A Tool to Optimize the Layout of Ground-Based PV Installations Taking into Account the Economic Boundary Conditions

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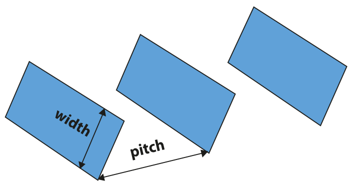
Abstract

Current optimization tools and methods for the layout of large PV installations aim at maximizing the yield or the performance ratio of the installation. Nevertheless, there are situations, where the economical boundary conditions, namely the investment and maintenance costs, the availability of surface and the feed-in tariff have an impact on the optimal design choices. We propose a tool which addresses this problem by finding the ground covering ratio, tilt angle and the azimuthal orientation that maximize the economic benefits. The method is intended to support PV installation designers in making optimal design choices from an economical point of view.

Optimization Input

Parameters to be Optimized

	Impact on: Incident (PoA) Irradiance	Impact on: Shadings
Tilt	YES	YES
Pitch / GCR	NO	YES
Azimuth	YES	YES



Ground Covering Ratio (GCR)
GCR = width / pitch

The interplay between tilt and pitch, to maximize incident irradiation and minimize shading losses, is not straightforward and needs to be simulated.
The simulation considers shading losses for direct, diffuse and albedo irradiance.

Optimization Criteria

Energy yield is not always the best variable for optimization.
Economic Variables are often more important and need additional input parameters

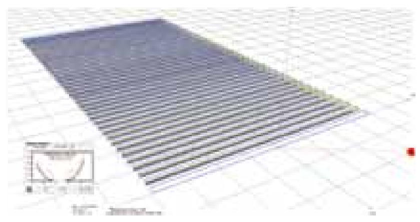
	$\propto P_{nom}$	$\propto$ Area
Investment	1500 $ / kWp	8 $ / m²
O&M	29 $ / kWp yr	0.03 $ / m² yr
Return $\propto E_{Grid}$	0.13 $ / kWh	
Timespan	16 years	
Discount rate	8.7 %	

Economic paramerters used in the examples

Simulation and Energy Yield

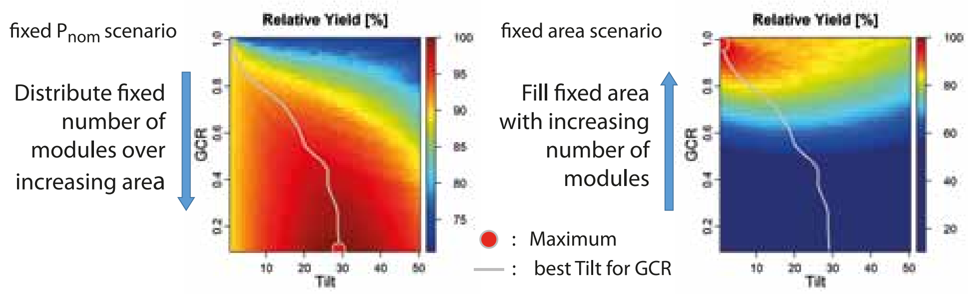
Reference Project

In a set of simulations, the optimization parameters are varied automatically.
The reference project should be regular and scalable to allow general conclusions.



Reference Project for the Shed Examples	
Layout	40 sheds, 3 rows per shed
Modules	Generic 250 W module
Inverters	Generic 500 kW inverter
Power	11520 modules, P_{nom} = 2.88 GW_p
Shadings	According to strings
Meteo Input	Meteonorm 6.1 for Geneva

Fixed Nominal Power vs. Fixed Area

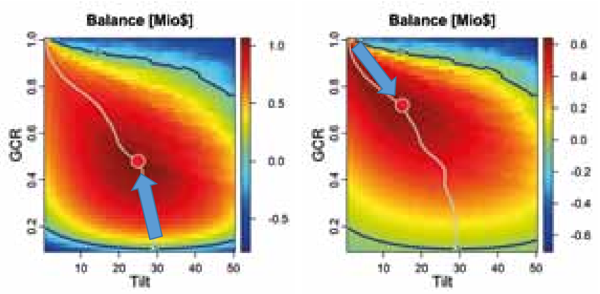


Optimum: 30° South, wide spacing

Optimum: horizontal, all area covered

Application Examples

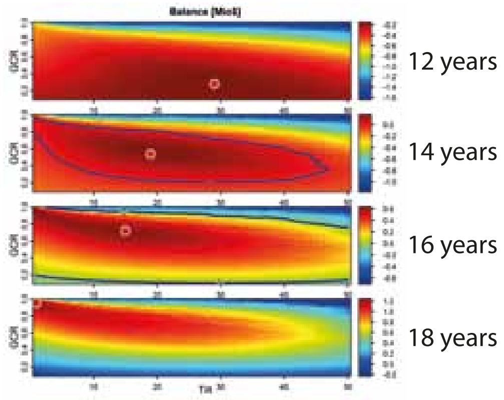
Maximize Benefits



fixed P_{nom} scenario | fixed area scenario

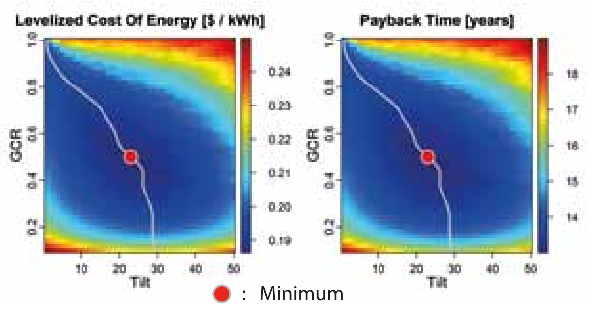
Balance = Revenues – Costs
Including Costs and Revenues moves the optimum away from GCR extremes.
GCR = 0 would need infinite Area
GCR = 1 has non-optimal yield per kWp
The exact optimum depends on financial input parameters

Changing the Timespan



The timespan has an impact on the optimal design parameters.
Optimizing short term returns neglects future benefits.

More Complex Financial Variables

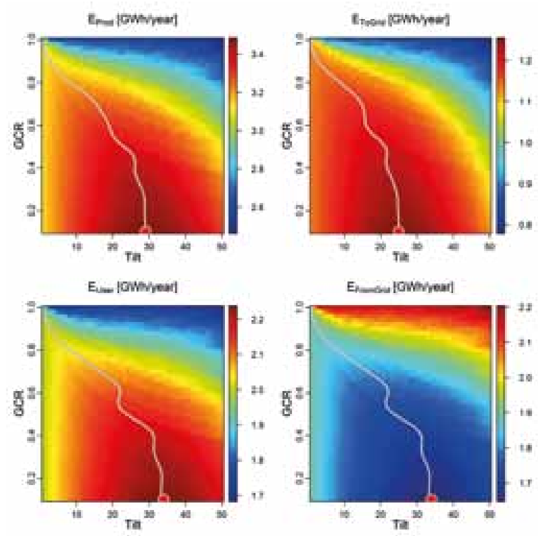


Any quantity that can be expressed as function of optimization parameters and energy yield, is a potential optimization criteria.
For example (using discount rate d as additional input):

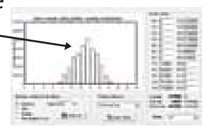
Levelized Cost of Energy (LCOE): $$LCOE = \sum_{n=0}^{N} \frac{C_n}{(1+d)^n} \div \sum_{n=1}^{N} \frac{Q_n}{(1+d)^n}$$

Discounted Payback Time (DPB): $$\sum_{n=0}^{DPB} \frac{\Delta I_n}{(1+d)^n} \leq \sum_{n=1}^{DPB} \frac{\Delta S_n}{(1+d)^n}$$

Net Metering



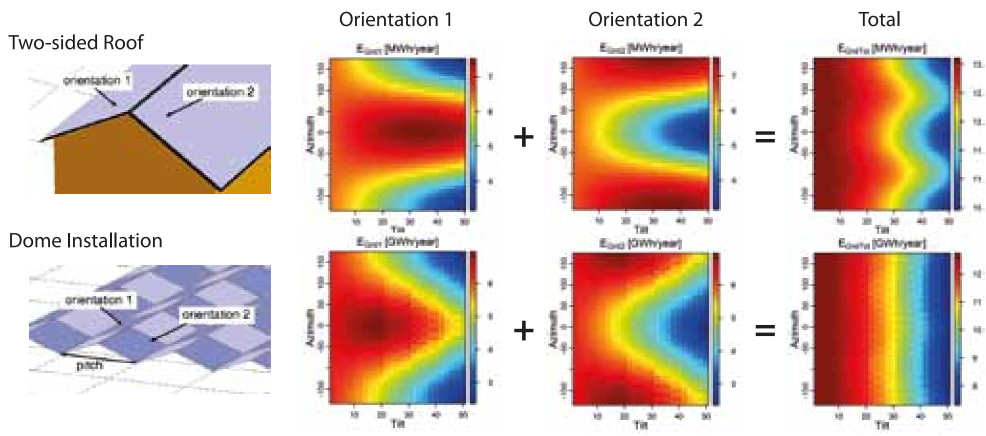
Additional Input needed:
- Electricity Price
- Load Profile



More complex output:
- Produced Energy E_{Prod}
- Used Energy E_{User}
- Energy injected to Grid E_{ToGrid}
- Energy bought from Grid $E_{FromGrid}$

A high grid feed-in tariff favors lower tilt angles.
A high electricity price favors larger tilt angles.

Two Opposite Orientations



Low tilt has always a higher yield.
For a roof with two opposite orientations the best yield is obtained with E-W alignment.
For the dome installation the yield does almost not depend on the azimuthal orientation.

Optimization graphs offer powerful help in finding the best design parameters.
These tools are being implemented in the PVsyst software and will soon be available.
In addition to these examples, there will be more parameters and variables, and the possibility to optimize tracking installations.