LA SILLA PV PLANT

INNOVATIVE BIFACIAL PV PLANT AT LA SILLA OBSERVATORY IN CHILE

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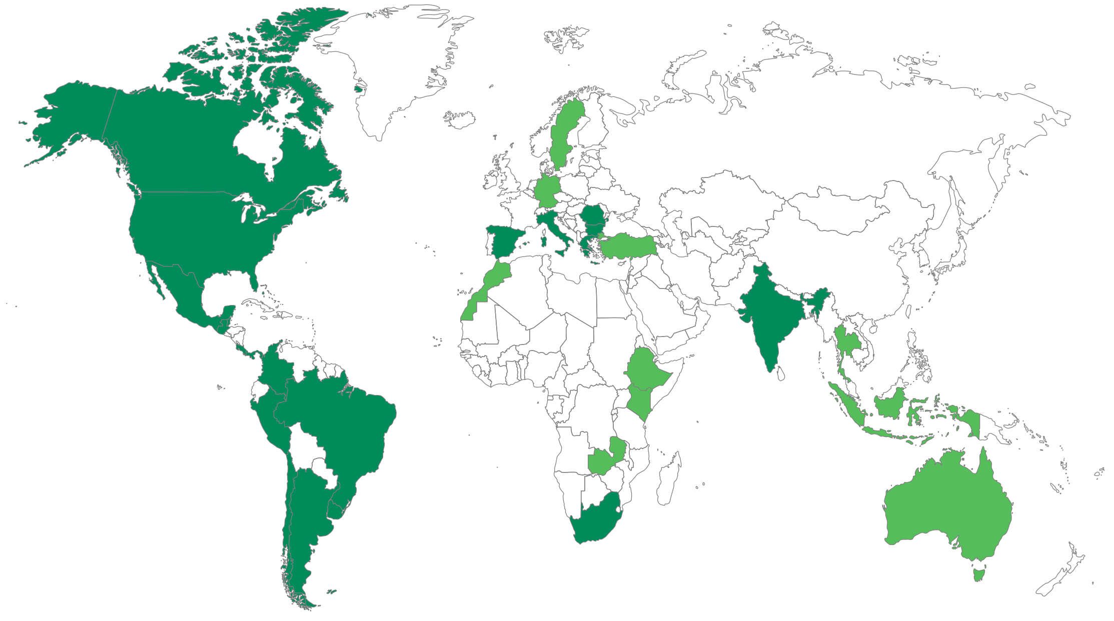
Green Power

EGP positioning and key figures



Countries of presence Countries of interest

Net installed capacity[1] (GW) 6.4 1.2 2.5 0.8 0.1 24.8

Key figures	2016	Old perimeter	Large hydro
Capacity[1] (GW)	35.7	10.9	24.8
Production (TWh)	92.4	37.4	55.0

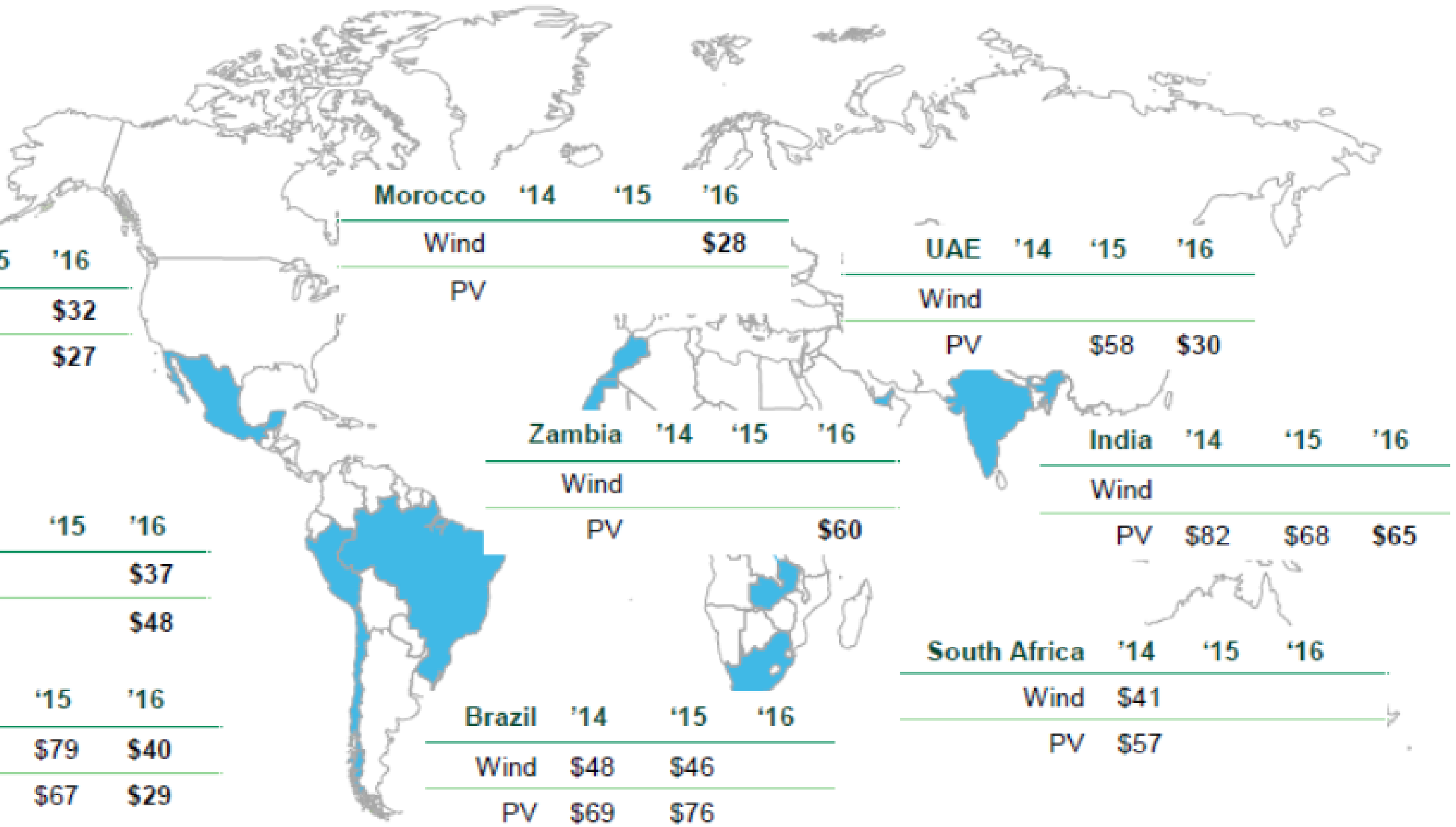
Key financials (€bn)	2016	Old perimeter	Large hydro
EBITDA	4.2	2.0	2.2
Opex	1.4	0.8	0.6
Maintenance capex	0.4	0.2	0.2
Growth capex[1]	2.8	2.7	0.1

Geo Hydro Wind Solar Biomass Large hydro

1. Old perimeter capacity and growth capex not including USA projects managed through BSO model (Build Sell and Operate)

EGP positioning and key figures
Renewable Energies PRICES

Global prices reference recent auctions outcome, $/MWh)



Mexico	'14	'15	'16
Wind			$32
PV			$27

Morocco	'14	'15	'16
Wind			$28
PV			

UAE	'14	'15	'16
Wind			
PV		$58	$30

Zambia	'14	'15	'16
Wind			
PV			$60

India	'14	'15	'16
Wind			
PV	$82	$68	$65

Peru	'14	'15	'16
Wind			$37
PV			$48

Chile	'14	'15	'16
Wind		$79	$40
PV		$67	$29

Brazil	'14	'15	'16
Wind	$48	$46	
PV	$69	$76	

South Africa	'14	'15	'16
Wind	$41		
PV	$57		

Source: BNEF Prices refer to $/MWh

HOW WE CAN INCREASE competitiveness of Renewable Sources???

Bifacial: testing of innovative technologies

Introduction

Objective: Improve the performances of PV plants and reduce the LCOE

One technological sector: Innovative PV modules

First approach: Lab test

Utility-scale test for evaluating global behavior and interaction between strings

Objective: Test innovative modules solutions starting from OUTDOOR LAB scale to utility scale level with the aim to assess their high potential for future application and LCOE reduction of EGP PV plants, in a scenario in which the effect of real operating conditions can be evaluated

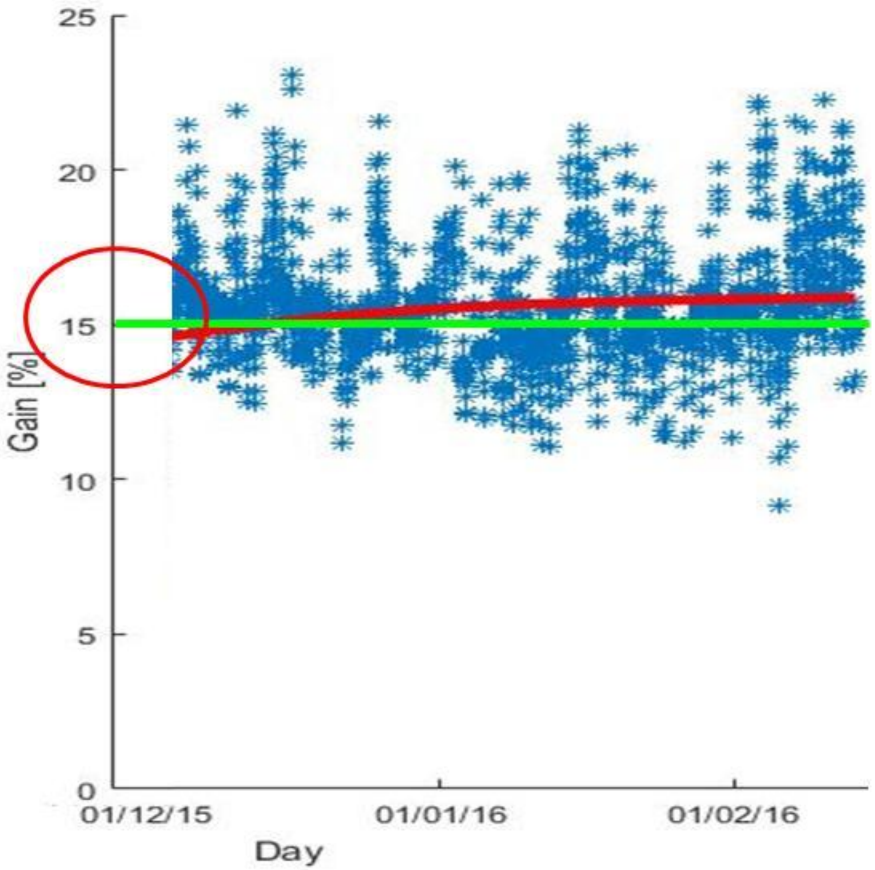
INNOVATION LAB in Catania: different kind of test with different albedo on fixed system; leveraging the know how of our techinicians and new PV factory 3SUN

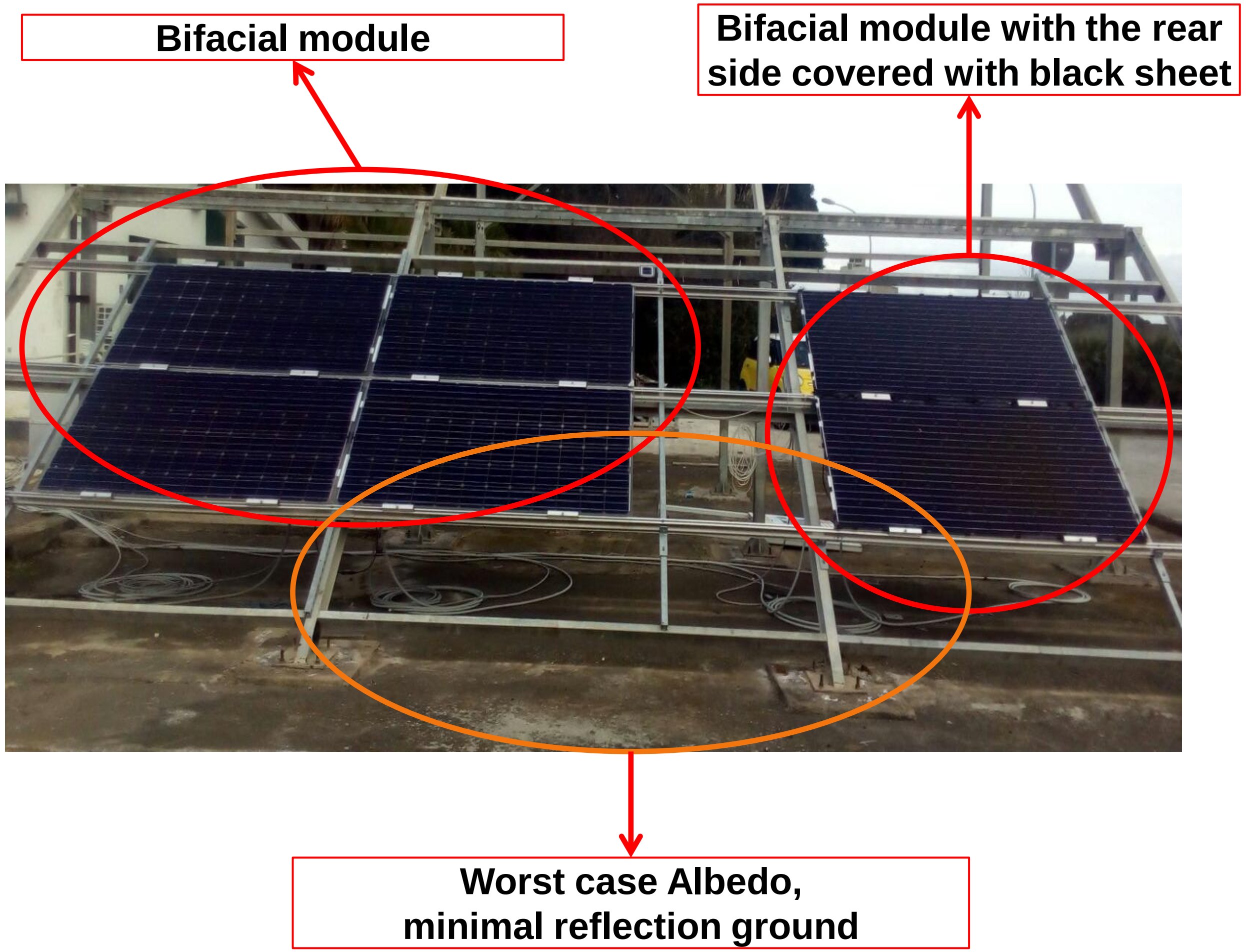
LA SILLA Plant: 1.7MW PV plant named La Silla (Chile), COD 2016, located at the La Silla Observatory, run by the European Southern Observatory (ESO), and is the first observatory in Chile to be supplied by an innovative PV plant.

The PV plant has the double purpose to test innovative technologies in real operating conditions of utility-scale PV plants, and meanwhile to produce energy and have revenues from this production.

3SUN 2.0 Project

Bifacial Module Tests Enel LAB Passo Martino (No Tracker)





La Silla: testing of innovative technologies

Technology focus: bifacial modules

High Efficiency Bi-facial Monocrystalline N-type Photovoltaic Module, developed by Megacell in collaboration with the ISC Konstanz, characterized by long-term stability due to technology design, high performance thanks also to the bifacial effect

Advantages:

1. High efficient n-type silicon cells instead of traditional p-type cells: lower power degradation; Light Induced Degradation effect near 0% despite all the common P-type cells
2. Higher energy yield by use of diffuse and reflected light on the rear side (>85% bifaciality factor)
3. Less modules and area with the same equivalent energy yield, resulting in significant BOS cost savings (land, labor, mounting structures etc.): reduction of KWh cost.

			Traditional poly-Si	*Bifacial (n-type)*
+	High productivity	Bifaciality	-	10%-15%
		Lower temperature coefficient	-	1%-2%
		LID and PID free	-	3%-5%
+	High module efficiency		17-18%	18-19%
+	Longer Lifetime (less degradation)	Lifetime	30 years	35-40 years
		Degradation	0,5%/y	<0,5%/y
-	Cost [€/Wp]			+5%+10%
	LCOE reduction compare to the traditional technology			5%-10%

La Silla: testing of innovative technologies

The Project

Technologies to be tested:

- to minimize mismatch effects thus maximizing the performance of PV strings
- to take advantage of the ground albedo for producing extra-energy from the back of the modules.

The test is carried out as a side-by-side test comparison of the three subfields:

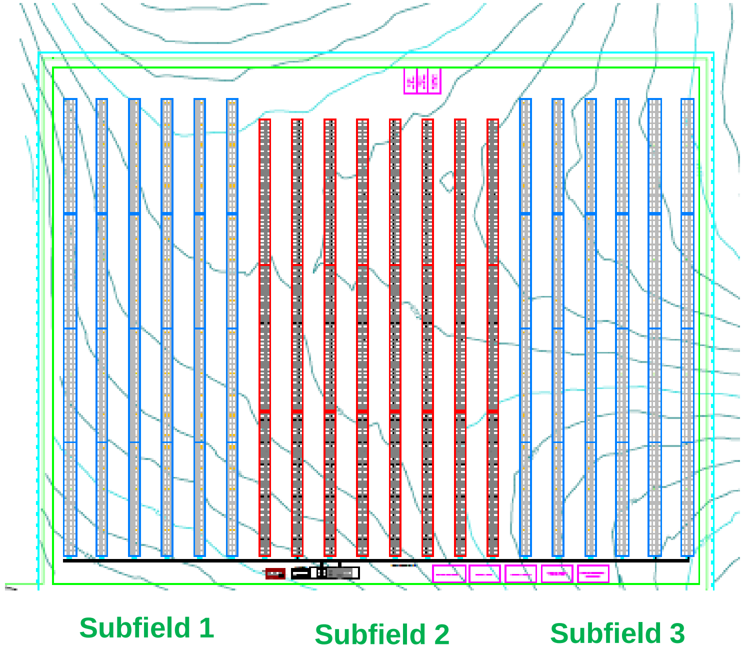
Subfield 1 550 kWp crystalline standard modules as reference field

Subfield 2 550 kWp smart modules optimized with Maxim solar cells optimizers, with the aim to increase the roduction due to minimization of mismatch effect and mutual shading losses.

Subfield 3 550 kWp of bifacial modules, with the aim to increase the energy production thanks to bifacial effect

The test allows monitoring the long period behavior of the technologies and detecting the variations in the gain due to the seasonality.

La Silla PV Plant



Subfield for tests: inverter three 500 kW

La Silla: testing of innovative technologies

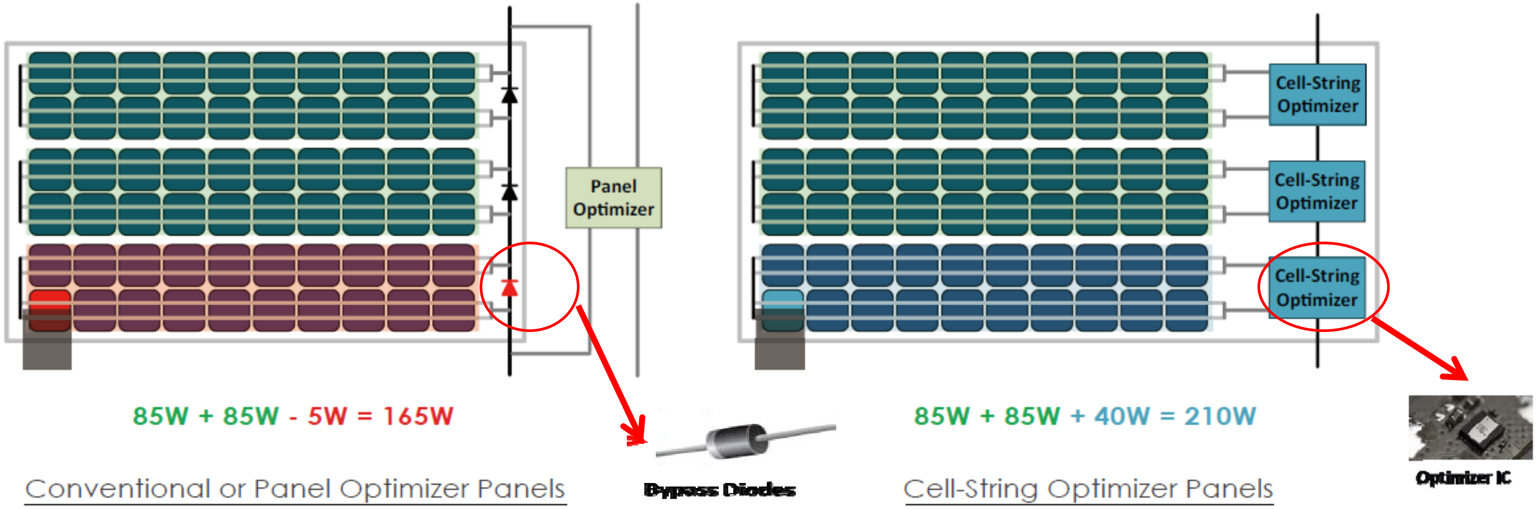
Technology focus: Maxim solar cells optimizers

Maximized modules replace the bypass diodes in the module with the optimizer chip in order to push the MPPT function deep into the PV system. Cell string optimizers allow to produce the most energy possible regardless of shading issues and mismatch, without the complexity of DC Optimizers and with simplified system design, improving also the reliability of the modules .

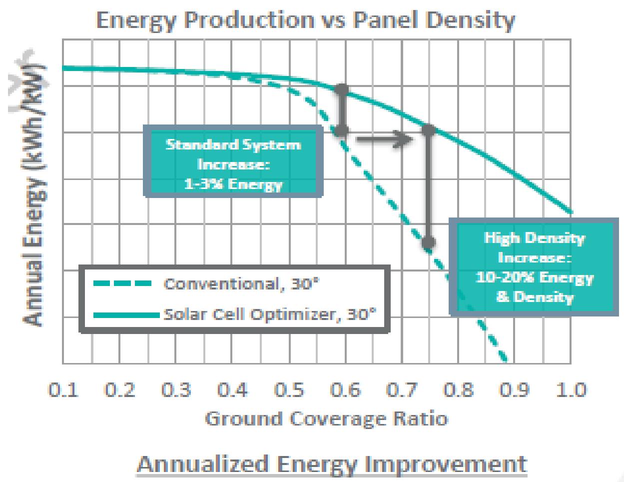
Advantages:

1. Increase energy yield (each cell string delivers maximum power at the best current)
2. Increase ground coverage and improve land utilization (allows 10%-20% tighter row pitch at the same energy production per panel)
3. Higher reliability: minimize power degradation over the panel and eliminate hot spots
4. No additional BOS (control unit, network cabling, network configuration)

Soiling impact minimized by cell optimizers



Increase panel density



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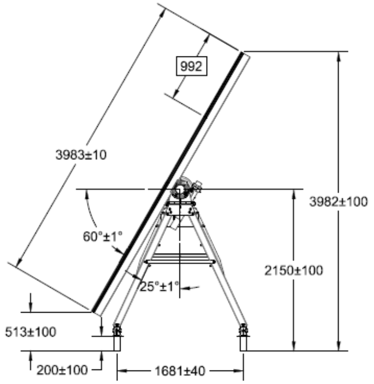
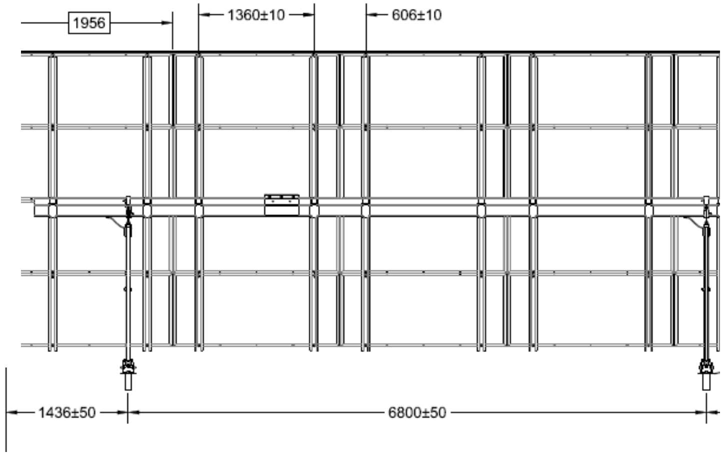
Experimental set up and layout

Maxim Subfiled

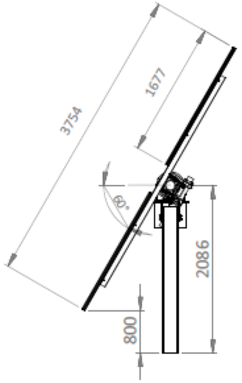


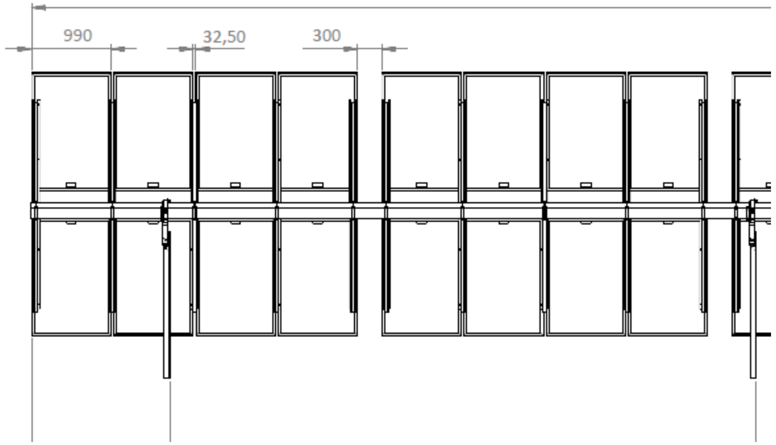


- Landscape configuration of trackers with smart optimized modules
- Compare the advantages with respect to standard PV plants:

1. Actual test: Energy gain with respect to standard configuration thanks to optimizing mutual shading effect and mismatch (with the same row pitch)
2. Future tests: Tighter row pitch (that can be reduced of about 10%) guaranteeing lower BOP costs and the same energy production as standard fields

Bifacial Subfield

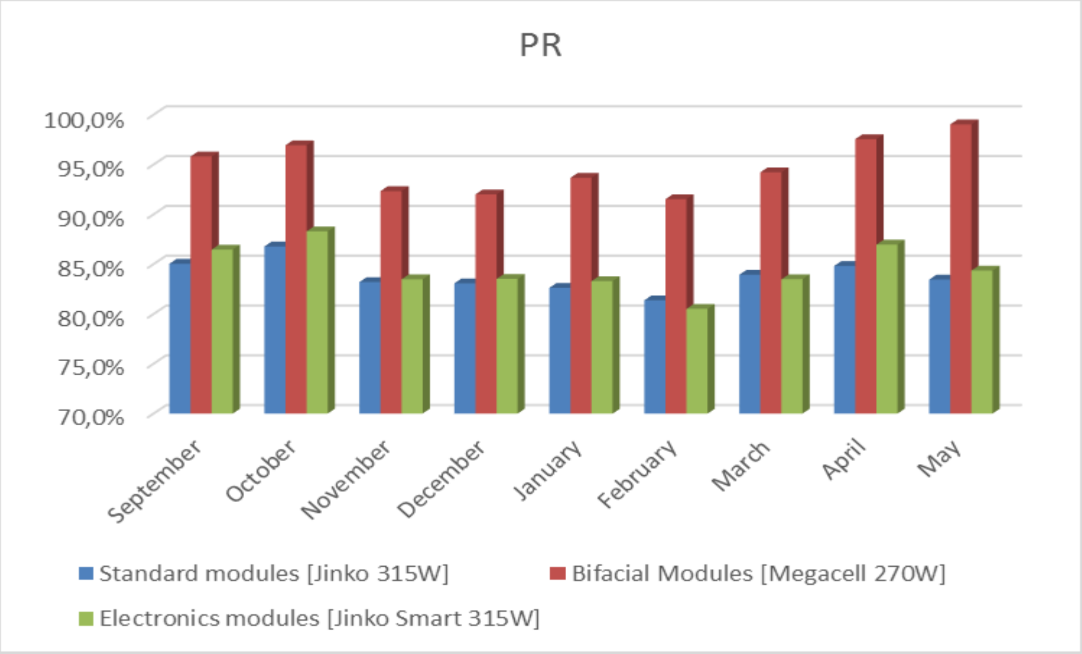


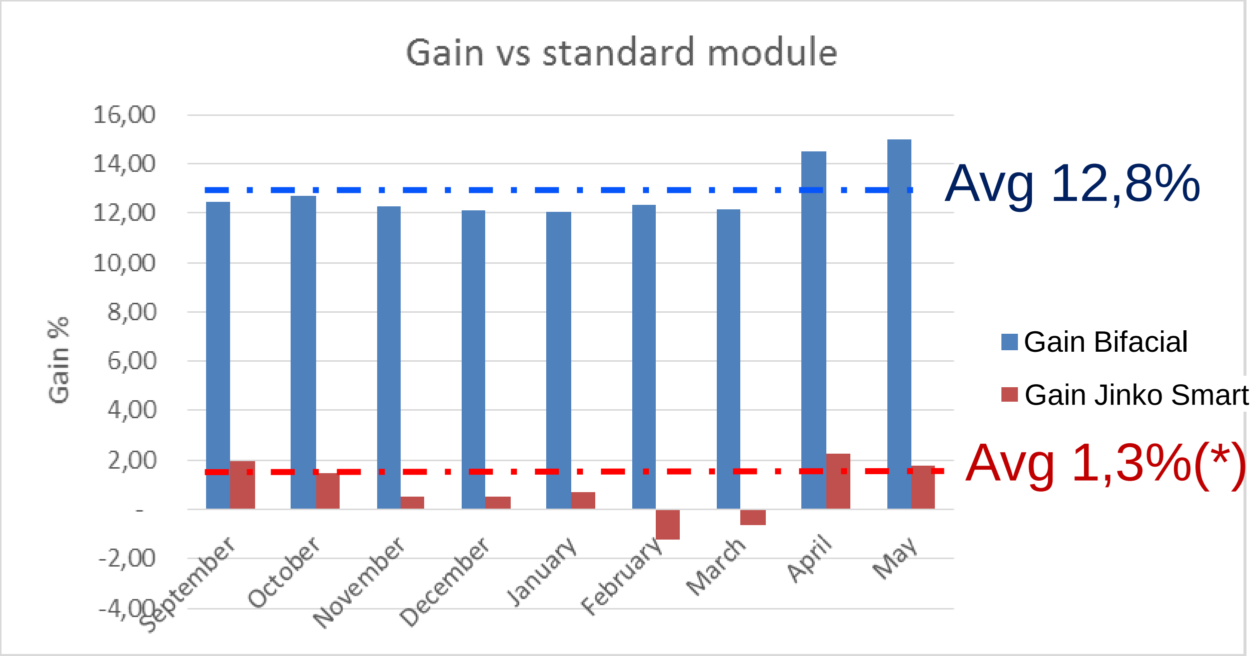


- Portrait configuration of trackers with bifacial modules
- Free space between modules to maximize bifacial effect
- Tracker designed for the specific configuration
- Two different MPPTs to minimize mismatch between upper and lower rows
- Simulated bifacial gain: about 12%

La Silla: testing of innovative technologies

Test results: comparison of the three subfields





$PR_{m\_standard}$= 84,1%

$PR_{m\_bifacial}$= 94,8%

PR_{m_smart}= 85,2%

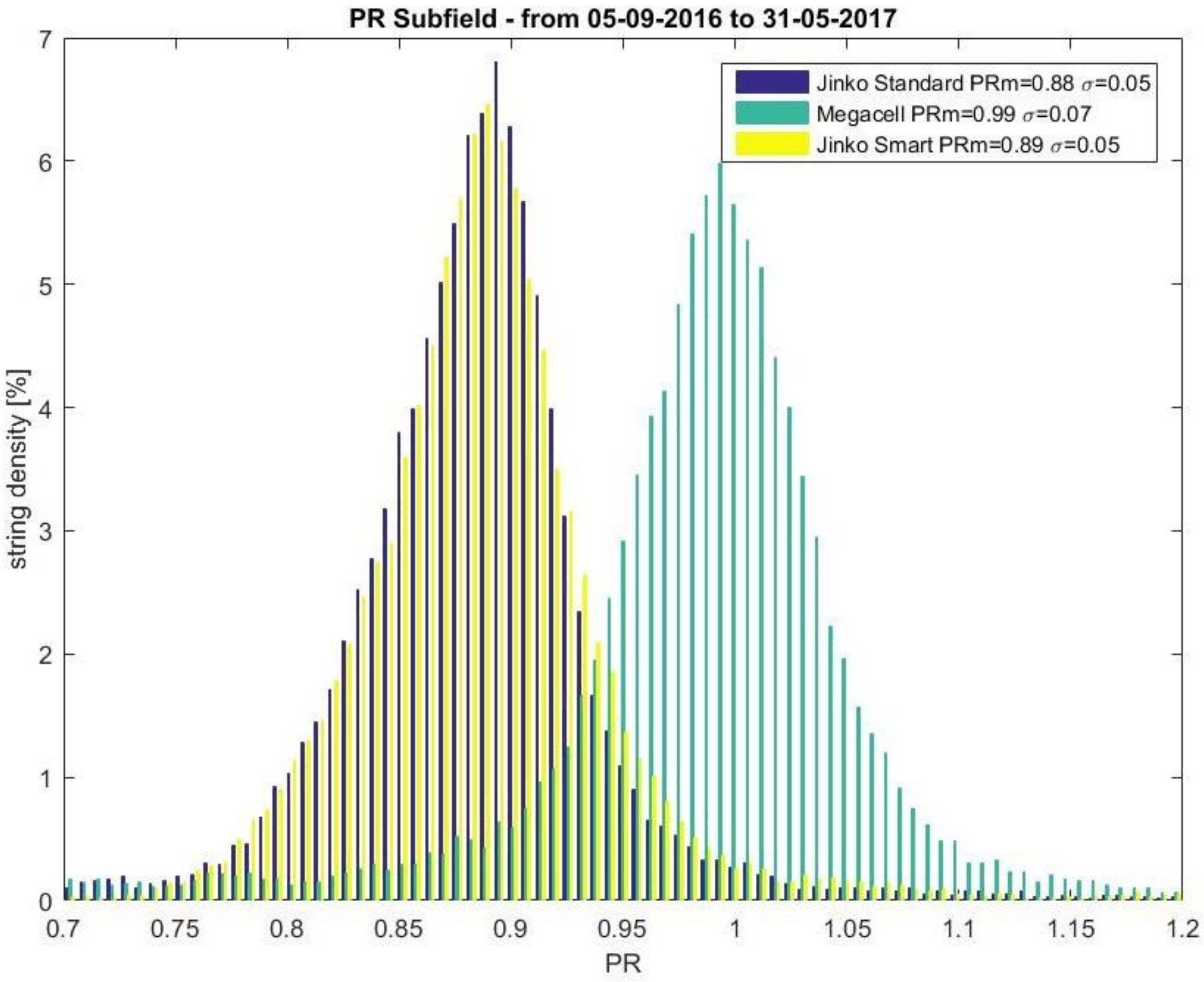
Comparison of the three subfields:

- Analysis of inverter data ➔ Daily comparison and monthly average of PR data of the three subfields (IEC 61724)
- Calculation of daily and monthly average gain of the innovative technologies respect to the standard

(*) Feb and Mar gain is negative because tracking problems occurred in this subfield.

La Silla: testing of innovative technologies

Test results: Analysis of each subfield



<u>*Analysis of string data in DC:*</u>

Distribution of string PR within the same subfield to measure the variability of the strings performances (daily PR of each string during all the observation period)

The graph is characterized by a distribution peaked around average PR and a standard deviation of 5% for standard and smart field and 7% for bifacial field, that is indication of the variability of the performances of the strings.

La Silla: testing of innovative technologies

Conclusions

Smart modules	From first evaluations the technology, with a slight performance increase of about 1%, would not result convenient for utility scale installations in which there are not significant sources of mismatch (different orientations, shading, soiling and so on). Anyway the advantage of distributed electronics should be evidenced after some year of operation of the plant, when the modules start to degrade in different ways and the system performances degradation results higher than the modules performance degradation.
Bifacial modules	The results on bifacial modules confirm their potentiality, allow a 12% performance increase with respect to standard technology.
Utility scale test	The test of innovative solutions directly on field on utility scale PV plants has been an opportunity to evaluate the technologies in a not controlled environment, which is different from laboratory, and in which different factors influence the performances of the strings as it happens in the normal operation of the plant.