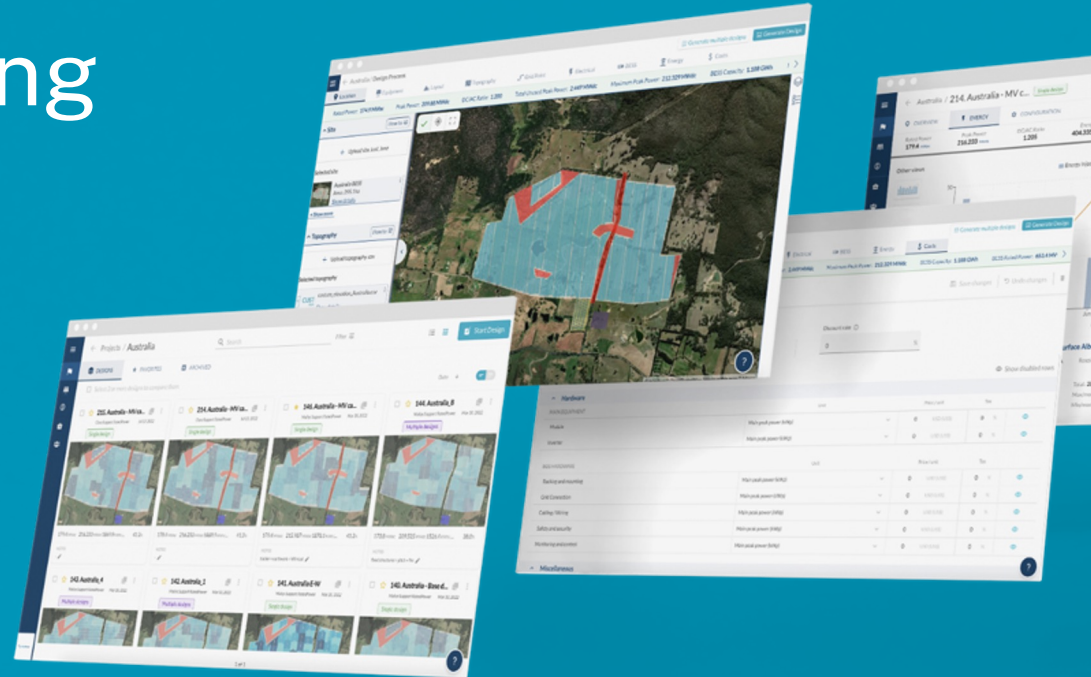


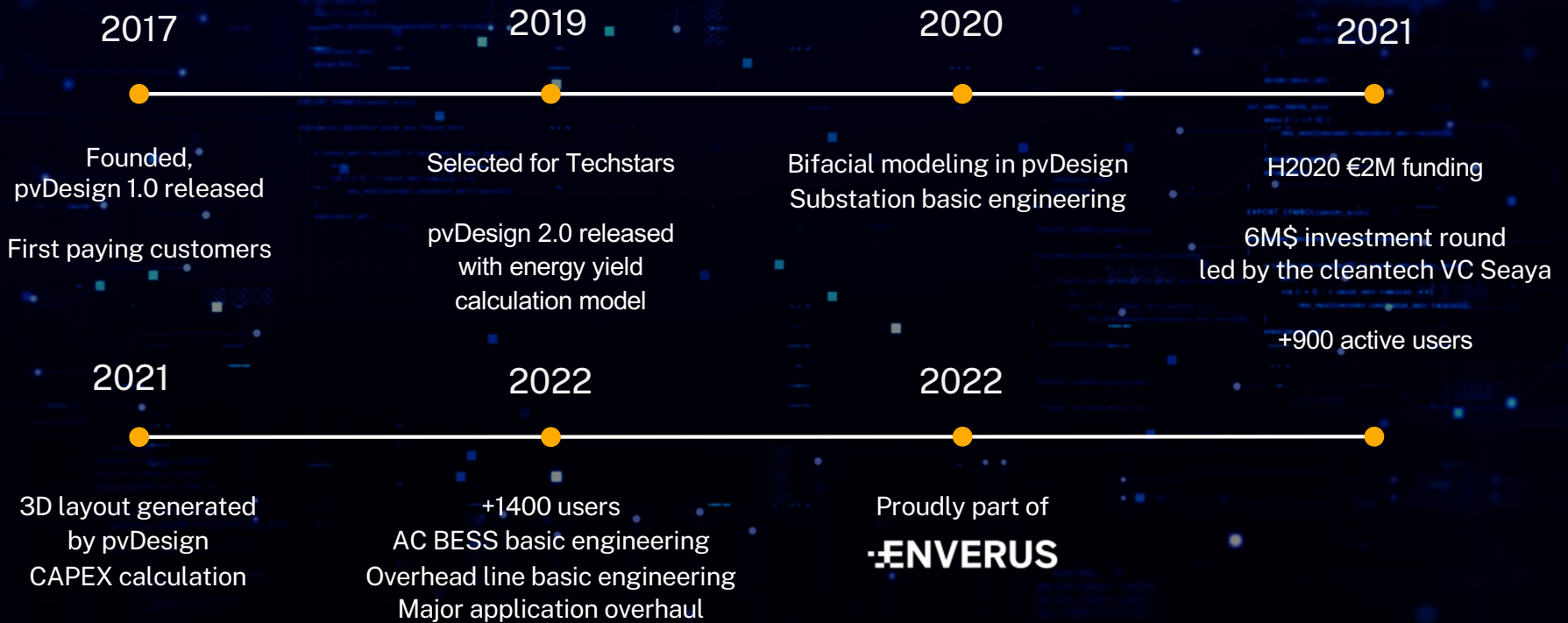
# Energy yield modeling using the pvDesign software

Félix Ignacio Pérez Cicala

2023 PV Performance Modeling  
Collaborative



## RatedPower's journey





# RatedPower and pvDesign by the numbers

**+200**

Customers

**+30000**

Users worldwide

**+50k**

Yearly sites  
uploaded

**+100k**

Yearly simulations



01 Calculation  
model

02 Bifacial  
modeling

03 Degradation  
case study

04 Layout complexity  
case study



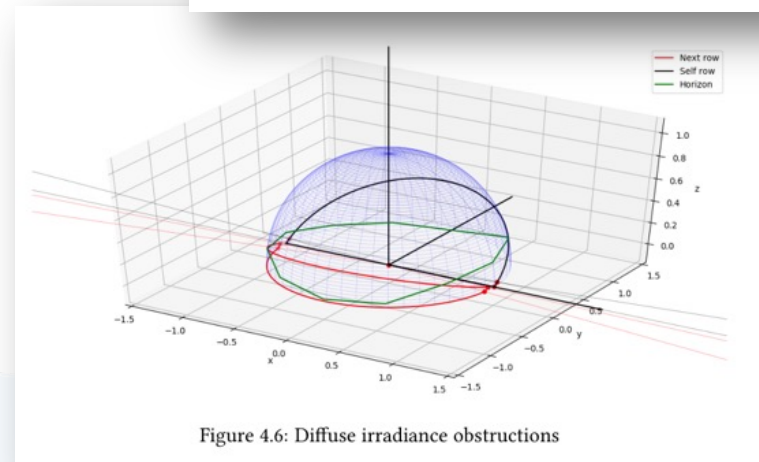
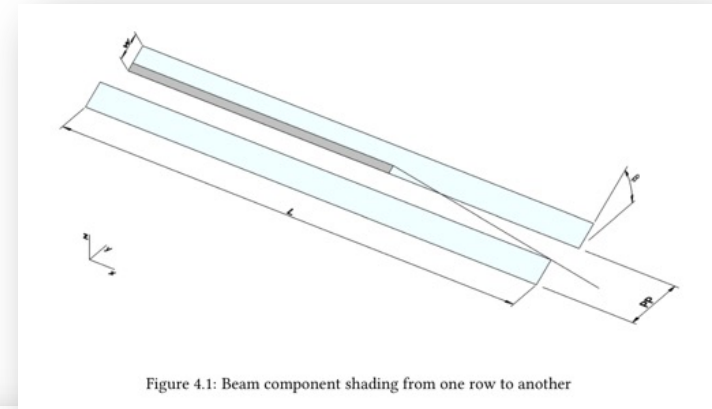
Calculation  
model

01

# Irradiation

Summary: Flat terrain, 2D shading calculation

- Perez diffuse transposition model
- Linear shading for the beam component, 2D geometry
- Diffuse shading using sky vault integration
- Ground reflected irradiation using view factor model
- Far horizon considered



## Electrical model

Summary: Standard one diode model, inverter and MV system

- Standard one diode model using PAN file parameters
- Inverter modeling using OND file parameters (efficiency and MPPT)
- MV system including transformers
- Power factor calculation

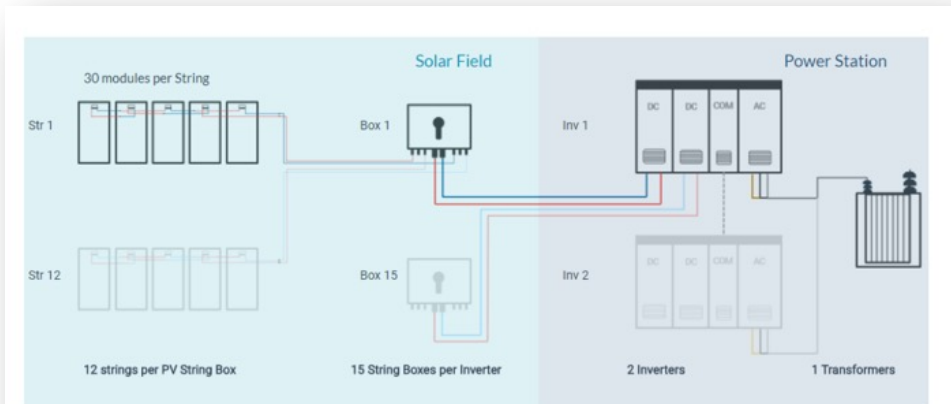
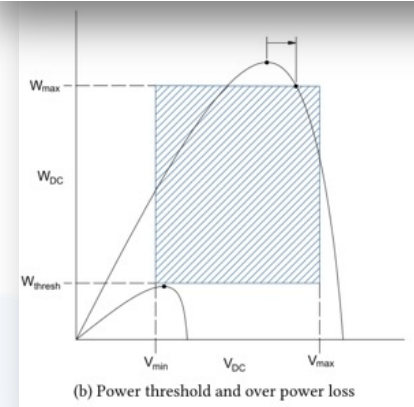


Figure 7.1: Electrical connections in a photovoltaic power plant [40]

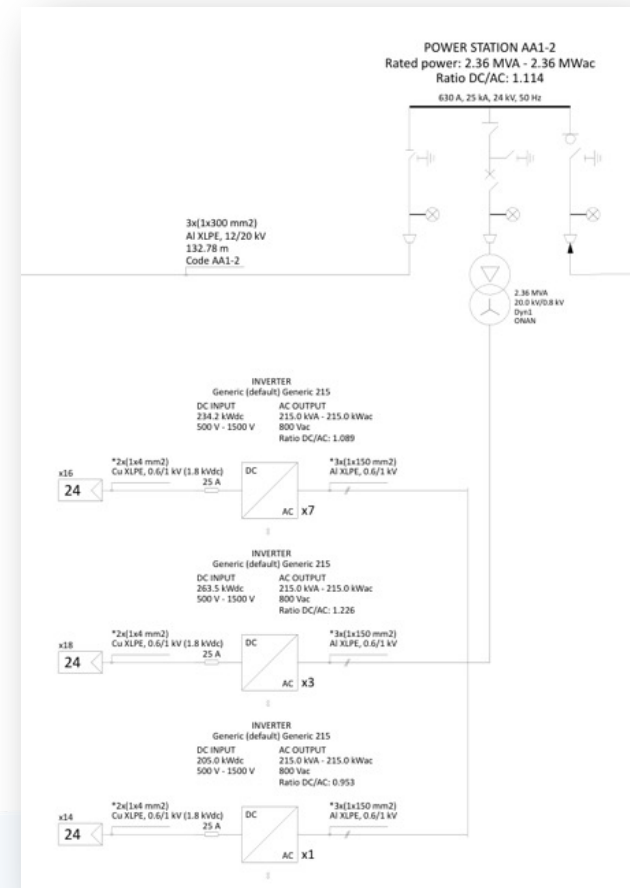




# Electrical system

Summary: Consumed from pvDesign simulation

- pvDesign automatically generates full electrical system, considering layout
- It can be very heterogeneous, with different inverter models, DC/AC ratios, and transformer capacities
- The system is directly fed into the energy simulation
- For this reason, the user only needs to set energy-specific inputs





Bifacial  
modeling

02

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## Back face irradiation

### Summary: View factor model

- Considers vision of the sky from the ground
- Takes into account the shades cast by the structures on the ground
- Calculates the irradiance perceived by the backface, considering the structure behind and the torque beam
- Far horizon considered (beam shading only)
- IAM loss considered for the backface

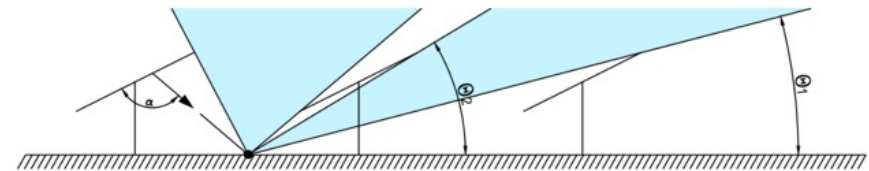


Figure 5.7: Arcs of sky vault visible through the gaps between structures.

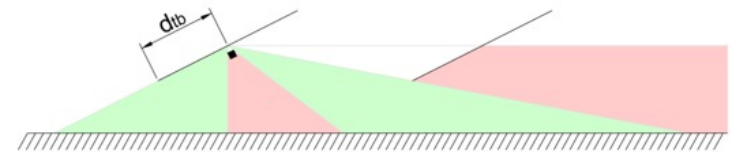


Figure 5.10: Ground reflected irradiance loss due to the near obstacles (torque beam and contiguous structure), evaluated at the middle point of the table for a worse case scenario representation.



## Reporting losses

Without view factor model: Loss due to albedo, and gain due to backface vision of the sky vault.

With view factor model, comparing with previous value:

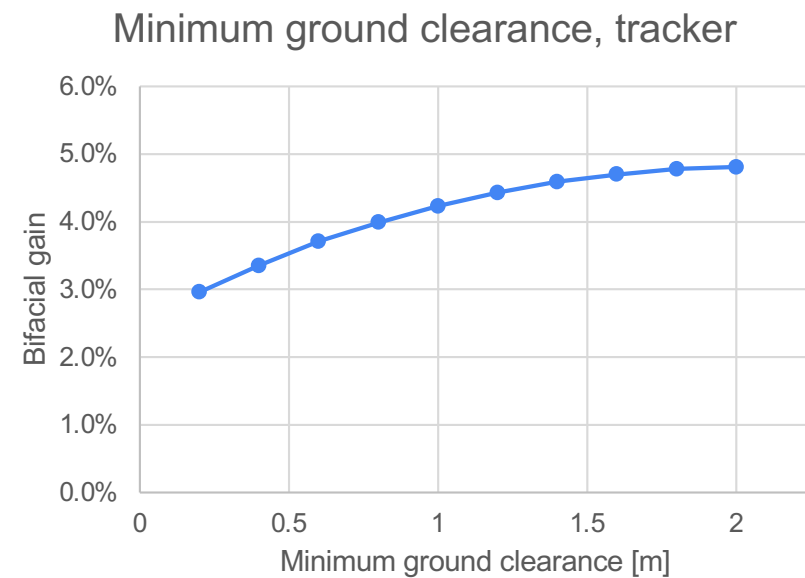
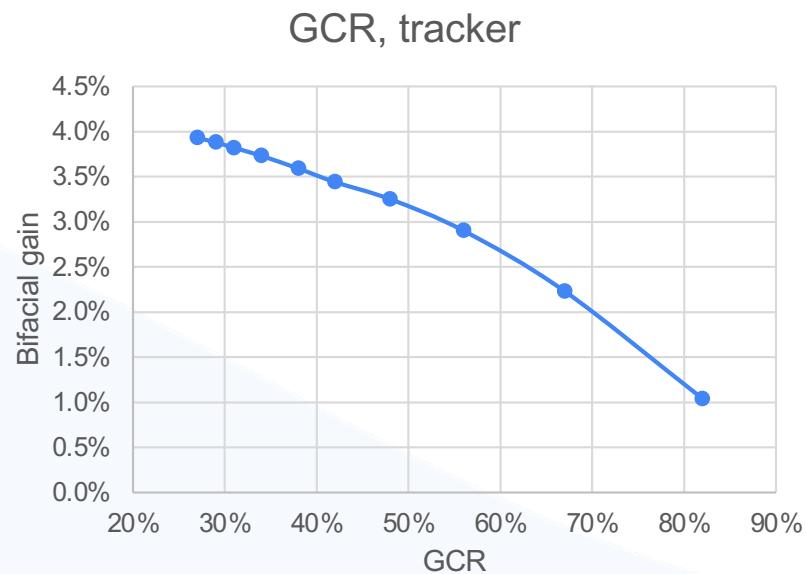
- Loss due to the shades cast from the structures to the ground (ground shades)
- Near shading loss due to structures and torque beam
- Other losses: Backface soiling, IAM model loss

Description	Value	Unit	Loss
<b>Solar resource</b>			
Global horizontal irradiation	2559.6	kWh/m2	
Ground reflected irradiance	511.9	kWh/m2	-80.00 %
Transposition to the plane of array	529.6	kWh/m2	+3.45 %
Effect of ground shades	191.1	kWh/m2	-63.92 %
Far shadings	191.1	kWh/m2	0.00 %
Near shadings	172.0	kWh/m2	-9.97 %
Soiling	172.0	kWh/m2	0.00 %
IAM loss	159.9	kWh/m2	-7.06 %
<b>Back-face effective irradiation</b>	<b>159.9</b>	<b>kWh/m2</b>	

Table 17. Yields and losses for the first year.



## Bifacial gain sensitivity to GCR and ground clearance in trackers



Simulations using 1P tracker, backtracking, module with 80% bifaciality factor.  
GCR simulations have a minimum ground clearance of 0.5 m.  
Minimum ground clearance have a GCR of 40%.



# Degradation case study

# 03



## Degradation in pvDesign

pvDesign simulates module degradation by reducing module output.

Each year is simulated using the entire calculation model, so we can observe:

- Decreasing production
- Changes in inverter losses
- Decreasing curtailment loss

### 7.3. 25 years energy yield (P50)

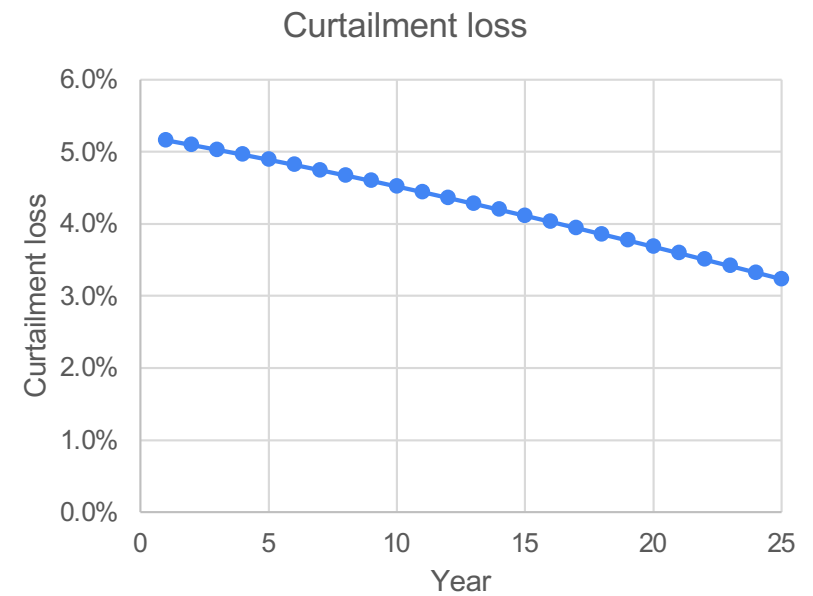
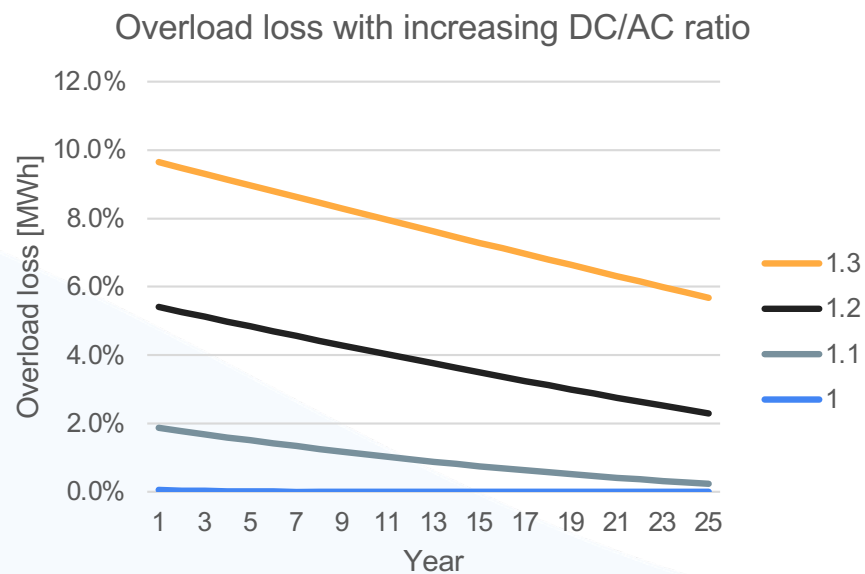
The energy yield of the photovoltaic plant has been calculated for a period of 25 years. In Table 19 the energy yield, specific production and performance ratio are shown for each year.

Table 19. Results for the 25 year period.

Year	Energy yield [GWh]	Specific production [kWh/kWp]	Performance Ratio [%]
1	63.6	2463.6	72.00
2	63.5	2460.0	71.90
3	63.4	2456.5	71.80
4	63.3	2453.0	71.69
5	63.2	2449.4	71.59
6	63.1	2445.7	71.48
7	63.0	2441.9	71.37
8	62.9	2438.3	71.26
9	62.8	2434.5	71.15
10	62.7	2430.7	71.04
11	62.6	2426.8	70.93
12	62.5	2422.8	70.81
13	62.4	2418.9	70.70
14	62.3	2414.9	70.58
15	62.2	2410.8	70.46
16	62.1	2406.7	70.34
17	62.0	2402.7	70.22
18	61.9	2398.5	70.10
19	61.8	2394.3	69.98
20	61.7	2390.0	69.85
21	61.6	2385.7	69.73
22	61.4	2381.2	69.60
23	61.3	2376.5	69.46
24	61.2	2371.3	69.30
25	61.1	2366.1	69.15
<b>Total</b>	<b>1559.6</b>	<b>2417.6</b>	<b>70.7</b>



## Losses over 25 years



Simulations using 1P tracker, backtracking, bifacial module, in a location with high irradiation (Atacama desert).

All simulations have 0.3% module degradation per year.

Curtailment loss simulation is a 23.1 MW AC plant, DC/AC ratio 1.1, with curtailment at 20 MW AC.



# Layout complexity case study

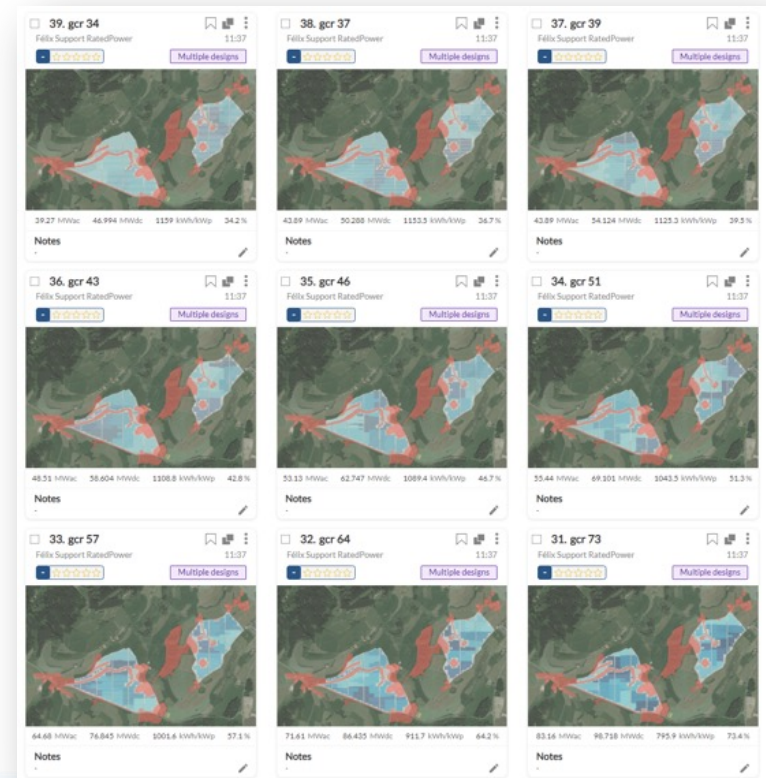
# 04

## Finding optimal values

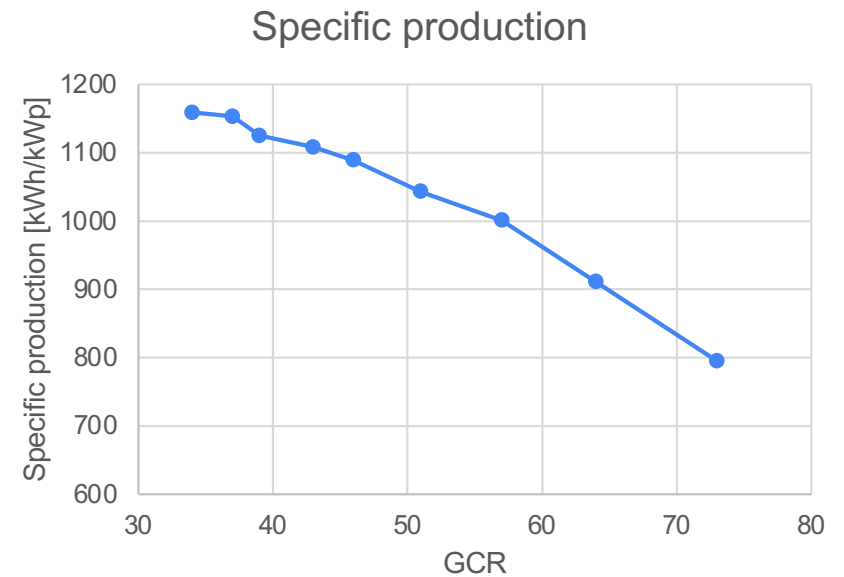
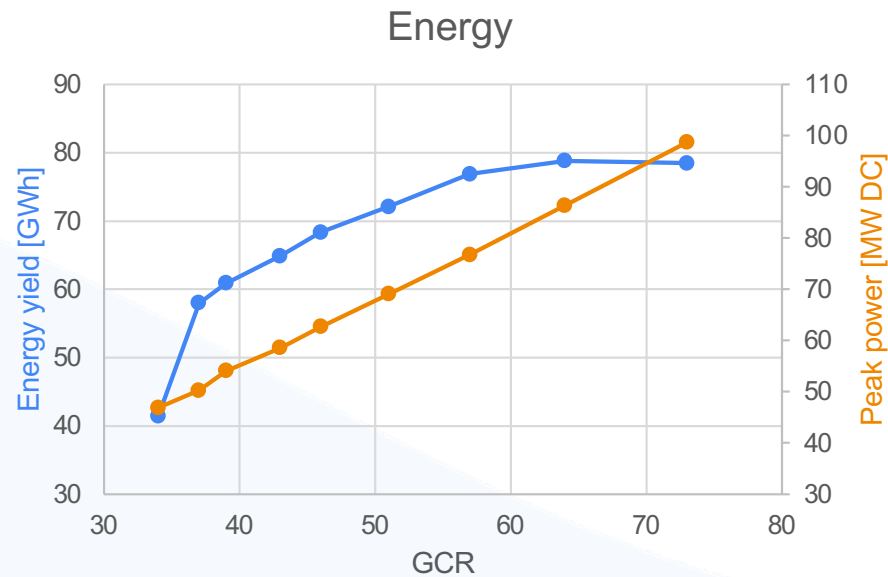
Generating the layout for complex perimeters can be challenging.

To find an optimum value for GCR, it is key to run layout and energy yield calculations.

pvDesign integrates layout generation and energy yield calculation. It is possible to evaluate tradeoffs between peak power and efficiency.



## Energy yield and specific production

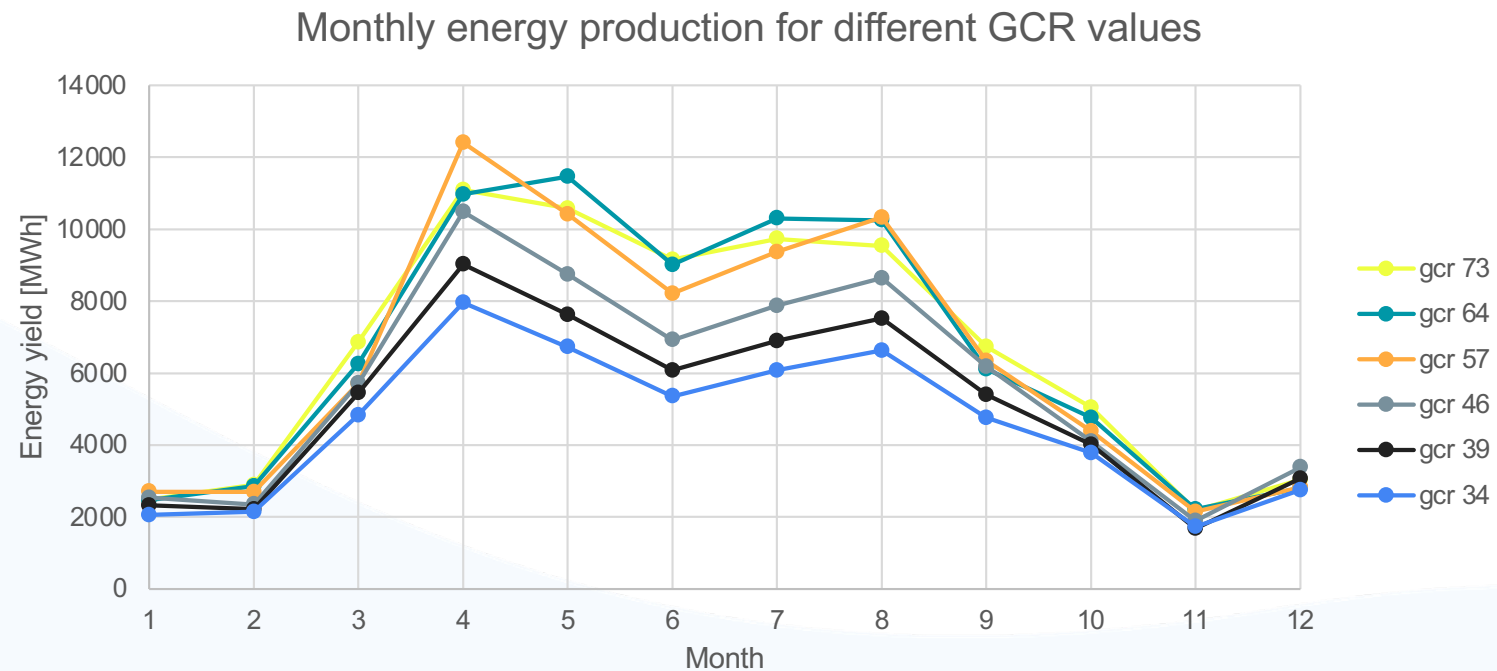


Simulations using 3L fixed structure, tilt 41 degrees, in a location with low irradiation (Germany).  
Using a central inverter with target DC/AC ratio of 1.2.  
Smaller structures are used to fill the gaps.





## Monthly production



Simulations using 3L fixed structure, tilt 41 degrees, in a location with low irradiation (Germany).  
Using a central inverter with target DC/AC ratio of 1.2.  
Smaller structures are used to fill the gaps.



# Thank you!

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fperez@ratedpower.com

For more information, please check out the  
[energy yield methodology](#)

