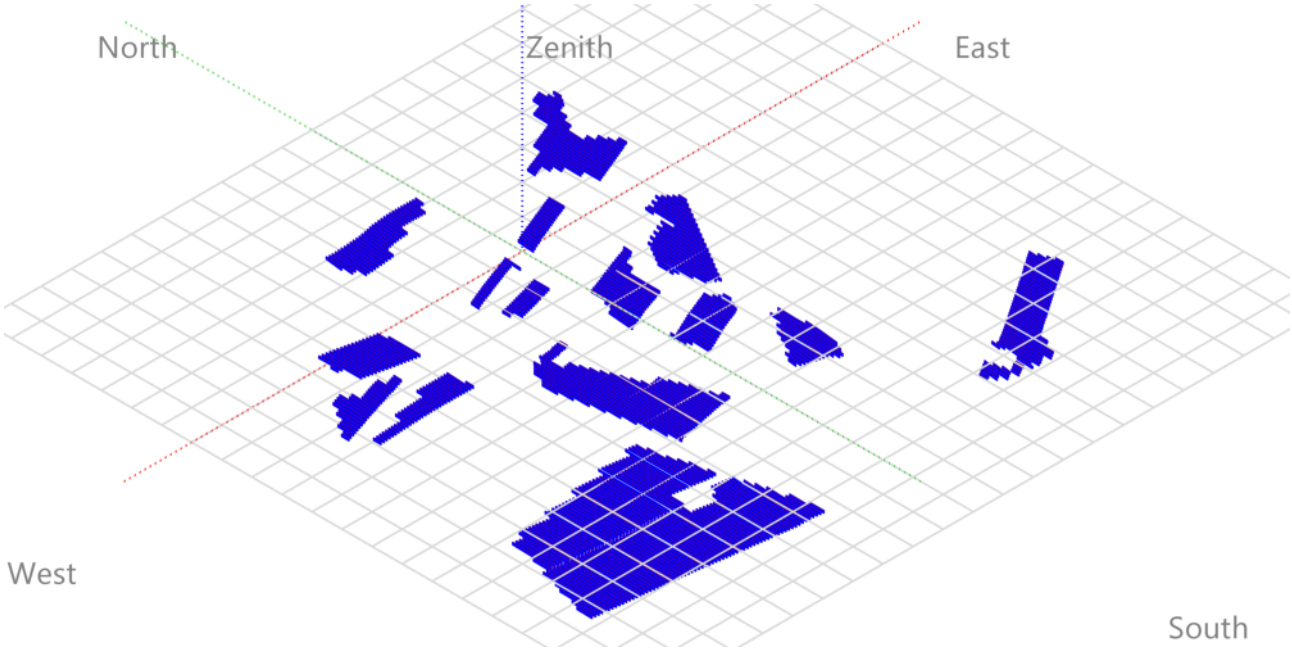
Azimuth [°]	-180	-173	-165	-158	-150	-143	-135	-128	-120	-113	-105	-90	-83
Height [°]	8.0	6.1	5.3	5.3	5.7	5.7	3.4	3.8	3.8	3.1	2.7	2.7	1.9
Azimuth [°]	-75	-68	-60	-53	-45	-38	-15	-8	15	23	38	45	68
Height [°]	1.5	2.7	2.7	2.3	1.9	1.5	1.5	1.1	1.1	2.3	2.3	3.8	3.8
Azimuth [°]	75	105	113	120	128	135	143	150	158	165	173	180	
Height [°]	4.2	4.2	5.7	6.5	7.6	8.4	8.8	8.8	7.6	8.4	8.8	8.0	

Sun Paths (Height / Azimuth diagram)



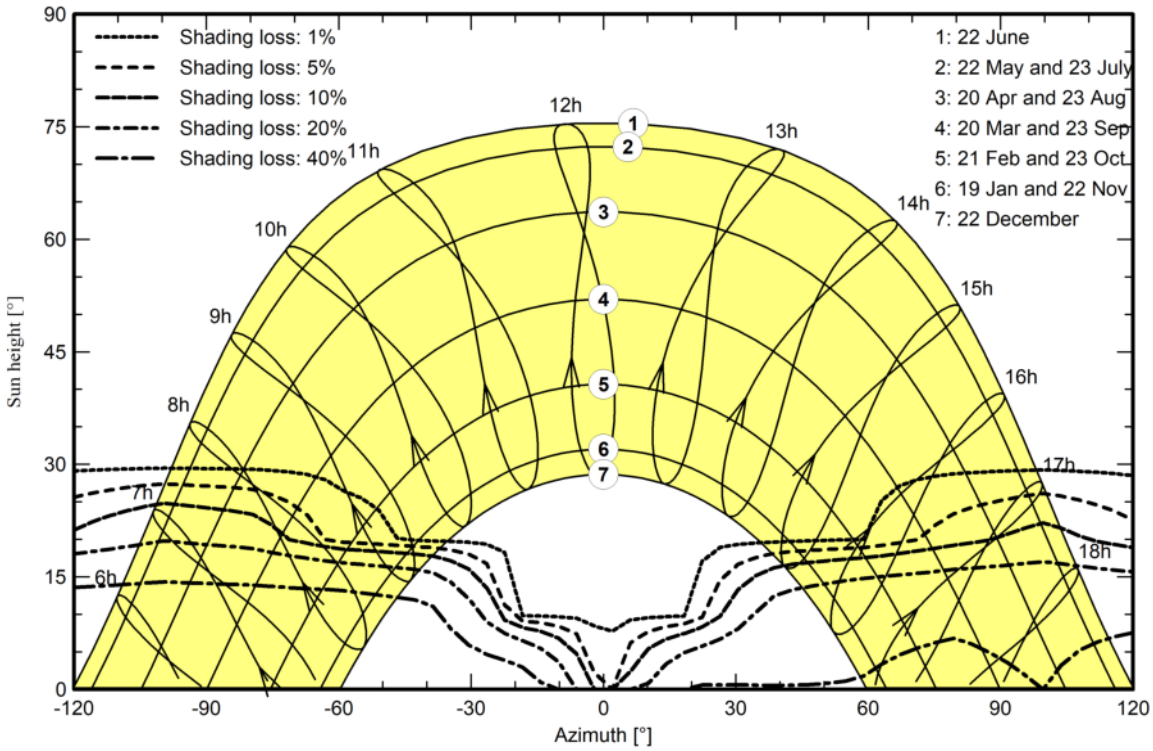
Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram

Orientation #1



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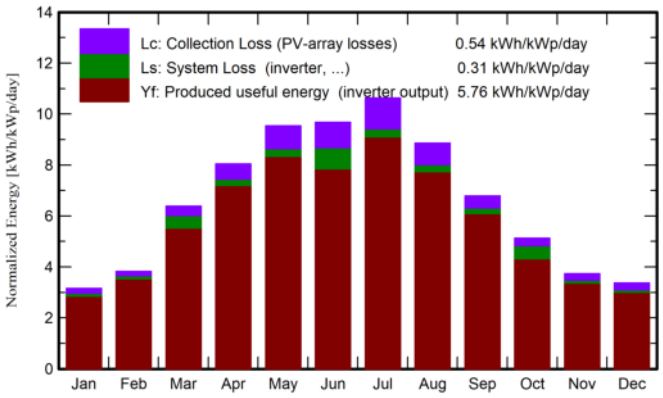
Main results

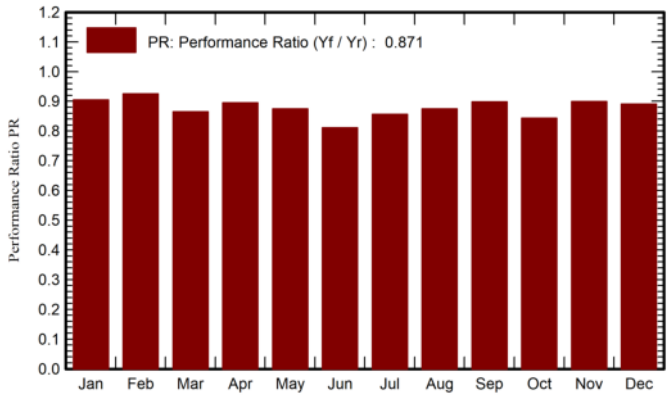
System Production

Produced Energy (P50)	46027.86 MWh/year	Specific production (P50)	2103 kWh/kWp/year	Perf. Ratio PR	87.10 %
Produced Energy (P90)	44208.71 MWh/year	Specific production (P90)	2020 kWh/kWp/year		
Produced Energy (P95)	43696.87 MWh/year	Specific production (P95)	1996 kWh/kWp/year		

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	71.0	34.55	11.08	98.0	90.7	2014	1940	0.905
February	79.6	40.26	9.10	107.0	100.6	2247	2167	0.925
March	145.0	53.88	11.04	198.0	188.4	4090	3750	0.865
April	180.1	63.93	14.77	241.3	232.0	4898	4728	0.895
May	224.5	68.21	18.60	295.7	284.8	5864	5661	0.875
June	223.1	69.71	23.77	290.4	279.3	5701	5157	0.811
July	246.3	62.50	28.25	329.7	318.4	6398	6178	0.856
August	204.4	63.43	26.93	274.5	264.1	5441	5255	0.875
September	150.2	56.50	22.33	203.8	195.1	4150	4007	0.898
October	114.7	45.40	17.11	159.1	150.9	3284	2937	0.843
November	79.3	33.14	14.90	112.2	104.5	2292	2210	0.900
December	72.4	31.63	11.01	104.5	95.7	2113	2038	0.891
Year	1790.7	623.17	17.46	2414.2	2304.5	48492	46028	0.871

Legends

GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

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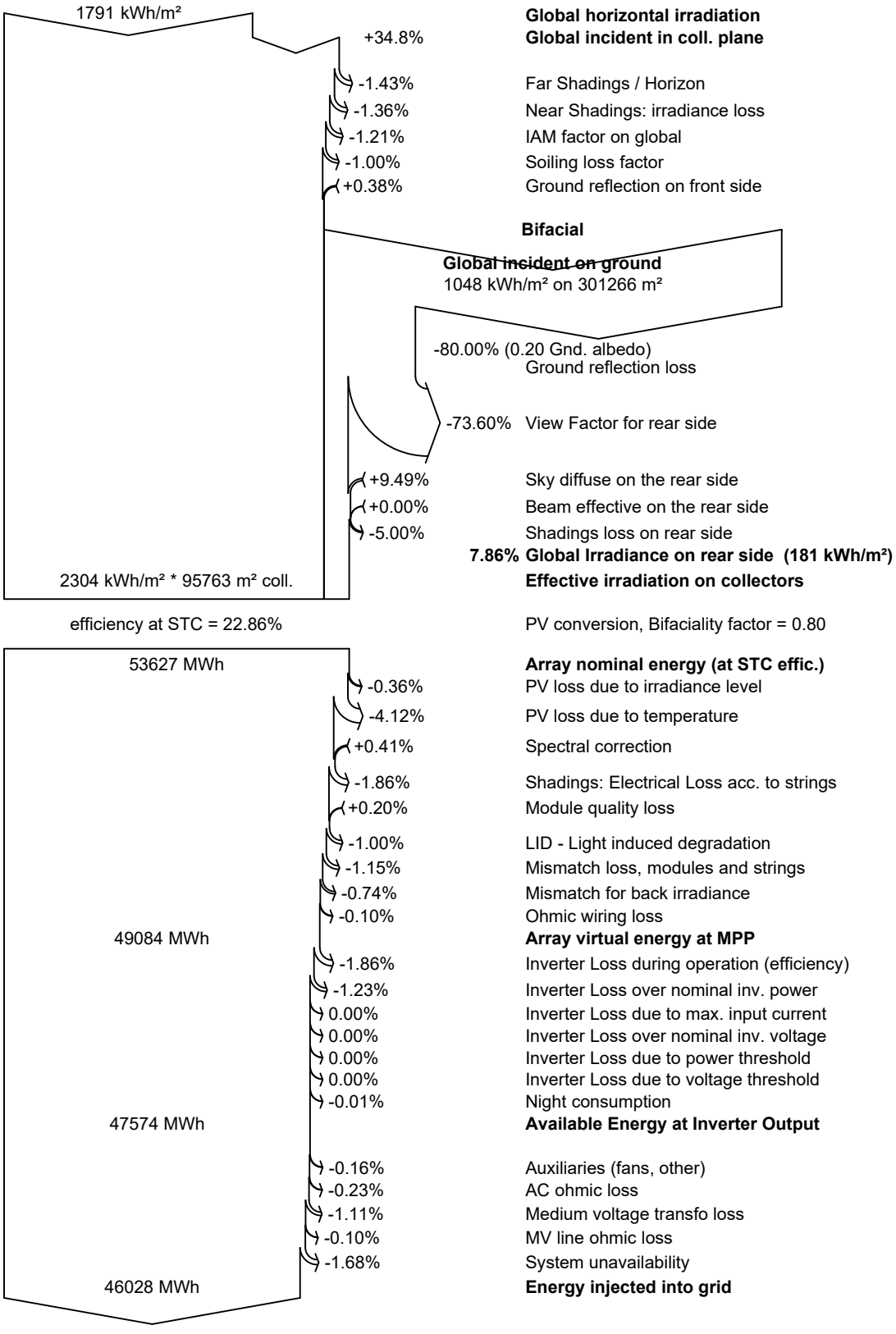
Loss diagram



P50 - P90 evaluation

Meteo data

Source	PVGIS api TMY
Kind	TMY, multi-year
Year-to-year variability(Variance)	2.5 %
Specified Deviation	
Climate change	0.0 %

Simulation and parameters uncertainties

PV module modelling/parameters	1.0 %
Inverter efficiency uncertainty	0.5 %
Soiling and mismatch uncertainties	1.0 %
Degradation uncertainty	1.0 %

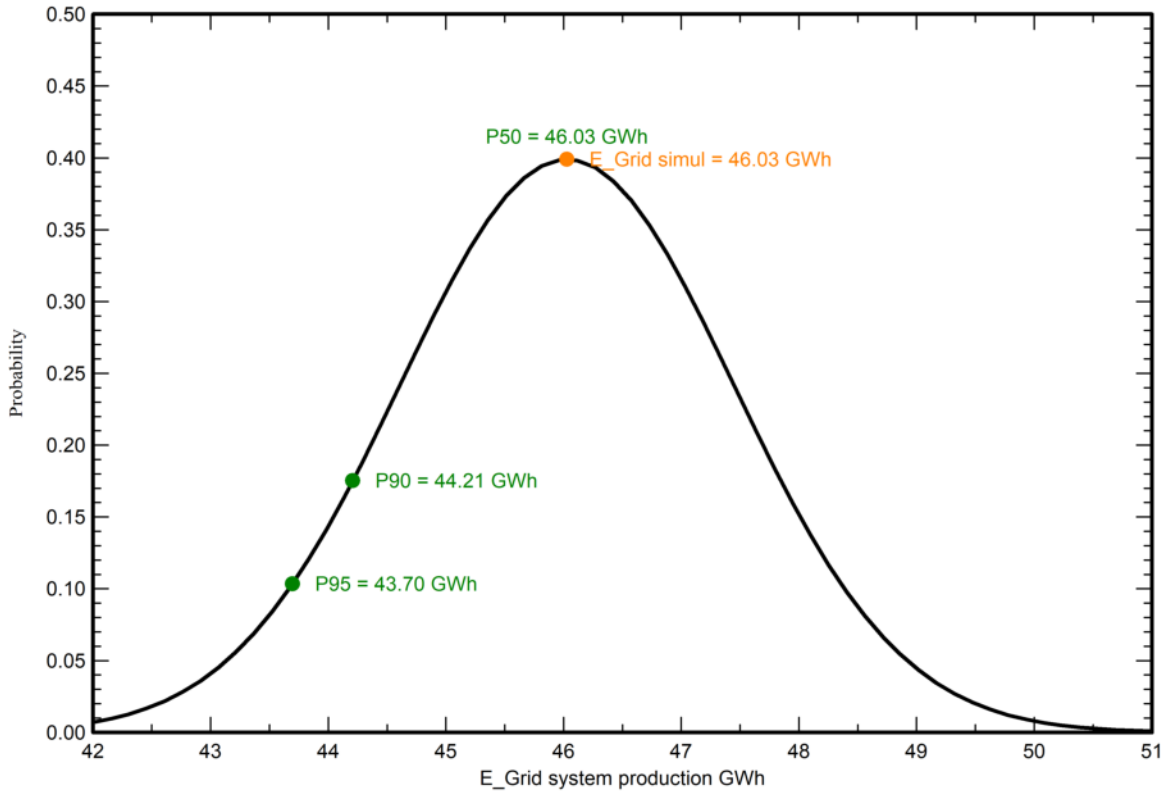
Global variability (meteo + system)

Variability (Quadratic sum)	3.1 %

Annual production probability

Variability	1.42 GWh
P50	46.03 GWh
P90	44.21 GWh
P95	43.70 GWh

Probability distribution



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with v7.4.2

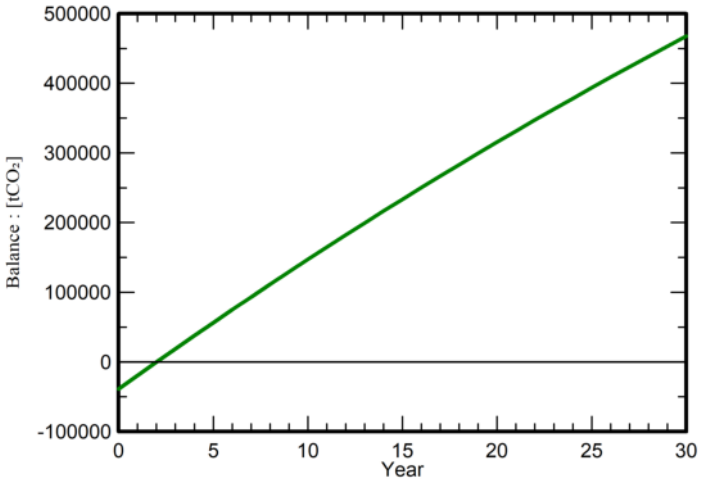
CO_2 Emission Balance

Total: 467809.9 tCO_2

Generated emissions
Total: 38987.85 tCO_2
Source: Detailed calculation from table below

Replaced Emissions
Total: 584093.5 tCO_2
System production: 46027.86 MWh/yr
Grid Lifecycle Emissions: 423 gCO_2/kWh
Source: IEA List
Country: Italy
Lifetime: 30 years
Annual degradation: 1.0 %

Saved CO_2 Emission vs. Time



System Lifecycle Emissions Details

Item	LCE	Quantity	Subtotal
			[$kgCO_2$]
Modules	1713 kgCO2/kWp	21252 kWp	36398246
Transport1	35.0 gCO2/km	15100 km	613780
Transport2	59.7 gCO2/km	1350 km	93600
Supports	2.82 kgCO2/kg	565440 kg	1595338
Concrete	177 kgCO2/m^3	400 m^3	70800
Inverters	280 kgCO2/units	12.0 units	3354
Wiring	14.8 kgCO2/m	14400 m	212731

Version 7.4.2

PVsyst - Simulation report

Grid-Connected System

Project: Alcamo_Monteleone_Project

Variant: 08_Alcamo_Monteleone_CTR_VIG_7.5m_Sottocampo K

Tracking system with backtracking

System power: 1730 kWp

Casa Valdibella - Italy

Author

E-Way Finance S.p.A. (Italy)

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Project summary

Geographical Site
Casa Valdibella
Italy

Situation

Latitude	37.91 °N
Longitude	13.00 °E
Altitude	180 m
Time zone	UTC+1

Project settings

Albedo	0.20

Meteo data
Casa Valdibella
PVGIS api TMY

System summary

Grid-Connected System

Tracking system with backtracking

PV Field Orientation
Orientation

Tracking plane, tilted axis	
Avg axis tilt	1.1 °
Avg axis azim.	0 °

Tracking algorithm

Irradiance optimization	
Backtracking activated	
Wind stow	
Wind Speed threshold	12 m/s
Wind stow position	0 °

Near Shadings

According to strings : Fast (table)	
Electrical effect	80 %
Diffuse shading	Automatic

System information

PV Array

Nb. of modules	2436 units
Pnom total	1730 kWp

Inverters

Nb. of units	1 unit
Pnom total	1559 kWac
Pnom ratio	1.109

User's needs
Unlimited load (grid)

Results summary

Produced Energy	3662.57 MWh/year	Specific production	2118 kWh/kWp/year	Perf. Ratio PR	88.32 %

Table of contents

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General parameters

Grid-Connected System

Tracking system with backtracking

PV Field Orientation

Orientation

Tracking plane, tilted axis	
Avg axis tilt	1.1 °
Avg axis azim.	0 °

Tracking algorithm

Irradiance optimization	
Backtracking activated	
Wind stow	
Wind Speed threshold	12 m/s
Wind stow position	0 °

Backtracking array

Nb. of trackers	92 units

Sizes

Tracker Spacing	7.50 m
Collector width	2.38 m
Ground Cov. Ratio (GCR)	31.8 %
Phi min / max.	-/+ 45.0 °

Backtracking strategy

Phi limits for BT	-/+ 79.9 °
Backtracking pitch	7.50 m
Backtracking width	2.38 m

Models used

Transposition	Perez
Diffuse	Imported
Circumsolar	separate

Horizon

Average Height	4.1 °

Near Shadings

According to strings : Fast (table)	
Electrical effect	80 %
Diffuse shading	Automatic

User's needs

Unlimited load (grid)

Bifacial system

Model: 2D Calculation
unlimited trackers

Bifacial model geometry

Tracker Spacing	7.50 m
Tracker width	2.38 m
GCR	31.8 %
Axis height above ground	3.05 m

Bifacial model definitions

Ground albedo	0.20
Bifaciality factor	80 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

PV Array Characteristics

PV module

Manufacturer	Mysolar
Model	Mysolar GOLD N-Type HJT BIFACIAL MS710N-HJTGB
(Custom parameters definition)	
Unit Nom. Power	710 Wp
Number of PV modules	2436 units
Nominal (STC)	1730 kWp
Modules	87 Strings x 28 In series
At operating cond. (50°C)	
Pmpp	1617 kWp
U mpp	1104 V
I mpp	1465 A

Inverter

Manufacturer	Ingeteam
Model	INGECON SUN 1560TL B600 IP54 H1000
(Custom parameters definition)	
Unit Nom. Power	1559 kWac
Number of inverters	1 unit
Total power	1559 kWac
Operating voltage	853-1300 V
Pnom ratio (DC:AC)	1.11

Total PV power

Nominal (STC)	1730 kWp
Total	2436 modules
Module area	7567 m²

Total inverter power

Total power	1559 kWac
Number of inverters	1 unit
Pnom ratio	1.11

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Array losses

Array Soiling Losses
Loss Fraction 1.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 29.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 0.67 mΩ
Loss Fraction 0.1 % at STC

LID - Light Induced Degradation
Loss Fraction 1.0 %

Module Quality Loss
Loss Fraction -0.2 %

Module mismatch losses
Loss Fraction 1.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.2 %

IAM loss factor
Incidence effect (IAM): Fresnel smooth glass, n = 1.526

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.998	0.981	0.948	0.862	0.776	0.636	0.403	0.000

Spectral correction
FirstSolar model
Precipitable water estimated from relative humidity

Coefficient Set	C0	C1	C2	C3	C4	C5
Monocrystalline Si	0,85914	-0,02088	-0,0058853	0,12029	0,026814	-0,001781

System losses

Unavailability of the system
Time fraction 1.5 %
5.5 days,
3 periods

Auxiliaries loss
constant (fans) 2.00 kW
390.0 kW from Power thresh.

AC wiring losses

Inv. output line up to MV transfo
Inverter voltage 600 Vac tri
Loss Fraction 0.01 % at STC
Inverter: INGECON SUN 1560TL B600 IP54 H1000
Wire section (1 Inv.) Copper 1 x 3 x 1200 mm²
Wires length 2 m

MV line up to Injection
MV Voltage 36 kV
Wires Copper 3 x 185 mm²
Length 900 m
Loss Fraction 0.01 % at STC

AC losses in transformers

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AC losses in transformers

MV transfo

Medium voltage	36 kV
Transformer parameters	
Nominal power at STC	1.70 MVA
Iron Loss (24/24 Connexion)	1.80 kVA
Iron loss fraction	0.11 % at STC
Copper loss	16.93 kVA
Copper loss fraction	1.00 % at STC
Coils equivalent resistance	3 x 2.11 mΩ

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Horizon definition

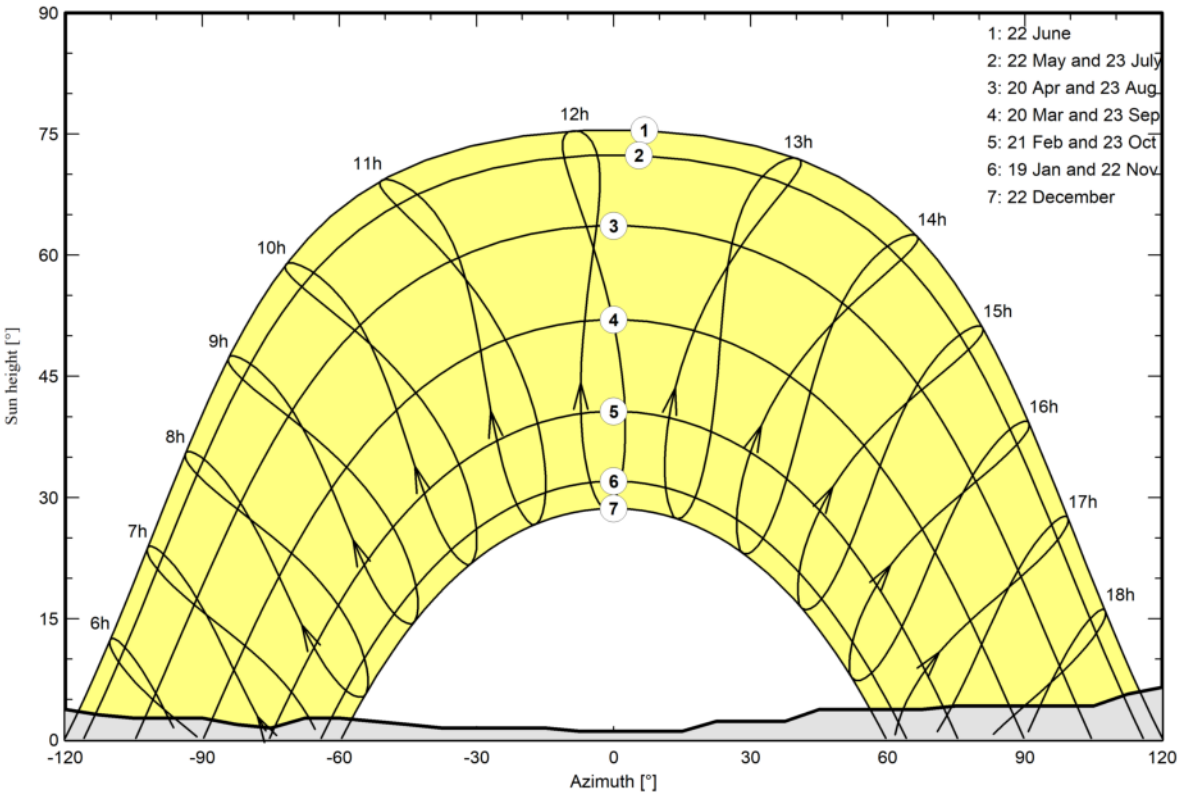
Horizon from PVGIS website API, Lat=37°55'53", Long=13°0'14", Alt=221m

Average Height	4.1 °	Albedo Factor	0.76
Diffuse Factor	0.95	Albedo Fraction	100 %

Horizon profile

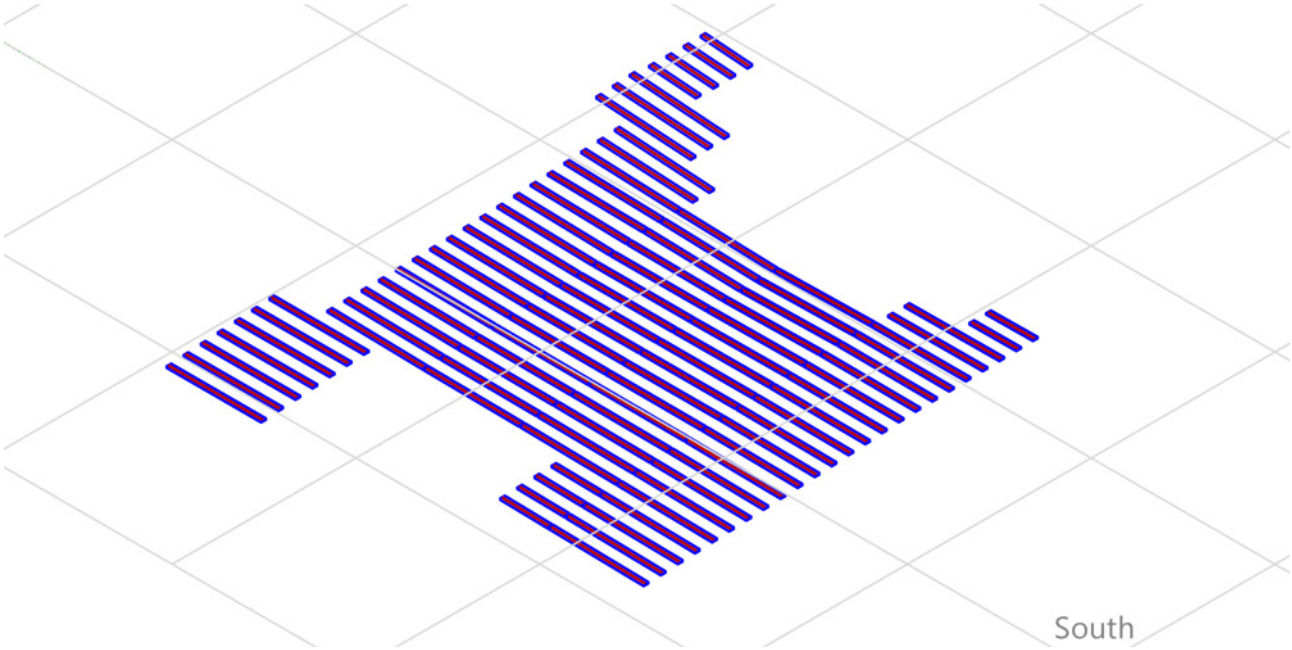
Azimuth [°]	-180	-173	-165	-158	-150	-143	-135	-128	-120	-113	-105	-90	-83
Height [°]	8.0	6.1	5.3	5.3	5.7	5.7	3.4	3.8	3.8	3.1	2.7	2.7	1.9
Azimuth [°]	-75	-68	-60	-53	-45	-38	-15	-8	15	23	38	45	68
Height [°]	1.5	2.7	2.7	2.3	1.9	1.5	1.5	1.1	1.1	2.3	2.3	3.8	3.8
Azimuth [°]	75	105	113	120	128	135	143	150	158	165	173	180	
Height [°]	4.2	4.2	5.7	6.5	7.6	8.4	8.8	8.8	7.6	8.4	8.8	8.0	

Sun Paths (Height / Azimuth diagram)



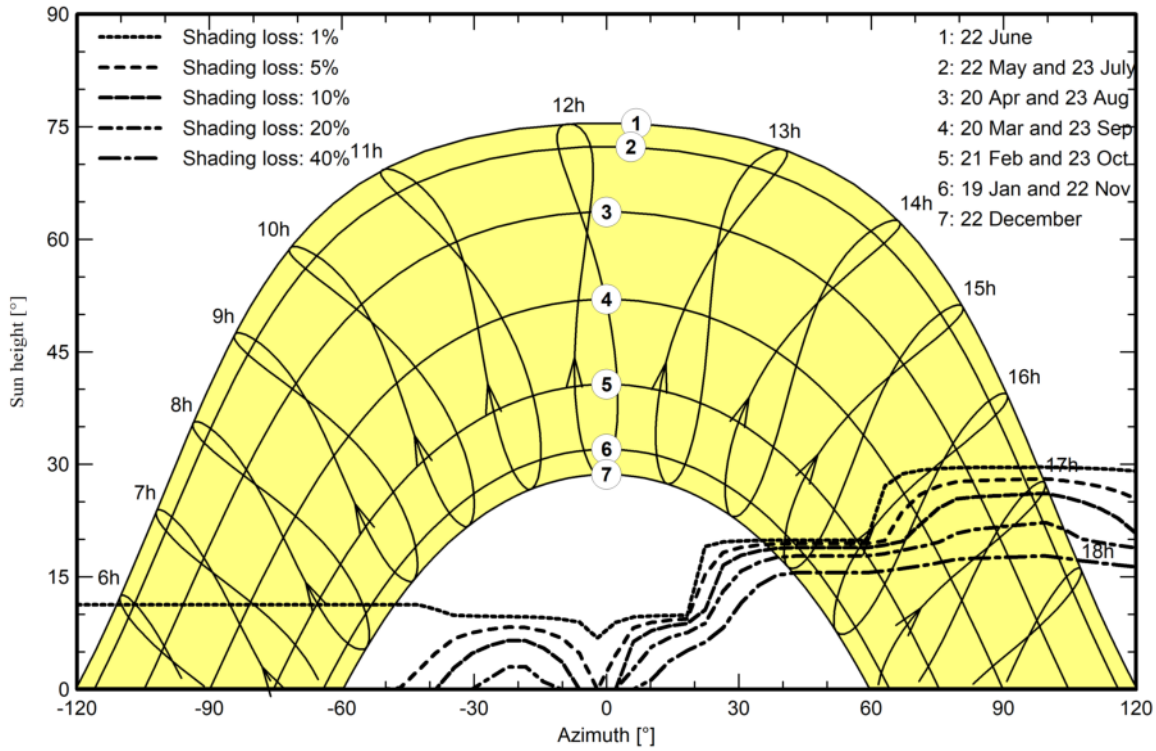
Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram

Orientation #1



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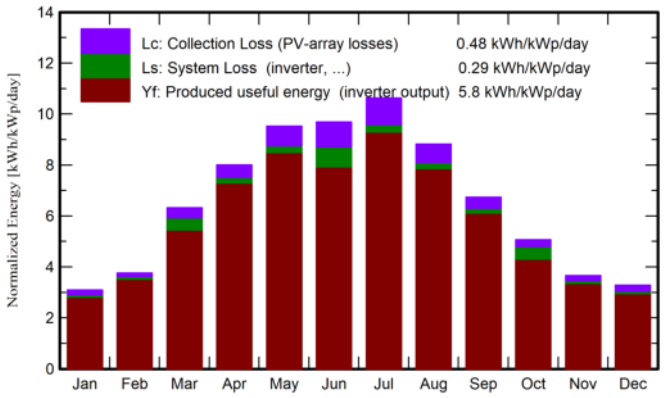
Main results

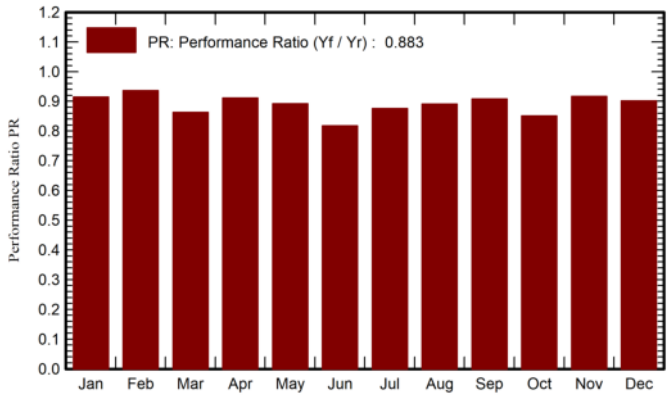
System Production

Produced Energy (P50)	3662.57 MWh/year	Specific production (P50)	2118 kWh/kWp/year	Perf. Ratio PR	88.32 %
Produced Energy (P90)	3517.82 MWh/year	Specific production (P90)	2034 kWh/kWp/year		
Produced Energy (P95)	3477.09 MWh/year	Specific production (P95)	2010 kWh/kWp/year		

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	71.0	34.55	11.08	95.8	88.5	156.8	151.5	0.914
February	79.6	40.26	9.10	105.4	98.9	176.4	170.6	0.936
March	145.0	53.88	11.04	196.0	185.3	317.8	292.4	0.862
April	180.1	63.93	14.77	240.3	230.6	390.7	378.7	0.911
May	224.5	68.21	18.60	295.3	284.1	469.9	455.6	0.892
June	223.1	69.71	23.77	290.7	278.1	452.6	411.2	0.818
July	246.3	62.50	28.25	329.6	317.9	514.4	499.0	0.875
August	204.4	63.43	26.93	273.6	263.2	434.9	421.8	0.891
September	150.2	56.50	22.33	202.2	193.4	327.6	317.6	0.908
October	114.7	45.40	17.11	157.0	148.6	257.6	231.1	0.851
November	79.3	33.14	14.90	110.0	102.3	180.1	174.3	0.916
December	72.4	31.63	11.01	101.8	93.0	164.2	158.8	0.902
Year	1790.7	623.17	17.46	2397.8	2283.8	3843.1	3662.6	0.883

Legends

GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

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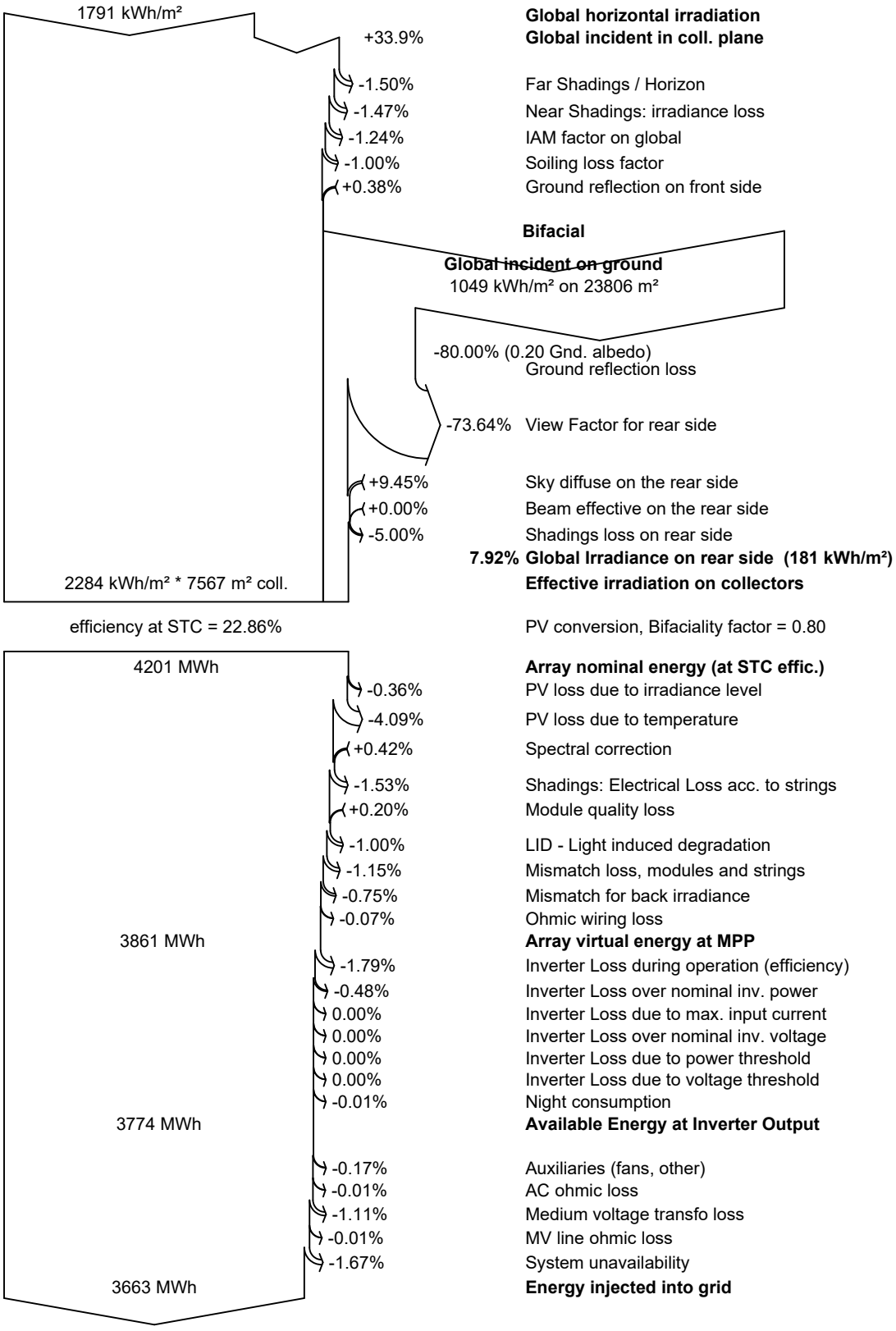
Loss diagram



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P50 - P90 evaluation

Meteo data

Source	PVGIS api TMY
Kind	TMY, multi-year
Year-to-year variability(Variance)	2.5 %
Specified Deviation	
Climate change	0.0 %

Simulation and parameters uncertainties

PV module modelling/parameters	1.0 %
Inverter efficiency uncertainty	0.5 %
Soiling and mismatch uncertainties	1.0 %
Degradation uncertainty	1.0 %

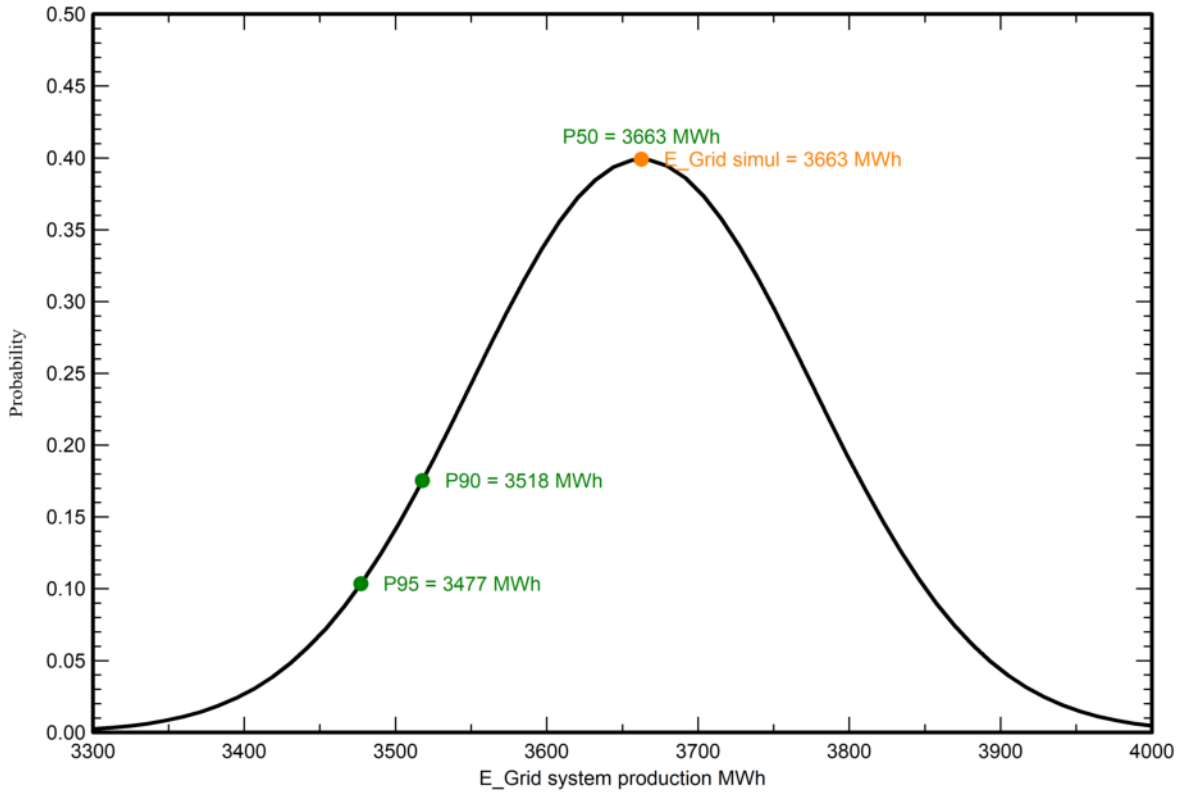
Global variability (meteo + system)

Variability (Quadratic sum)	3.1 %

Annual production probability

Variability	113 MWh
P50	3663 MWh
P90	3518 MWh
P95	3477 MWh

Probability distribution



CO_2 Emission Balance

Total: 36940.6 tCO_2

Generated emissions

Total: 3386.77 tCO_2

Source: Detailed calculation from table below

Replaced Emissions

Total: 46478.1 tCO_2

System production: 3662.57 MWh/yr

Grid Lifecycle Emissions: 423 gCO_2/kWh

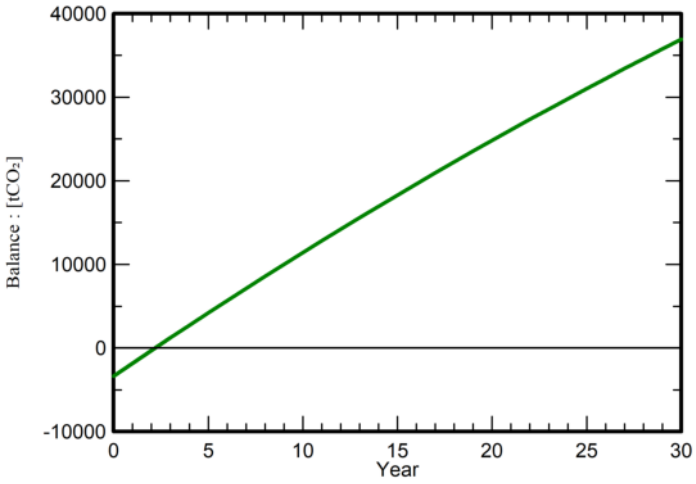
Source: IEA List

Country: Italy

Lifetime: 30 years

Annual degradation: 1.0 %

Saved CO_2 Emission vs. Time



System Lifecycle Emissions Details

Item	LCE	Quantity	Subtotal
			[$kgCO_2$]
Modules	1713 kgCO2/kWp	1730 kWp	2962252
Transport1	35.0 gCO2/km	15100 km	49952
Transport2	59.7 gCO2/km	1400 km	7900
Supports	2.82 kgCO2/kg	121800 kg	343648
Concrete	177 kgCO2/m³	45.0 m³	7965
Inverters	280 kgCO2/units	1.00 units	280
Wiring	14.8 kgCO2/m	1000 m	14773