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Bringing down LCOE through advanced cooling in central inverters

1 July 2020

4 PM - 5 PM | CEST, Berlin
10 AM - 11 AM | EDT, New York
7.30 PM - 8 .30 PM | IST, Delhi

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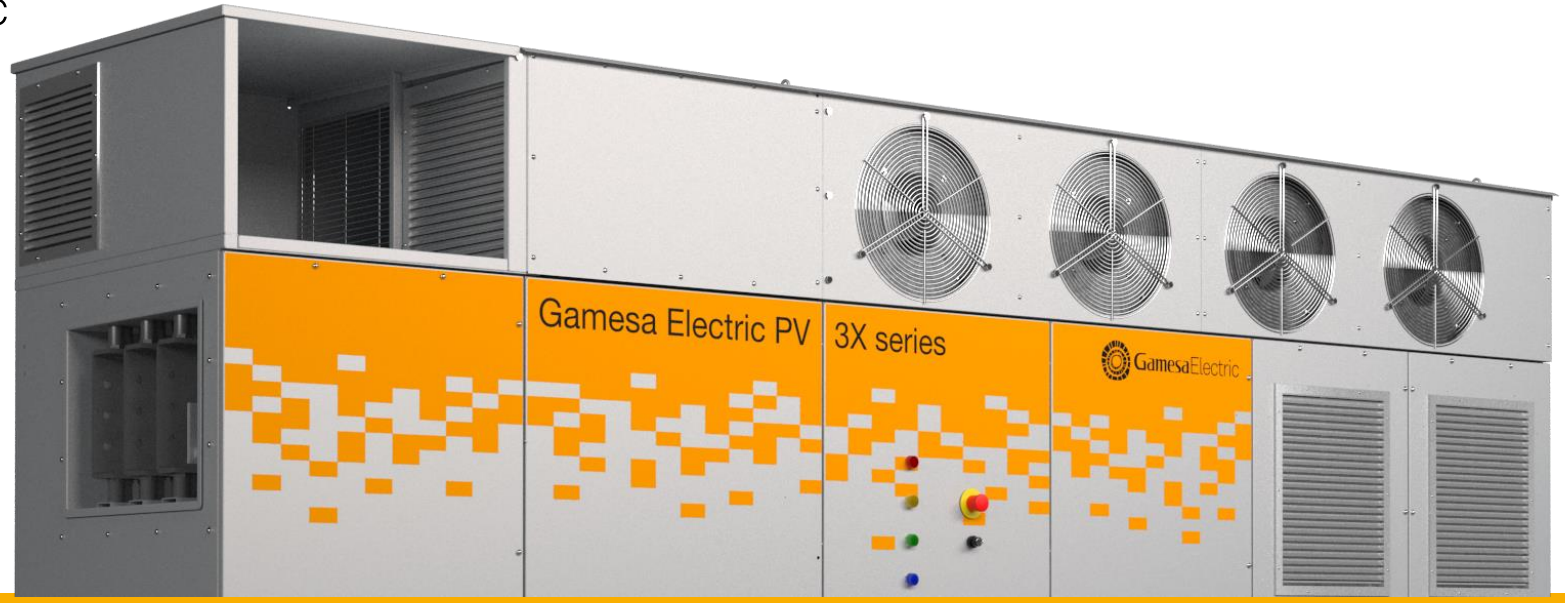

Bringing down LCOE through advance cooling in central inverters

Maximum energy for utility-scale projects

PV MAGAZINE WEBINAR
July 1st 2020

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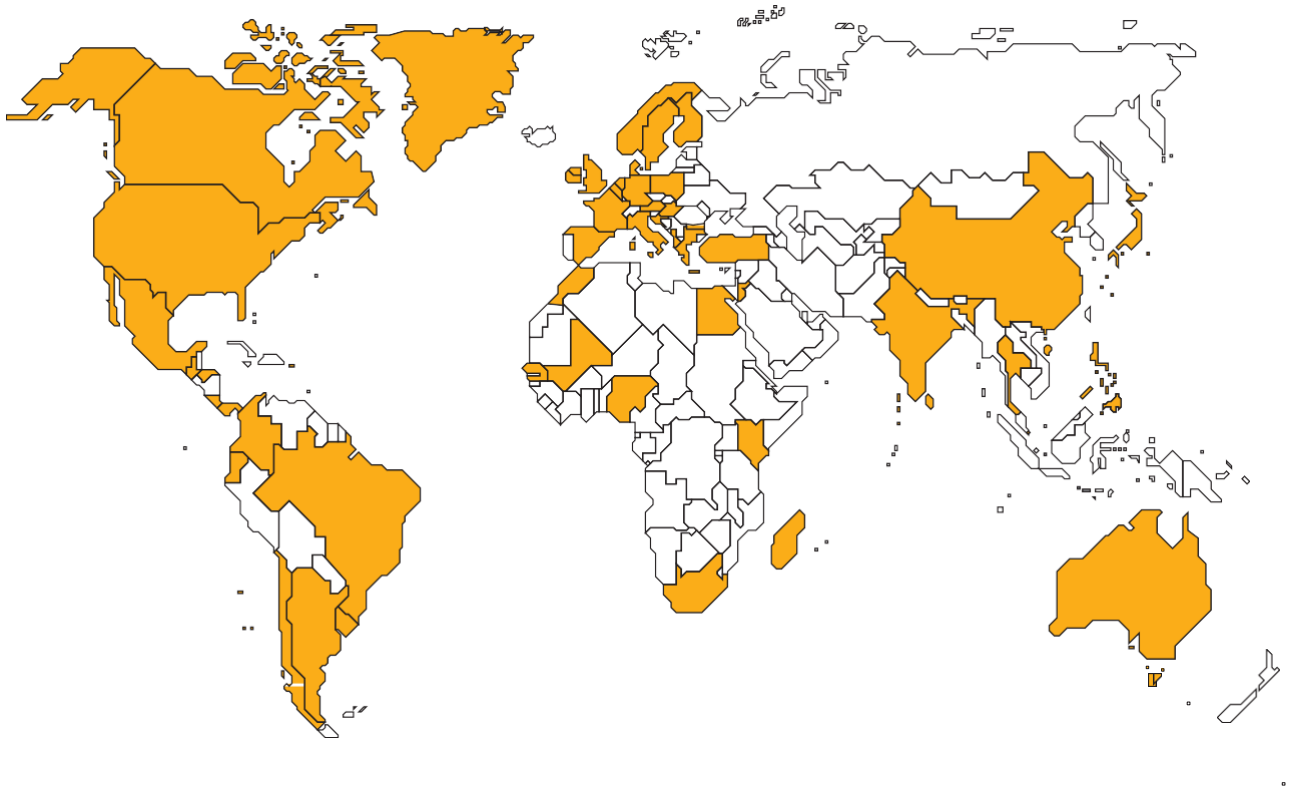
Company profile

A 100% Siemens Gamesa Renewable Energy company

With a worldwide installed capacity of over 101 GW, Siemens Gamesa Renewable Energy is a global technological leader in the wind industry with a presence in more than 90 countries.

Its end-to-end value chain expertise encompasses onshore and offshore wind turbine design, manufacturing, installation as well as cutting-edge service solutions.



Accumulated Installed Base (Dec 19)	101 GW
GW under O&M (Dec 19)	63 GW
Reported Backlog (Dec 19)	28 €B
Revenue (FY 2019 pro-forma)	10.2 €B
Market Capitalization (Dec 19)	10.7 €B
Worldwide presence	+90 countries

Albania
Argentina
Australia
Brazil
Bulgaria
Canada
Chile
China
Colombia
Costa Rica
Czech Rep.
Ecuador
Egypt
Finland
France
Germany
Greece
Guatemala
Honduras
India
Ireland
Italy
Japan
Jordan
Kenya
Madagascar
Mali
Mexico
Morocco
Nigeria
Norway
Panama
Philippines
Poland
Puerto Rico
Senegal
South Africa
Spain
Sri Lanka
Sweden
Turkey
UK
Uruguay
USA

GamesaElectric

Our facilities, our credentials

Generators and power electronics factories

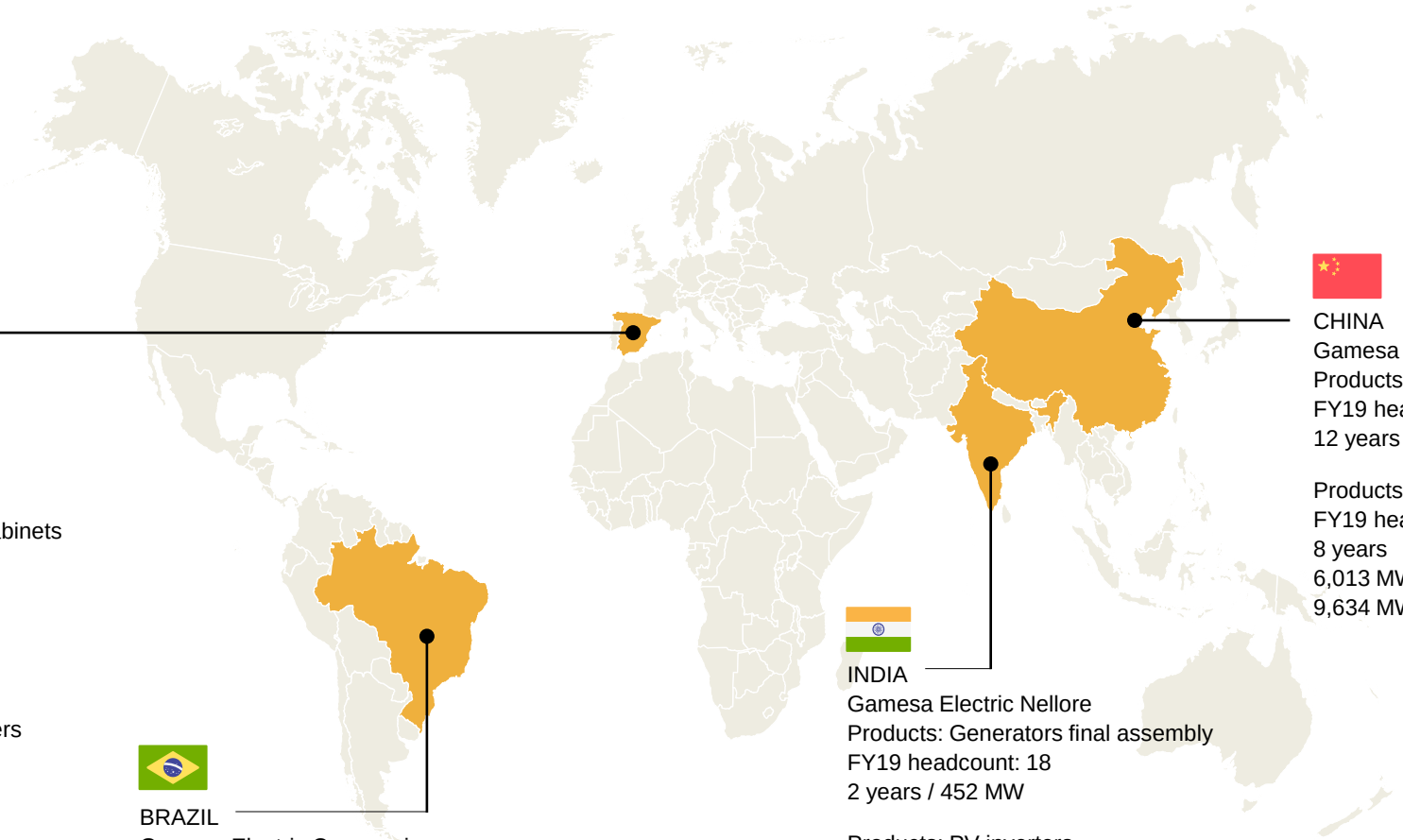
>2.6 GW* Solar inverters

>24 GW* Wind converters

8 Production centers

>900 Employees worldwide

315 MM€ Revenues FY2019



SPAIN
Gamesa Electric Reinosa
Products: Generators
FY19 headcount: 268
90 years / 23,355 MW

Gamesa Electric Valencia
Products: Converters, Control cabinets
FY19 headcount: 109
12 years
12,515 MW (converters)
33,735 MW (cabinets)

Gamesa Electric Madrid
Products: Converters, PV inverters
FY19 headcount: 177
40 years
5,536 MW (converters)
2180 MW (inverters)

BRAZIL
Gamesa Electric Camaçari
Products: Converters
FY19 headcount: 9
1 years / 131 MW

INDIA
Gamesa Electric Nellore
Products: Generators final assembly
FY19 headcount: 18
2 years / 452 MW

Products: PV inverters
FY19 headcount: 38
2 years / 440 MW

CHINA
Gamesa Electric Tianjin
Products: Generators
FY19 headcount: 104
12 years / 11,344 MW

Products: Converters, Control cabinets
FY19 headcount: 37
8 years
6,013 MW (converters)
9,634 MW (cabinets)

(*) Cumulative Wind (generators, converters & control cabinets) data at FY2019 closure (September 2019). Cumulative Solar PV(inverters) data at Q1 2020

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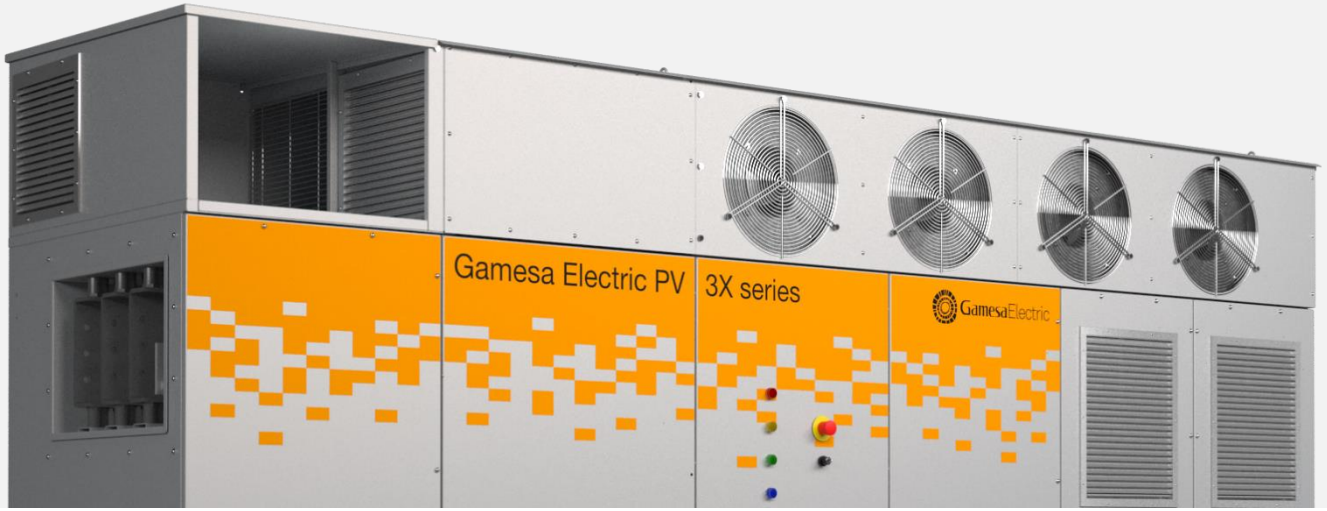
Solar inverters

Product evolution



Year	Model	
1993		PV 450 kW ACEF 100 kW
1998		ACEF 150 kW
2004		PV 100/500/630 kW
2012		Gamesa E – 100/500/630 kW Plus
2014		Gamesa E – 1.4 MVA (PV 1000 V)
		Gamesa Electric PV Controller
2017		Gamesa Electric PV 2X series – IEC (PV 1500 V – indoor)
2018		Gamesa Electric PV 2X series – UL (PV 1500 V – indoor)
2019		Gamesa Electric PV 3X series (PV 1500 V _ outdoor)

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Solar PV products

A complete catalogue for your project

CENTRAL INVERTERS

Gamesa Electric PV 3X series - Inverters

Gamesa Electric PV 2X series - Inverters

MV STATIONS

Gamesa Electric PV 3X series - PV Stations

Gamesa Electric PV 2X series - PV Stations

CONTROLLER

Gamesa Electric PV Controller

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Storage products

A complete catalogue for your project

BATTERY INVERTERS

Gamesa Electric Stor 3X series - PCS

Gamesa Electric Stor 2X series - PCS

Gamesa Electric Stor DC/DC 650

PCS STATIONS

Gamesa Electric Stor 3X series – PCS Stations

Gamesa Electric Stor 2X series – PCS Stations

CONTROLLER

Gamesa Electric Stor Controller

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Bringing down LCoE

Through higher capacity and better cooling

$$\downarrow \text{LCoE} = \frac{\downarrow \text{CapEx} + \downarrow \text{OpEx} \mid \text{lifetime}}{\uparrow \text{Energy production} \mid \text{lifetime}}$$

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Bringing down LCoE

Through higher capacity and better cooling

+44%

AC power output increase*

$$\downarrow \text{LCoE} = \frac{\downarrow \textbf{CapEx} + \downarrow \text{OpEx} \mid \text{lifetime}}{\uparrow \text{Energy production} \mid \text{lifetime}}$$

(*) PV 3X series vs PV 2X series

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Bringing down LCoE

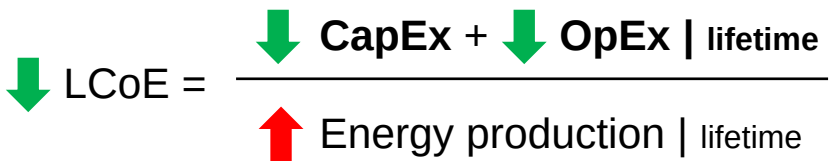
Through higher capacity and better cooling

+44%

AC power output increase*

-30%

Units installed*



(*) PV 3X series vs PV 2X series

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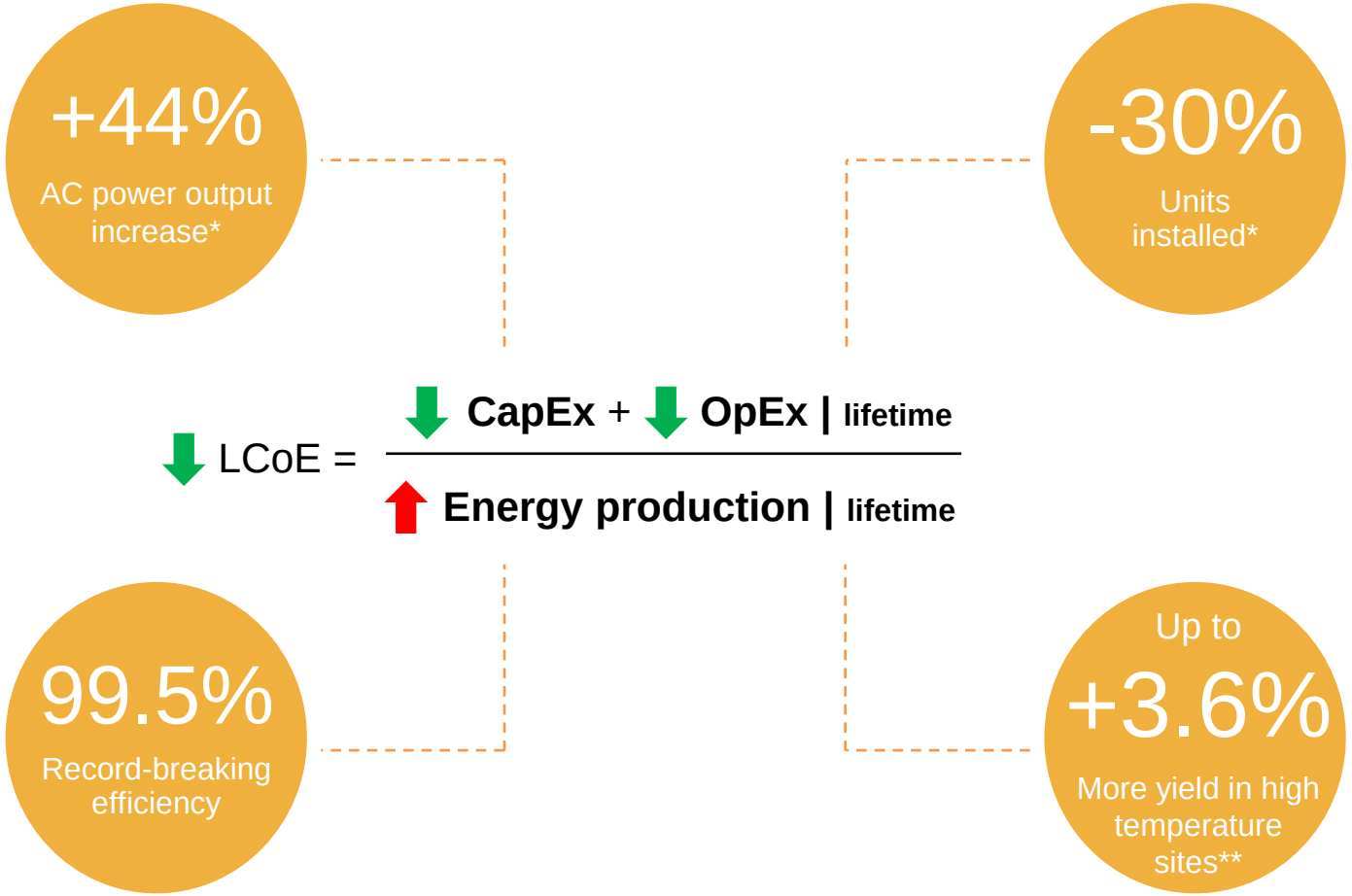
Bringing down LCoE

Through higher capacity and better cooling



(*) PV 3X series vs PV 2X series
(**) Based on independent 3rd party analysis

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PV 3X series – PV Inverters
PV 3400, PV 3600, PV 3750 & PV 3900
GENERAL CHARACTERISTICS

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Gamesa Electric PV 3X series

Product Overview

Compact and modular design

Heat exchangers

Compact design.
Up to 487 kVA/m³

Advanced liquid and air cooling system

Field-proven and reliable CCU

Up to 3900 kVA at 1500 V

99,52% efficiency

Outdoor solution

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Gamesa Electric PV 3X series inverter breaks the efficiency record with…

99,52%

GamesaElectric

Record-breaking Efficiency

Higher efficiency means more yield

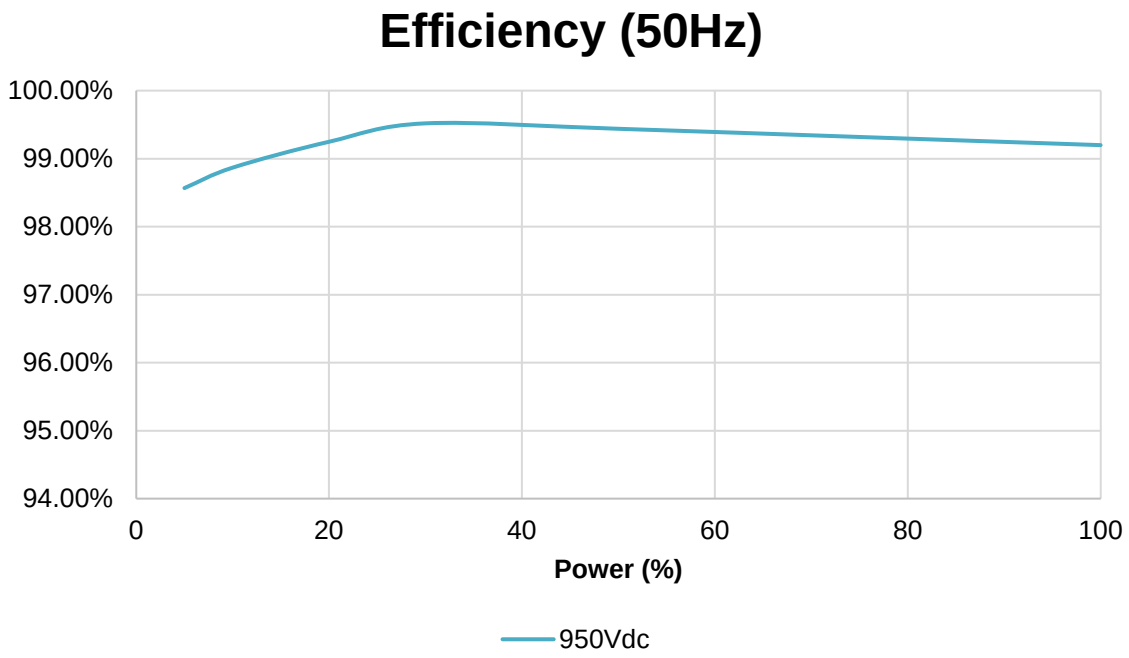
99,52% Maximum Efficiency

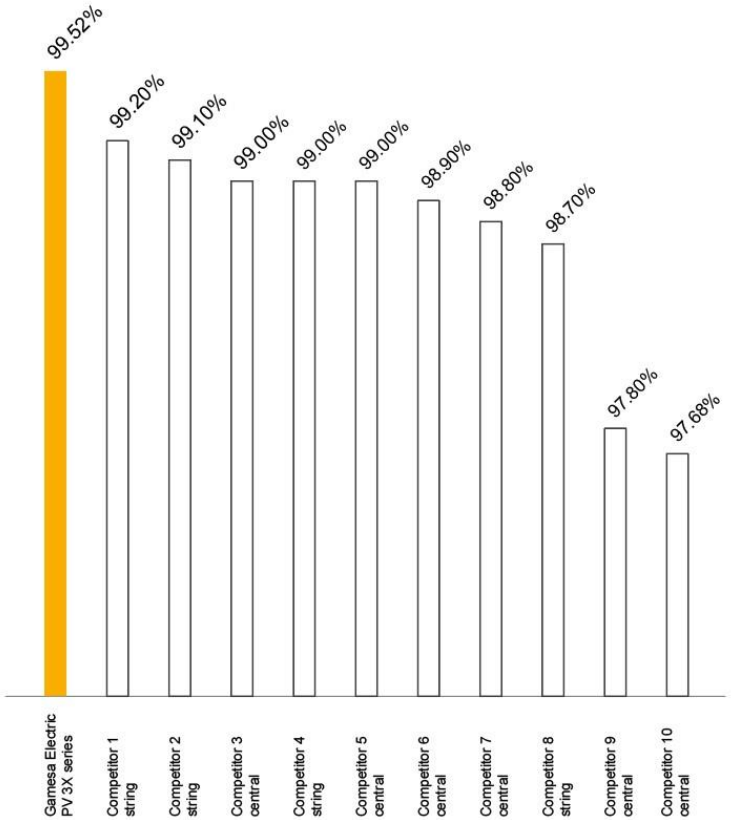
99,31% European Efficiency

THD I <1%

GUARANTEE BEST IN MARKET GUARANTEE

Electrical Efficiency





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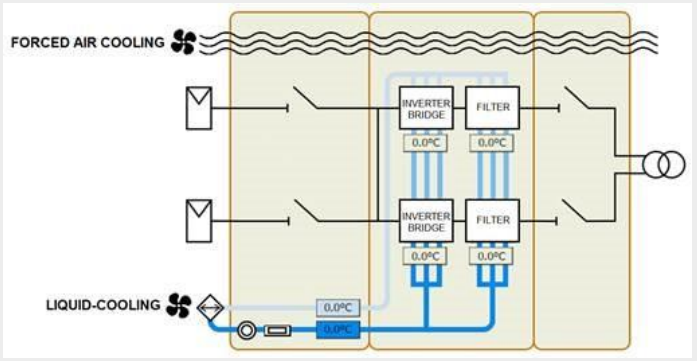
CoolBrid overview

Advanced Hybrid cooling system

Advanced Cooling System

CoolBrid



› **TARGETs:**

1. **Keep temperature on critical components far from the limits**
2. **Reducing losses, improving power conversion & heat dissipation**

- Hybrid cooling system: **Forced Air + Liquid ("the best of both worlds")**
- Liquid**: Semiconductors & Filters.** Air**:** Rest of equipment
- Both cooling subsystems use distinct conduits
- **Selective Cooling: Smart Cooling** system depending on power and temperature
- Better for dusty environment (less air exchange)
- Multiple temperature sensors

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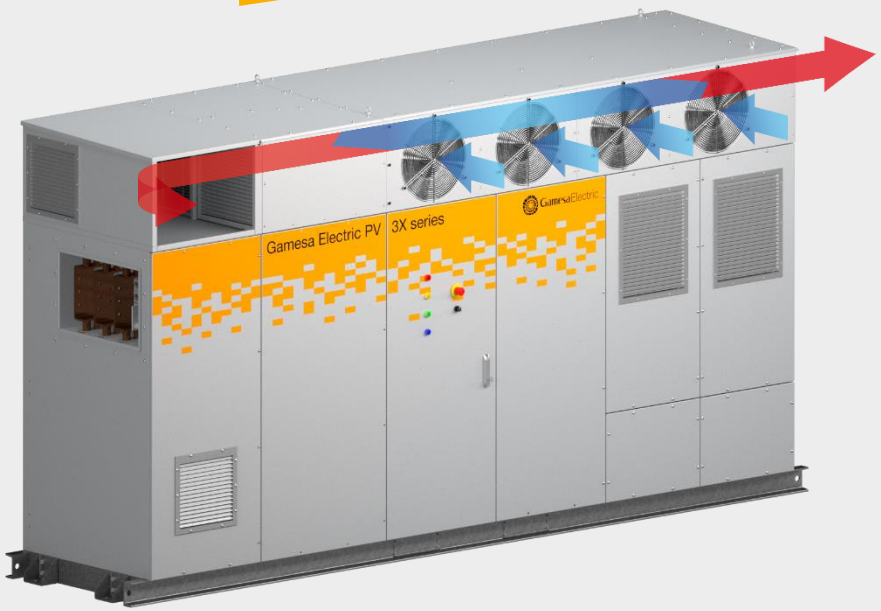
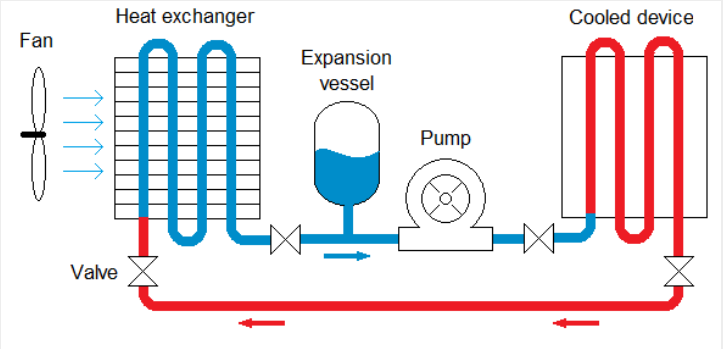
CoolBrid overview

Liquid cooling

Liquid Cooling

CoolBrid





Material	Thermal conductivity λ (W/mK)
Air	0.0262
Water	0.609
Ethylene Glycol	0.258

- Liquid cooling offers better power dissipation (higher thermal conductivity)
- Coolant liquid: Water + Glycol
- Liquid cooling system Functioning & Components
- Mechanical stress reduction by operating at low pressure
- **More than 70% inverter losses are dissipated through liquid cooling system**

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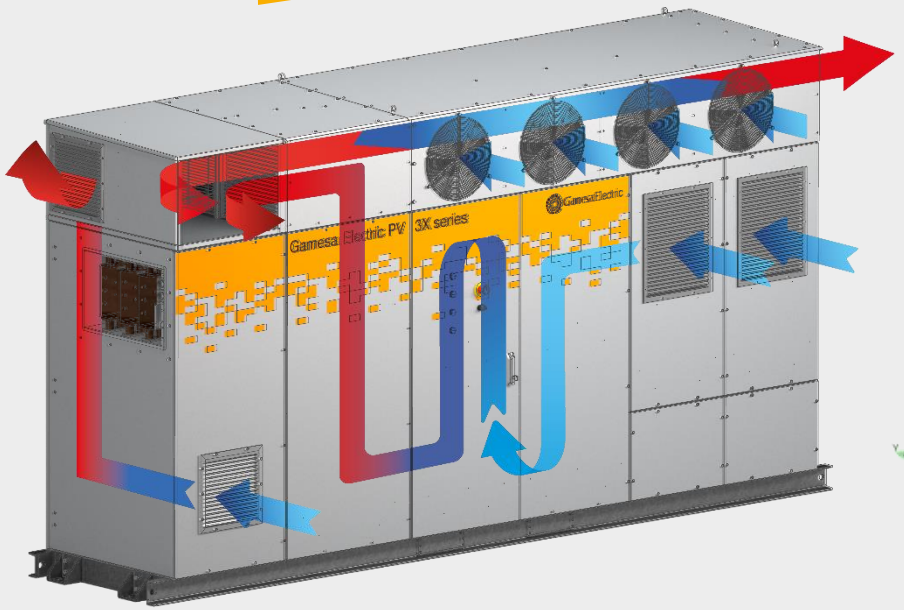
CoolBrid overview

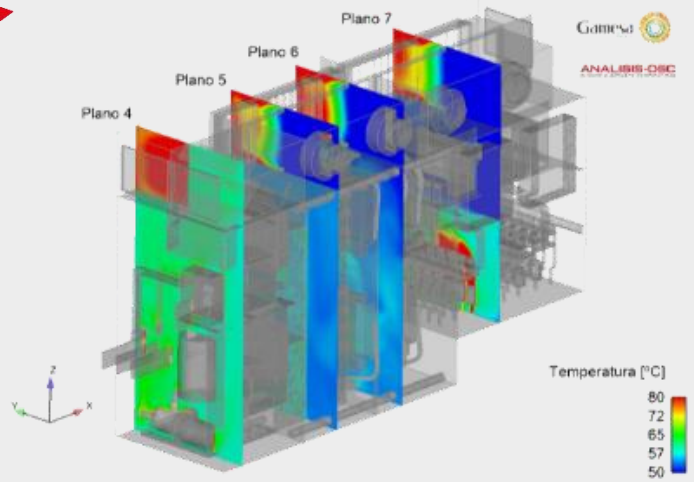
Smart forced air cooling

Forced

Air

CoolBrid





- **<u>Forced Air Cooling</u>**
- Speed-controlled Fan
- Continuous temperature monitoring
- Quick response to temperature changes
- Simplicity for “less sensitive” components
- Thermal modelling: finite elements

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PV 3X series – PV Inverters
PV 3400, PV 3600, PV 3750 & PV 3900
CASE STUDIES

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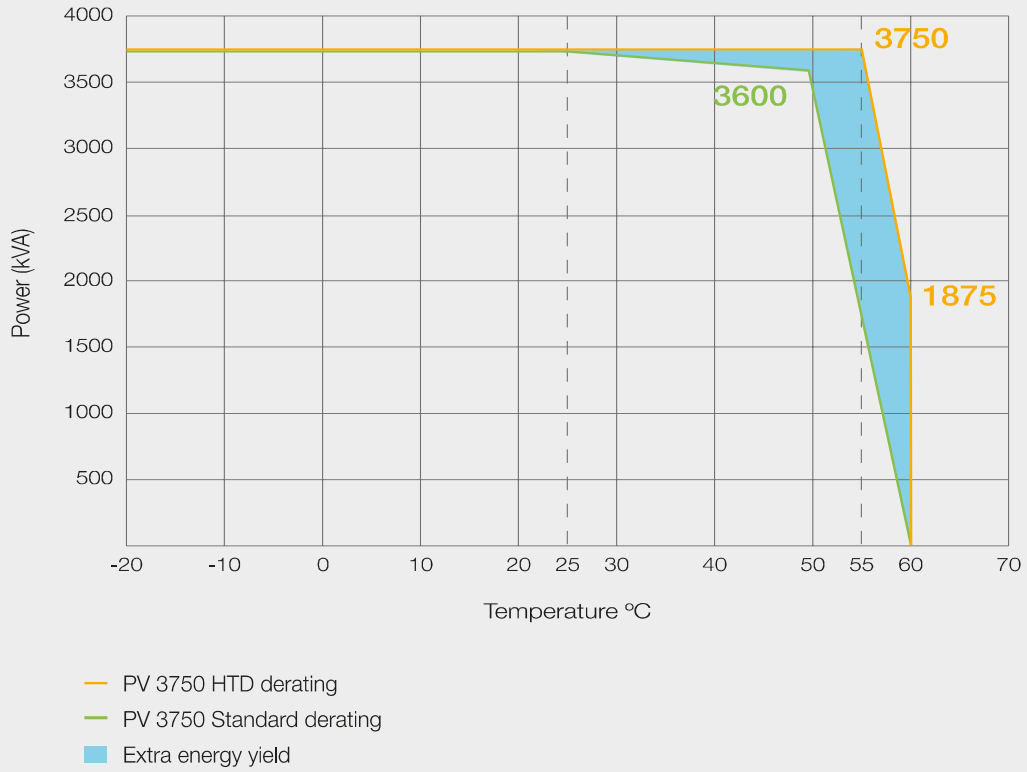
Gamesa Electric PV 3X series

Case Study: LCoE / IRR improvement by Inverter power derating

Enhanced temperature derating



- Power Derating conditioned by working **temperature of inverter bridge (semiconductors) and grid filter**
- ***CoolBrid* system** allows critical components to achieve maximum performance even in the most extreme temperature conditions.
- ***CoolBrid* system** allows key components to work at a thermal regime far from their limits
- STD variant initiates power derating from 25ºC (3,6 MVA @50ºC)
- **HTD variant** without derating up to 55ºC (**3,75 MVA up to 55ºC**)
- **HTD variant** allows **more DC power** keeping same DC/AC ratio

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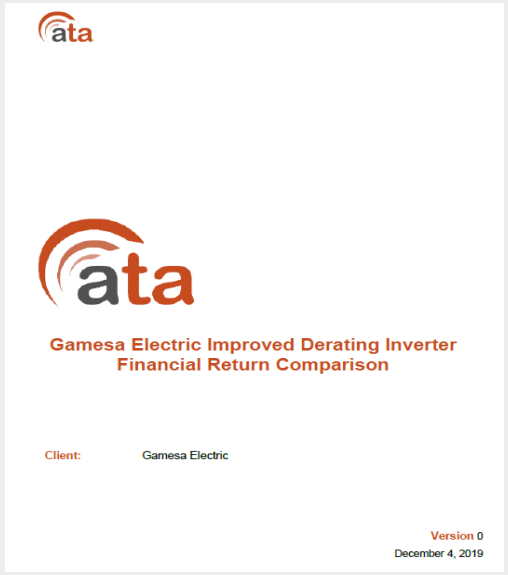
Gamesa Electric PV 3X series

Case Study: LCoE / IRR improvement by Inverter power derating

Location	Oman						Saudi Arabia					
Module	CS3U-380MB-FG			JAM72D10 410/MB			CS3U-380MB-FG			JAM72D10 410/MB		
Inverter	3750	3750 HTD		3750	3750 HTD		3750	3750 HTD		3750	3750 HTD	
Case	1	2	2b	3	4	4b	5	6	6b	7	8	8b
MWp	173.28	180.58	173.28	173.12	180.25	173.12	173.28	180.58	173.28	173.12	180.25	173.12
MWac	150	150	150	150	150	150	150	150	150	150	150	150
Energy production (GWh/y) (new & clean)	423.33	438.56	423.71	425.36	440.58	425.99	425.16	439.61	426.59	426.49	440.82	428.22



Up to

+3.6%

More yield in high temperature sites**

* Based on independent third-party analysis for a 150 MWac Project at Oman. Further details available under request.

Case Study data:

- PV plant size: 150 MWac
- Location: Saudi Arabia & Oman
- Module Technology: Bifacial
- Module suppliers:
  - Canadian Solar 380 Wp (CS3U-380MB-FG)
  - JA Solar 410 Wp (JAM72D10 410/MB)
- Inverter models:
  - Gamesa Electric PV 3750 STD
  - Gamesa Electric PV 3750 **HTD**

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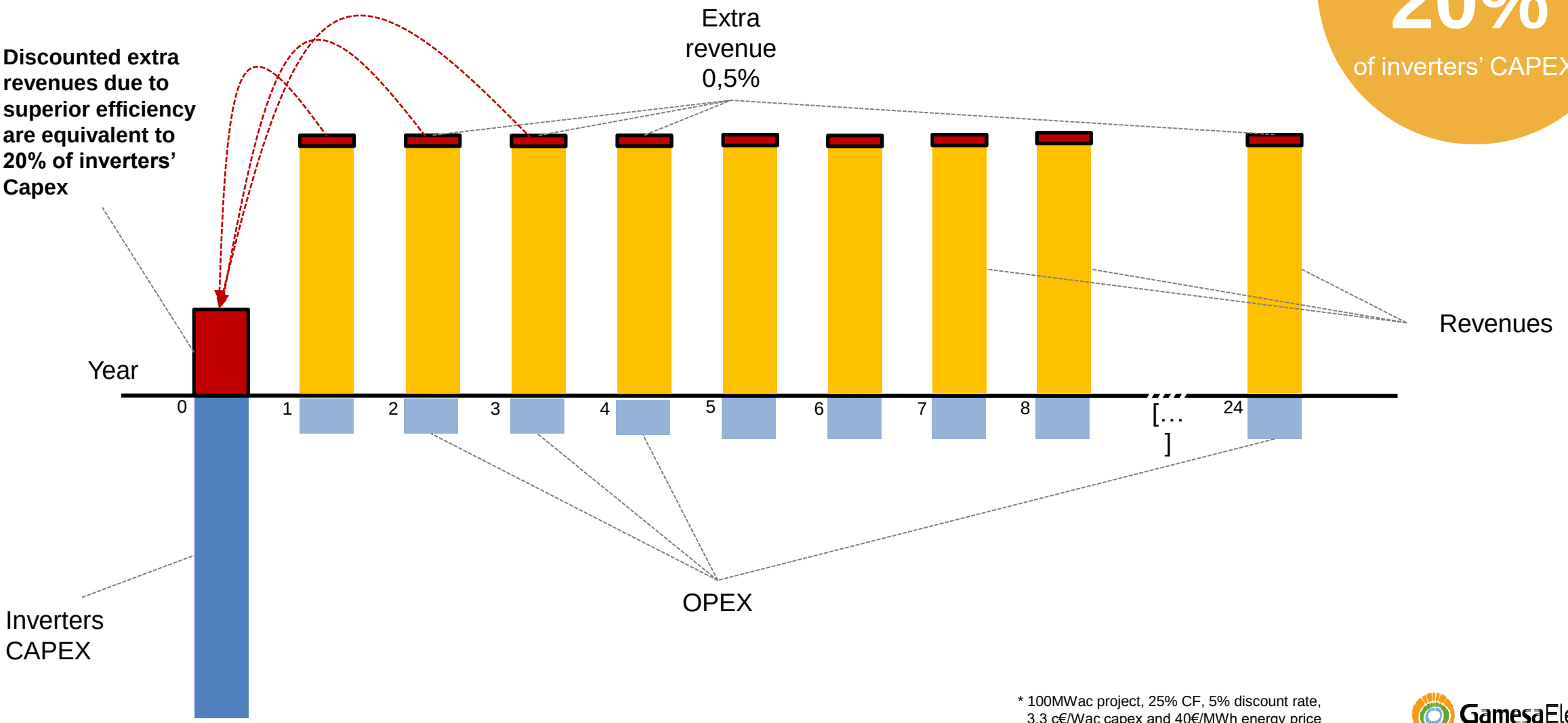
Extra efficiency case study

An extra 0,5% in efficiency during lifetime is equivalent to 20% of Inverters Capex

0,5%
extra efficiency offsets
20%
of inverters' CAPEX*

Discounted extra revenues due to superior efficiency are equivalent to 20% of inverters' Capex



* 100MWac project, 25% CF, 5% discount rate, 3,3 c€/Wac capex and 40€/MWh energy price

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Bringing down LCoE

Through higher capacity and better cooling

$$\downarrow \text{LCoE} = \frac{\downarrow \text{CapEx} + \downarrow \text{OpEx} \mid \text{lifetime}}{\uparrow \text{Energy production} \mid \text{lifetime}}$$

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Bringing down LCoE

Through higher capacity and better cooling

+44%

AC power output increase*

Logistic and construction cost reduction

$$\downarrow \text{LCoE} = \frac{\downarrow \textbf{CapEx} + \downarrow \text{OpEx} \mid \text{lifetime}}{\uparrow \text{Energy production} \mid \text{lifetime}}$$

(*) PV 3X series vs PV 2X series

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Bringing down LCoE

Through higher capacity and better cooling

+44%

AC power output increase*

Logistic and construction cost reduction

Less units to be maintained

-30%

Units installed*

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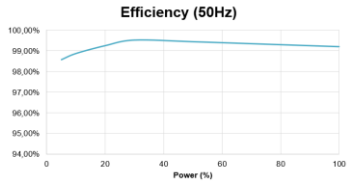
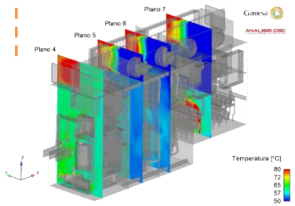
$$\downarrow \text{LCoE} = \frac{\downarrow \textbf{CapEx} + \downarrow \textbf{OpEx} \mid \textbf{lifetime}}{\uparrow \textbf{Energy production} \mid \textbf{lifetime}}$$

99.5%
Record-breaking efficiency



0,5-1,5% more efficiency than market average



CoolBrid allows enhanced temperature performance

Up to
+3.6%
More yield in high temperature sites**

(*) PV 3X series vs PV 2X series
(**) Based on independent 3rd party analysis

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