

Company presentation



Agenda

- REFU Elektronik GmbH
- REFU is part of Prettl Group
- Our Solar Product Portfolio
- Our Storage Product Portfolio
- Our References
- Why REFU?

REFU Elektronik GmbH

REFU at a glance

Founded: 1965

Competencies:

- Frequency converters
- Controllable power electronics
- Solar inverters
- Energy storage systems

~ 100 Employees (>40 people in R&D)

Certificates: ISO 9001 / ISO 14001



Headquarters Pfullingen



R&D Center Metzingen

REFU fields of activity

- Solar



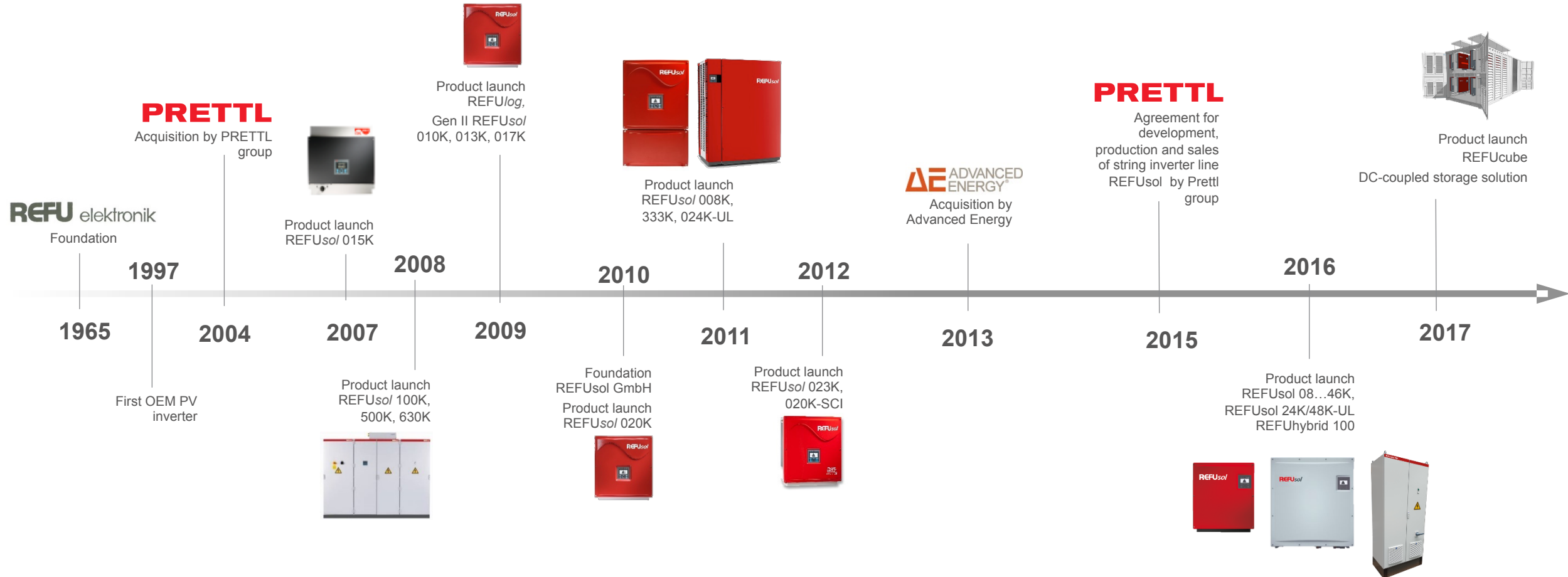
- Drive applications



- Energy Storage Systems



REFU solar and storage history



REFU is part of Prettl Group

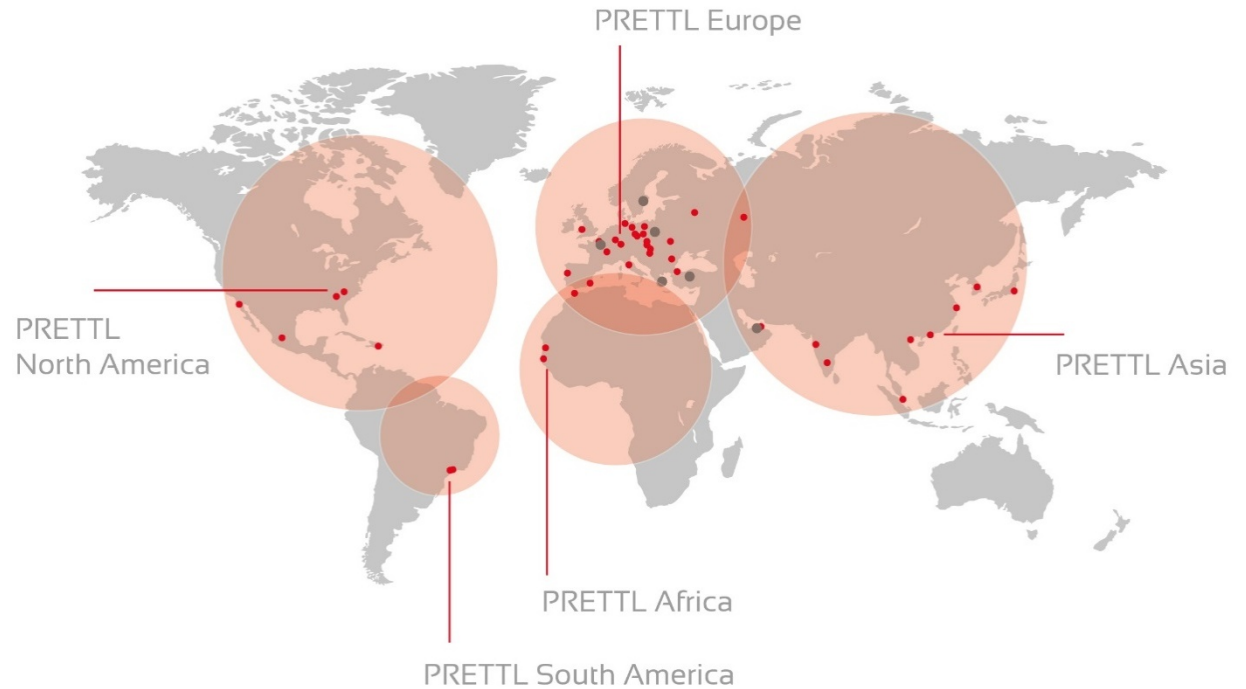
Prettl at a glance

33
Locations

5
divisions

Headquarter
in
Pfullingen
(D)

in over
25
countries



PRETTTL Business Divisions

Automotive



Coils, magnetic actuators and valves

Sensor cables and cable assemblies

Metal technology and seat structures

Appliance solutions

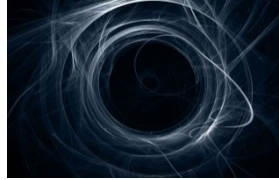


Lighting modules

Operating modules

Control panels for the white goods sector

Energy



Power generators and emergency power units

On- and off-grid systems and battery systems

Solar Inverters

Electronics

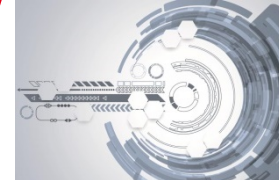


Electronic components for control and radio systems

Wireless communication modules

One of the leading system suppliers for EMS

ProSys



Emission Systems

Brake wear sensors

Catalyzers

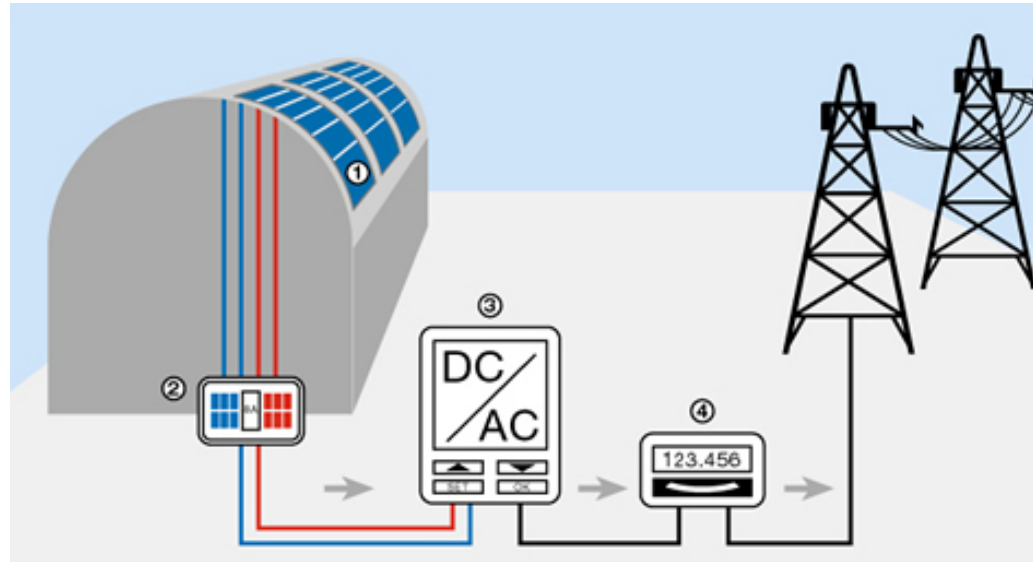
Prosumer

High-quality kitchen appliances

Drive systems for garage doors and gates

Our Solar Product Portfolio

Solar inverters: the heart and brain of a PV system



- DC-AC conversion
- plant performance monitoring and plant control
- Compliance with grid code and grid support (active/reactive power)
- interface to grid operator
- safety functions

REFUsol inverter products



REFUsol 24K-UL
for Americas



REFUsol 08K ... 23K-IEC
for Europe and other countries



REFUsol 22K-JP
for Japan



REFUsol 48K-UL
for Americas



REFUsol 40K / 46K-IEC
for Europe and other countries

IEC INVERTERS

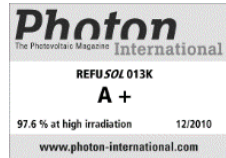
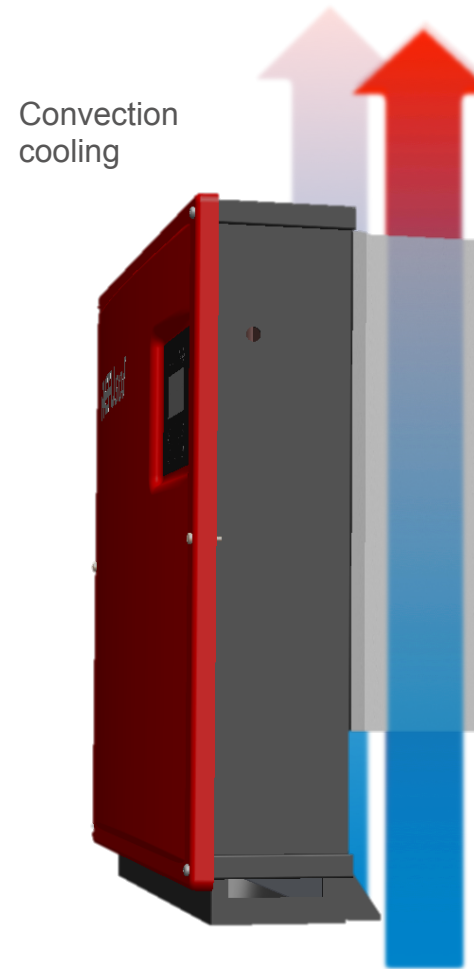


Broad
range of
power
classes

Product	REFUsoI 08K	REFUsoI 10K	REFUsoI 13K	REFUsoI 17K	REFUsoI 20K	REFUsoI 23K-MV	REFUsoI 40K	REFUsoI 46K-MV
Art. No.	867P008. 010	867P010. 010	867P013. 010	867P017. 010	867P020. 010	867P023. 010	840P040. 010	840P046. 010
Max. DC Power [kWp]	12,4	15,0	19,5	25,5	30,0	34,5	60,0	70,0
DC voltage range [V]	370 ... 850	410 ... 850	480 ... 850	460 ... 850	490 ... 850	575 ... 850	490 ... 850	575 ... 850
Max. AC power [kW]	8,25	10	13,0	17,0	20,0	23	40,0	46
AC voltage range [V]	320 ... 460	320 ... 460	320 ... 460	320 ... 460	320 ... 460	368 ... 529	320 ... 480	368 ... 529
Max. Efficiency [%]	98,0%	98,0%	98,0%	98,2%	98,2%	98,3%	98,2%	98,3%
European Efficiency [%]	97,3%	97,4%	97,5%	97,8%	97,8%	98,1%	97,8%	98,1%
Weight [kg]	38,4	38,4	38,4	38,4	38,4	38,4	74,0	74,0

REFU sol unique product features

- **Patented, UltraEta® 5 Level Topology**
 - High efficiency in real operation
 - Light weight inverter architecture
 - Low standby and night consumption
- **Convection cooling without external fan**
 - superior performance in harsh outdoor environments
 - Protection class IP65
 - No maintenance, no mechanical wearing
- **Compact string inverter design**
 - 38 kg for 20 kW – scalable for any size of PV system
 - Fail-safe through multi-inverter PV plants
- **Connected to REFUlog**
 - Professional monitoring and service portal
- **Award-winning performance tested by Photon Labs**



Which criteria to choose the right inverters?

Criteria for inverter selection

- **MAXIMUM OVERALL ENERGY YIELDS**
- **SAFE OPERATION**
- **INTELLIGENT MONITORING**
- **SUITABILITY FOR EXTREME INSTALLATION ENVIRONMENTS (HEAT/DUST)**
- **FLEXIBILITY AND RAPIDITY OF INSTALLATION**
- **RELIABILITY**

Criteria for inverter selection

- **MAXIMUM OVERALL ENERGY YIELDS**
- SAFE OPERATION
- INTELLIGENT MONITORING
- SUITABILITY FOR EXTREME INSTALLATION ENVIRONMENTS (HEAT/DUST)
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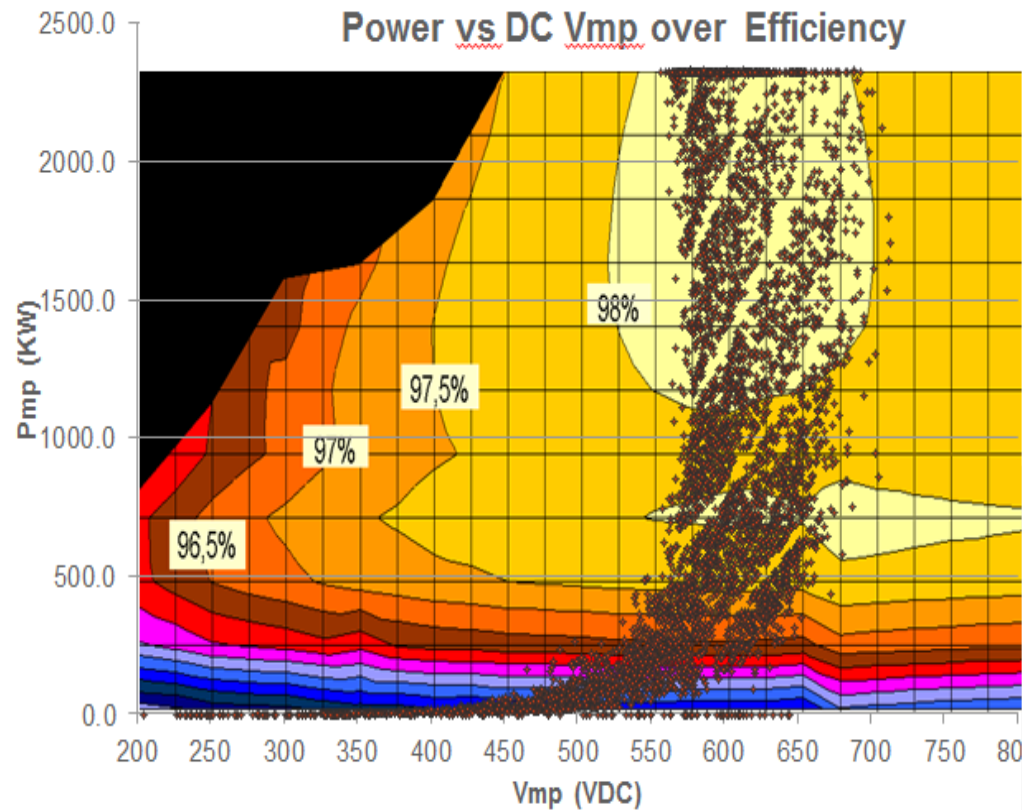
Yearly energy yields depend on operating conditions

- Conversion efficiency depends on the operating conditions of an inverter, this basically irradiation and module temperature, which are continuously changing
- This is similar to automobiles: „fuel-efficiency“ depends on driving style & conditions



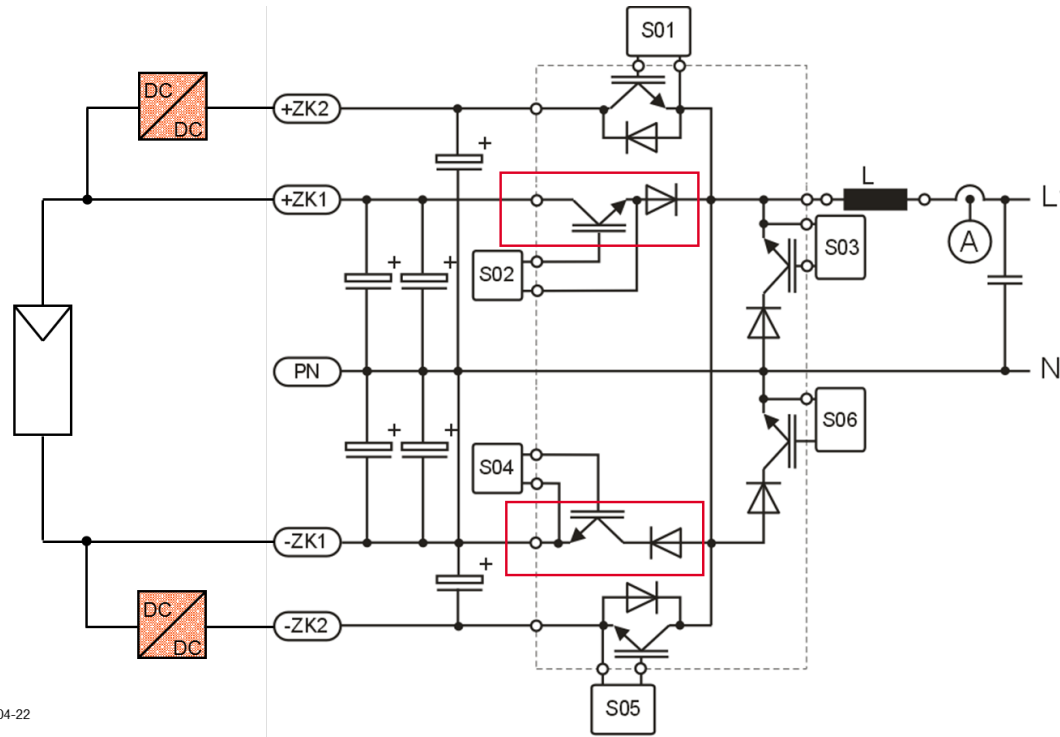
- Patented Ultra Eta ©Topology provides best conversion efficiency in all operating conditions
- Very low stand-by consumptions (<0.5W)
- Low start-up voltage

Varying operating conditions during the year



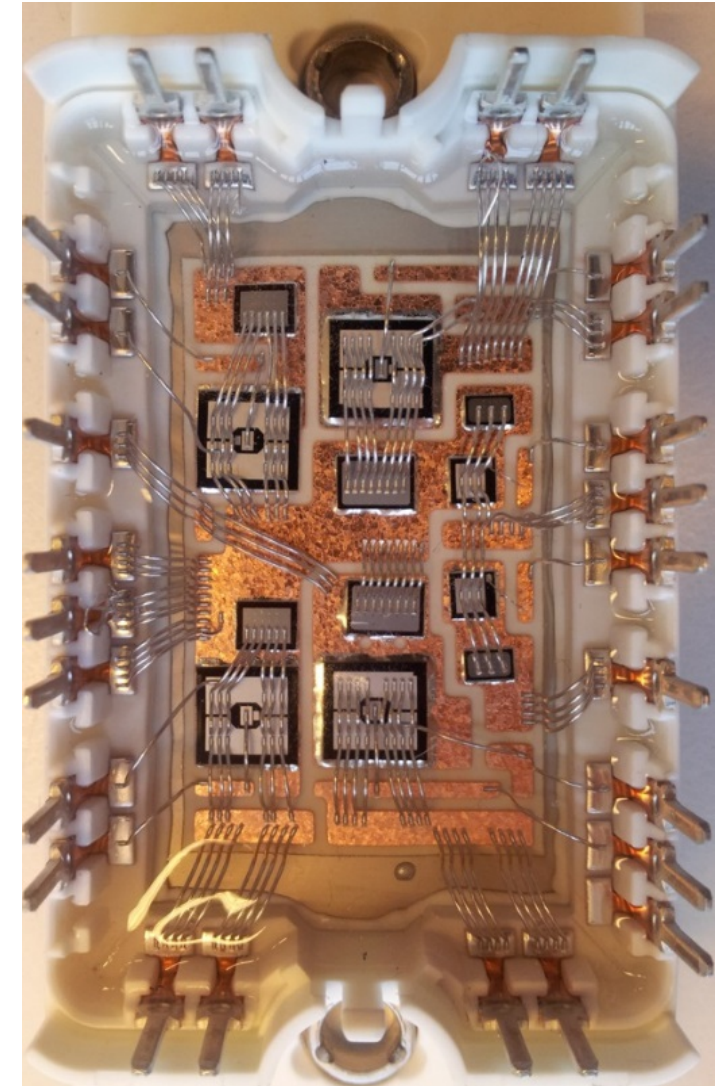
- Ambient Temperature variation over the year (~150 V)
- Power range variation over the day and year (0 .. 100% of nominal power)
- With UltraEta, the real operation over the year is within the best efficiency area

REFUsoI's patented Ultra-Eta Plus topology



6

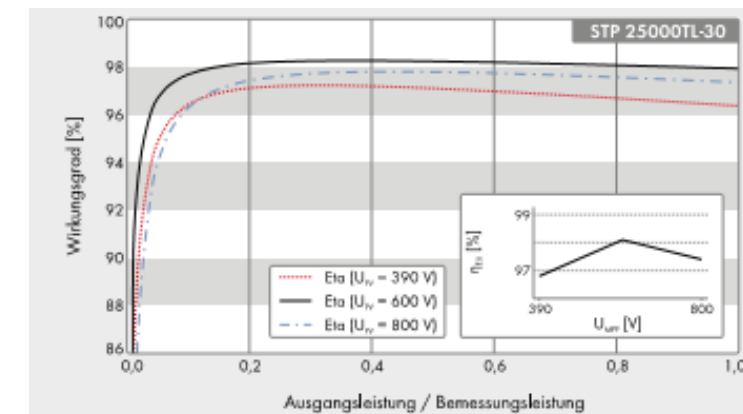
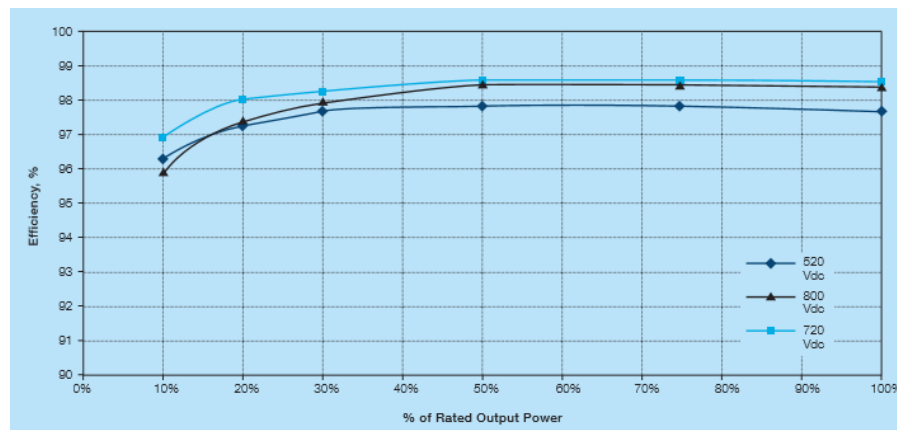
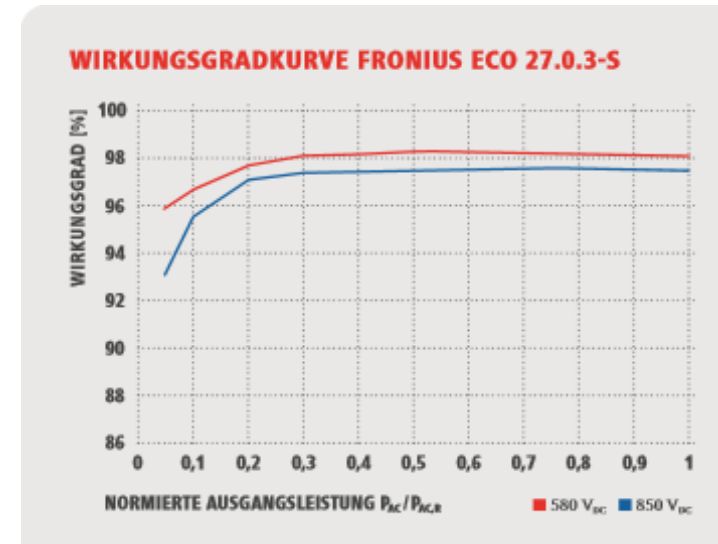
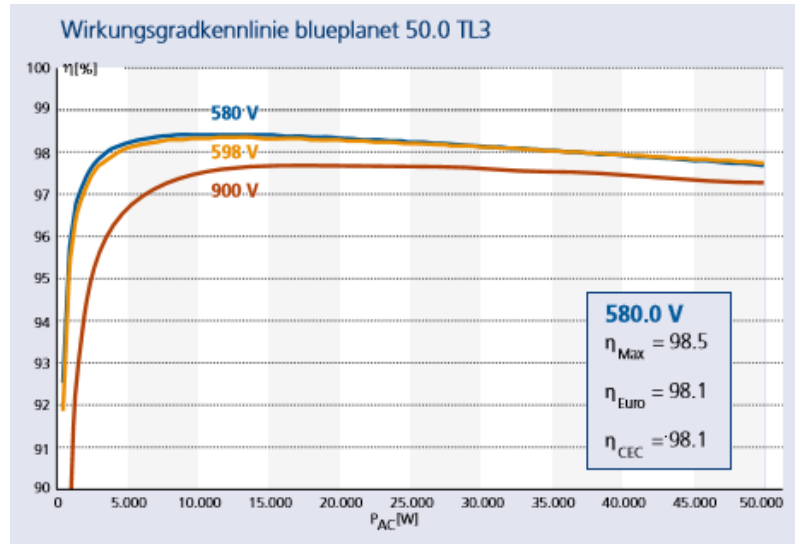
- Patented Technology – exclusively used by REFU
- More switches than competitors for optimized energy flow
- 5 voltage levels: boosted high, high, neutral, low, boosted low



REFUsoI UltraEta® efficiency – example REFUsoI 46K

AC Power	46,000	DC Voltage															Maximum
P/Pn	P (W)	275 V	325 V	375 V	425 V	475 V	525 V	575 V	625 V	675 V	725 V	775 V	825 V	850 V	900 V	950 V	Efficiency
2%	920	-	92.9%	93.8%	93.4%	94.1%	94.7%	94.2%	94.0%	94.2%	94.7%	96.5%	96.8%	96.2%	95.8%	-	96.76%
5%	2,300	96.6%	95.5%	96.0%	96.1%	96.1%	96.3%	97.0%	96.5%	96.7%	95.7%	97.1%	97.1%	97.1%	96.5%	-	97.14%
10%	4,600	96.8%	96.9%	96.7%	97.1%	97.2%	97.2%	97.5%	97.8%	98.0%	97.6%	97.9%	97.8%	97.7%	97.6%	-	97.95%
20%	9,200	97.1%	97.4%	97.5%	97.7%	97.8%	97.9%	98.0%	98.0%	98.1%	98.1%	98.1%	98.0%	97.9%	97.9%	97.8%	98.14%
30%	13,800	97.1%	97.3%	97.6%	97.8%	98.0%	98.0%	98.1%	98.2%	98.2%	98.2%	98.2%	98.1%	98.1%	98.0%	97.9%	98.25%
40%	18,400	97.1%	97.3%	97.5%	97.4%	98.0%	98.1%	98.2%	98.2%	98.3%	98.3%	98.3%	98.2%	98.2%	98.1%	98.0%	98.33%
50%	23,000	97.1%	97.3%	97.5%	97.7%	97.9%	98.1%	98.2%	98.2%	98.3%	98.3%	98.3%	98.2%	98.2%	98.1%	98.0%	98.30%
60%	27,600	97.1%	97.3%	97.5%	97.6%	97.8%	98.0%	98.1%	98.2%	98.3%	98.3%	98.2%	98.2%	98.1%	98.1%	98.0%	98.28%
70%	32,200	97.1%	97.3%	97.5%	97.6%	97.7%	97.9%	98.0%	98.1%	98.2%	98.2%	98.2%	98.1%	98.1%	98.0%	98.0%	98.22%
75%	34,500	97.1%	97.3%	97.5%	97.6%	97.6%	97.9%	98.0%	98.1%	98.2%	98.2%	98.2%	98.1%	98.1%	98.0%	98.0%	98.20%
80%	36,800	97.1%	97.3%	97.5%	97.6%	97.7%	97.8%	98.0%	98.1%	98.1%	98.2%	98.1%	98.0%	98.0%	98.0%	98.0%	98.17%
90%	41,400	97.1%	97.3%	97.5%	97.6%	97.7%	97.8%	97.9%	98.0%	98.1%	98.1%	98.1%	98.0%	97.9%	98.0%	98.0%	98.09%
100%	46,000	97.1%	97.3%	97.5%	97.6%	97.7%	97.8%	97.8%	98.0%	98.0%	98.0%	98.0%	97.9%	97.9%	98.0%	98.0%	98.03%
Maximum Efficiency		97.11%	97.37%	97.62%	97.79%	98.01%	98.13%	98.20%	98.25%	98.29%	98.30%	98.33%	98.21%	98.19%	98.13%	98.02%	98.33%
European Efficiency		97.0%	97.2%	97.4%	97.6%	97.8%	97.9%	98.0%	98.1%	98.1%	98.1%	98.1%	98.0%	98.0%	98.0%	89.2%	98.14%
CEC Efficiency		97.1%	97.3%	97.5%	97.6%	97.7%	97.9%	98.0%	98.1%	98.2%	98.2%	98.2%	98.1%	98.0%	98.0%	94.1%	98.19%

Superior performance vs. competitors



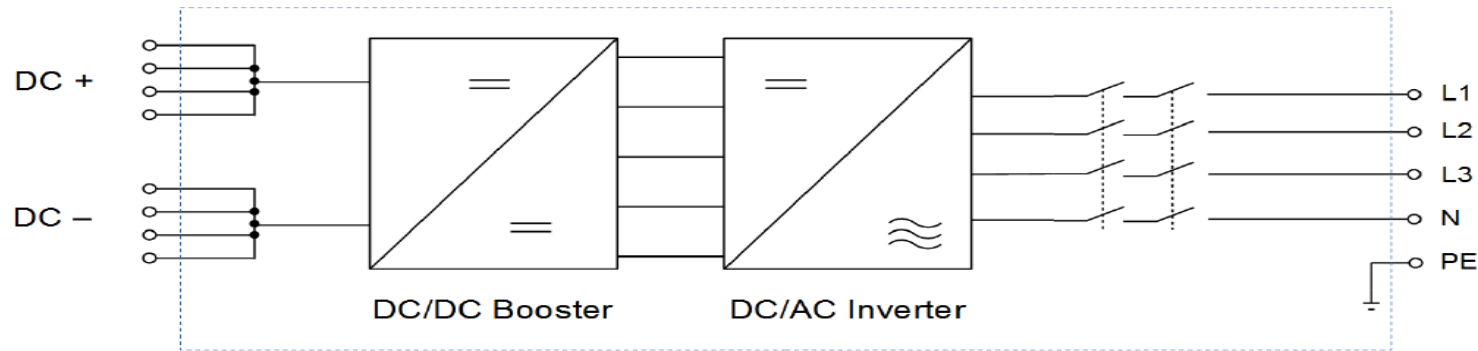
Criteria for inverter selection

- MAXIMUM OVERALL ENERGY YIELDS
- **SAFE OPERATION**
- INTELLIGENT MONITORING
- SUITABILITY FOR EXTREME INSTALLATION ENVIRONMENTS (HEAT/DUST)
- FLEXIBILITY AND RAPIDITY OF INSTALLATION
- RELIABILITY

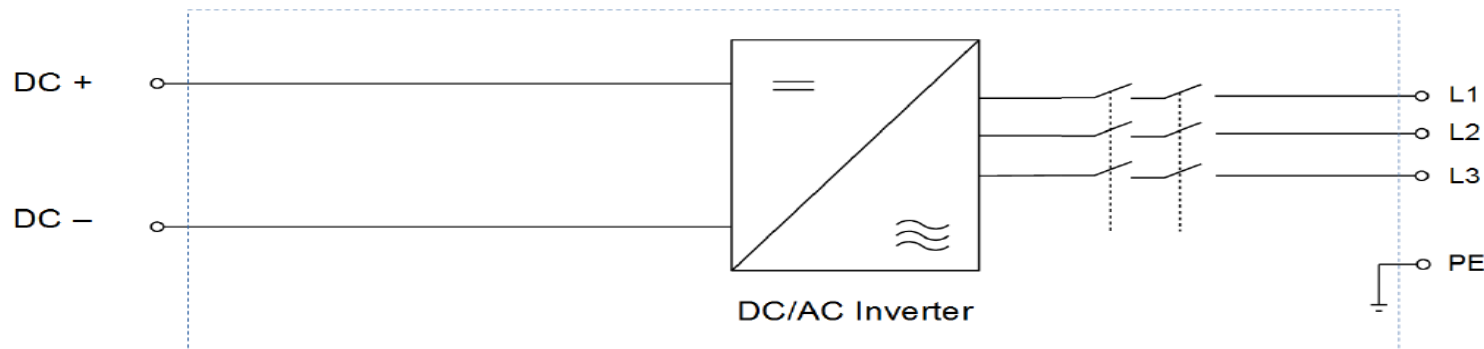


Other important features of REFUsol inverters: DC/DC booster

REFUsol's UltraEta® inverters feature a fully equipped solar inverter with a wide range of operation: DC/DC Booster and a DC/AC Inverter

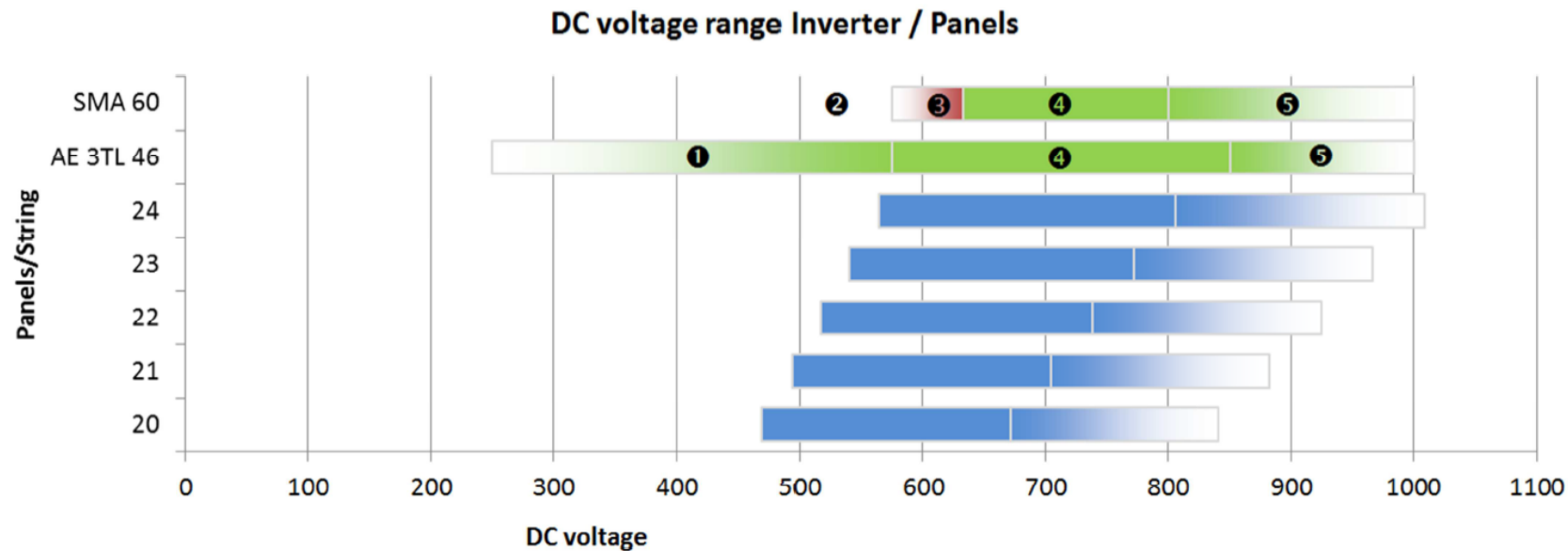


Other high power string inverter don't have a DC/DC booster, only the DC/AC inverter is part of the product. The trade-off is a limited DC operation window for full output power:



Benefit of DC/DC booster: wide DC voltage operating window

- DC/DC booster allows a flexible design with different module types mounting structures.
- No power derating due to low DC voltage (=high temperatures) or high grid voltage



Criteria for inverter selection

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- **INTELLIGENT MONITORING**
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PV system monitoring = performance control

➤ Why system monitoring?

Although PV is a low-maintenance technology there are a lot of failures which might impact on the success of your business plans:

- Modules (micro cracks, junction boxes, LID, PID, shadowing, hot spots, snail spurs, isolation problems, soiling, thefts, vandalism...)
- Cables (especially on metal sheet roofs)
- Connectors (bad crimping or water)
- Stringfuses (too low Amp-value, DC box too small))
- Circuit breakers (under-dimensioned, scarce ventilation,..)
- Inverters (temperature and voltage derating, firmware problems, parameter settings, hardware failures, fans, filters etc...)
- Telecommunication cables

REFUlog monitoring solution

www.refu-log.com



- INTEGRATED DATALOGGER
- Cloud – based FREE monitoring portal
- Remote firmware update and other service features
- Intelligent algorithms / analysis features
- Apps for IOS and Android
- Report and messaging service

Criteria for inverter selection

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such as:

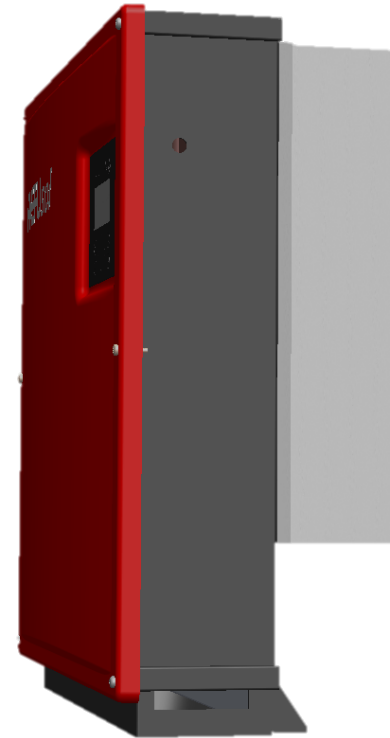
- Dust
- Sand
- Salty air
- Livestock breeding...

WITH LONG LIFETIME AND MINIMUM OPEX

Unlimited installation scenarios

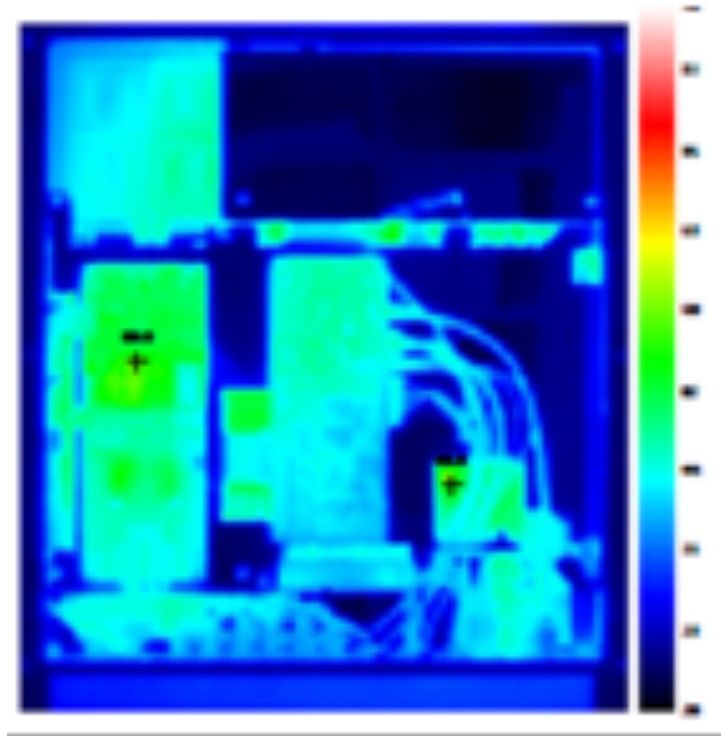
- Protection degree IP65
- Pure convection cooling
- No fans, therefore no control, no exchange, no stop of operation

„ Install it and forget it“.....

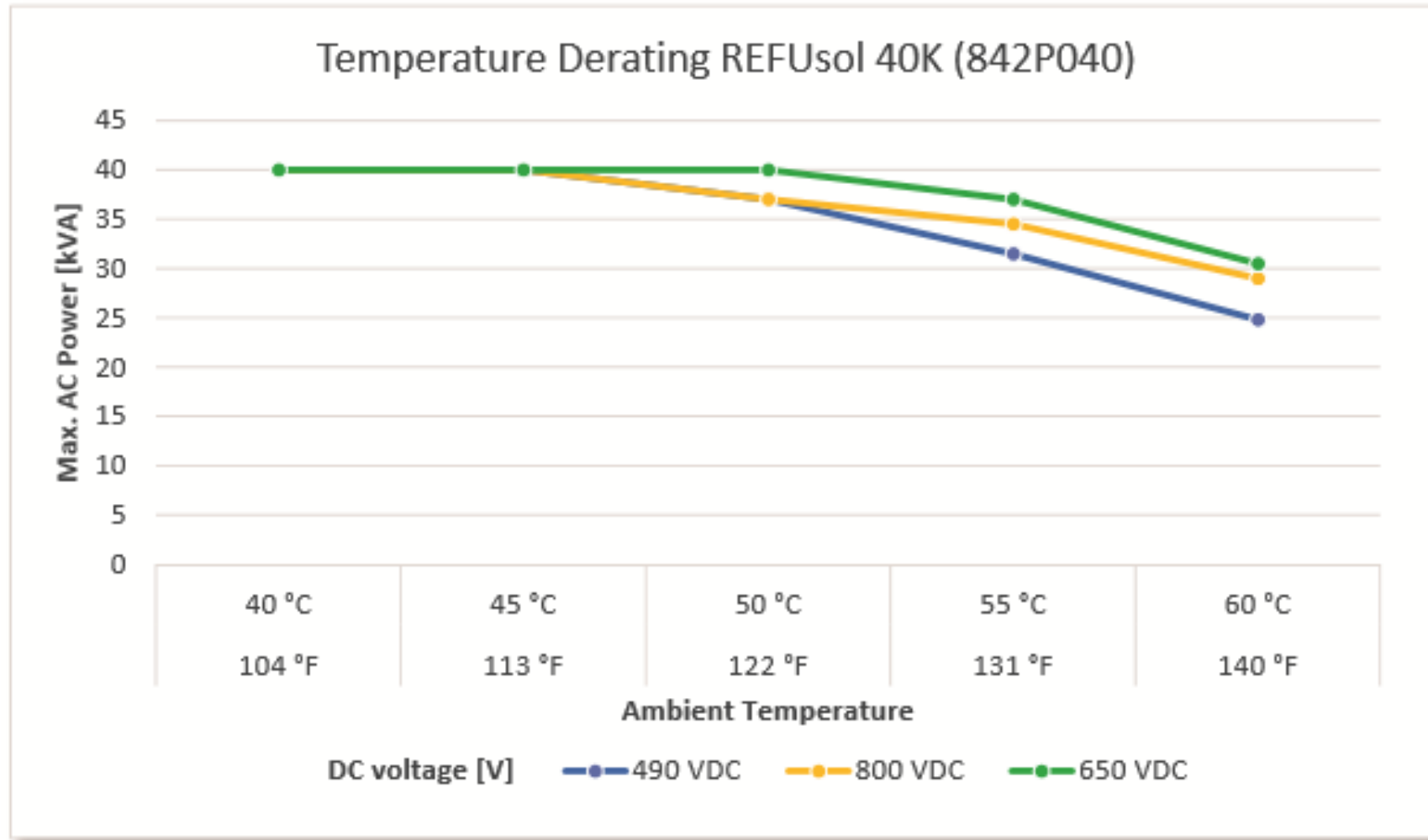


Pure convection cooling - excellent suitability for hot climates

- Best-of-class components temperature with REFU's natural convection cooling
- Longer life-time according to Arrhenius rule



Temperature derating curve REFUsol 40K/46K



Suitability for
climates with
ambient
temperatures of
50°C without
derating

Criteria for inverter selection

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REFU*sol* 08...23K

Description

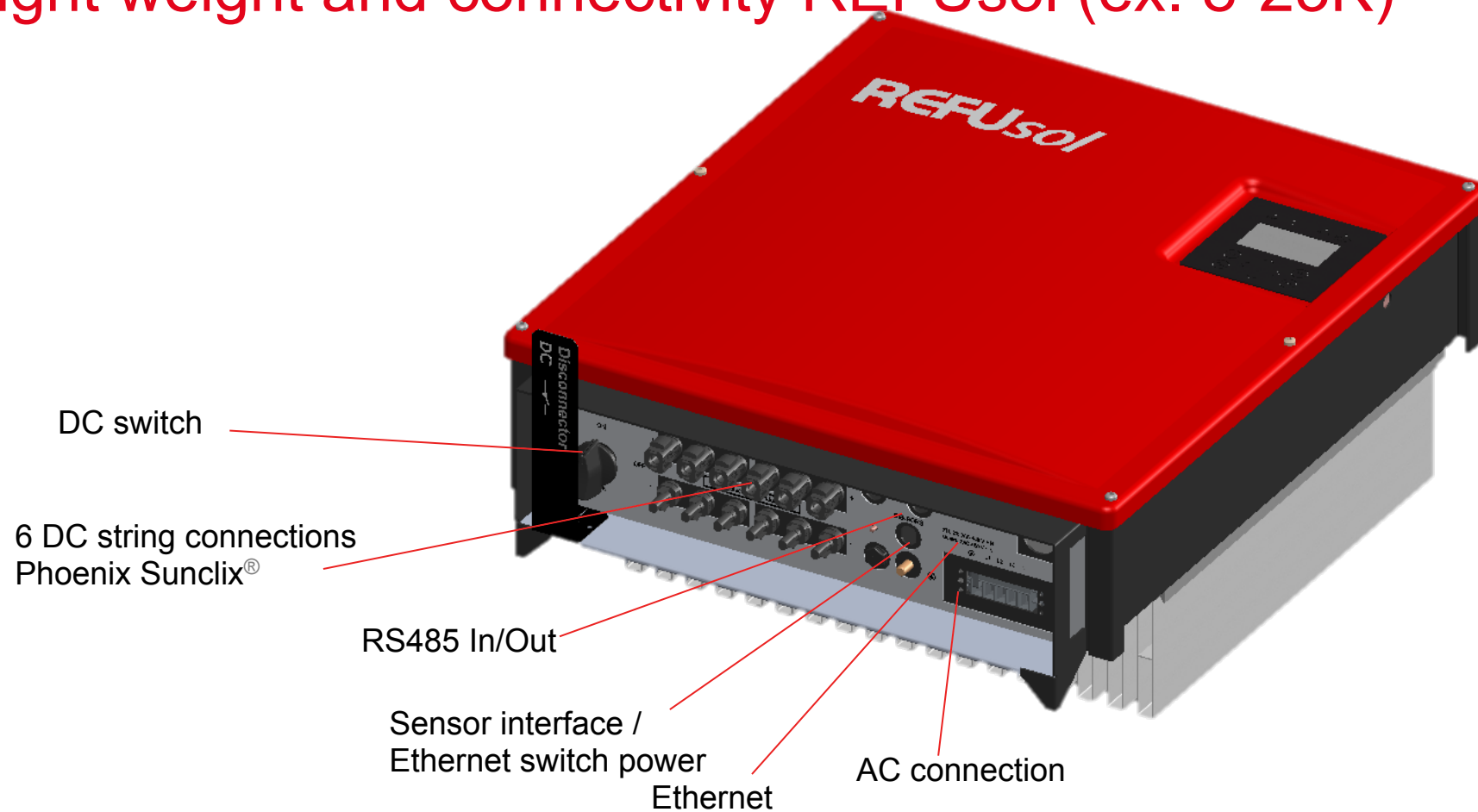
- Compact Outdoor String Inverter
- 8, 10, 13, 17, 20 (400 V grid), 23 kW (460 V grid)
- 6 Phoenix Sunclix DC inputs

Your benefits

- Maintenance free thanks to passive cooling
- High Energy yields thanks to Patented UltraEta[®] 5 Level Topology
- Easy installation and replacement thanks to low weight
- Easy monitoring with REFUlog
- Proven technology - more than 250,000 units sold
- Available in UL and JP variants



Light weight and connectivity REFUsol (ex. 8-23K)



Weight for REFUsol 20K is 38,4kg & high compactness

REFU^{sol} 40K/46K

Description

- Large Outdoor String Inverter
- 40 kVA (400 V grid) and 46 kVA (460 V grid)
- Available as 22 kW for 220 V AC
- External DC Connection Box with 10 String Inputs

Your benefits

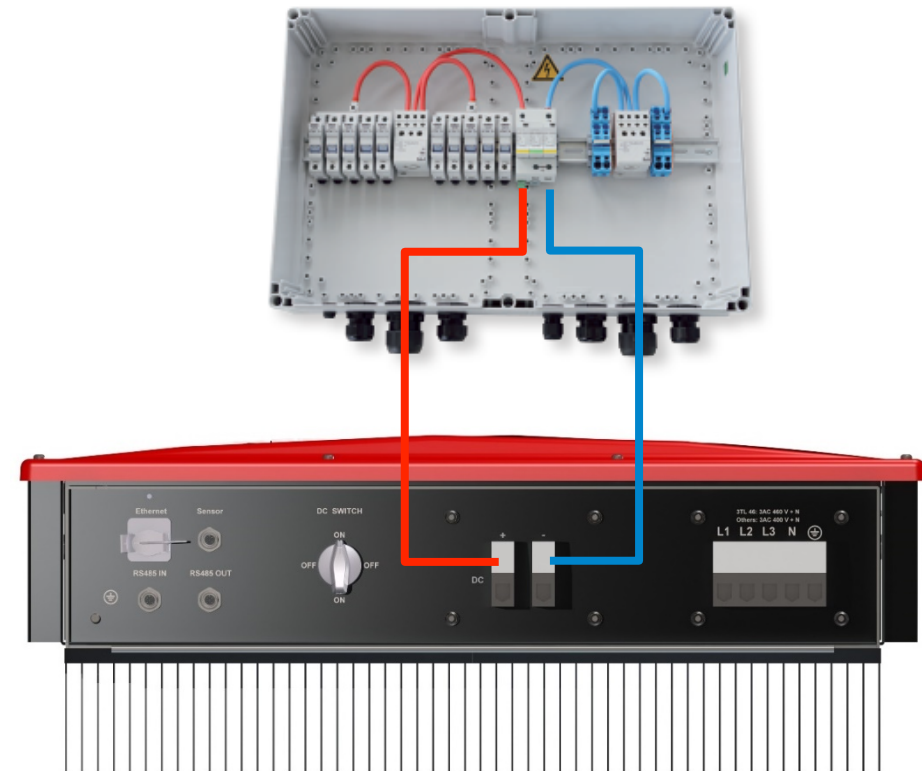
- Ideal for large Systems in rough environments thanks to max. power up to 50C ambient temperature and IP 65 protection
- High energy yields thanks to patented UltraEta[®] 5 Level Topology
- Easy Monitoring thanks to REFUlog
- Flexible use for different plant designs (centralized / decentralized)



REFUsoI 40K/46 K – DC Combiner

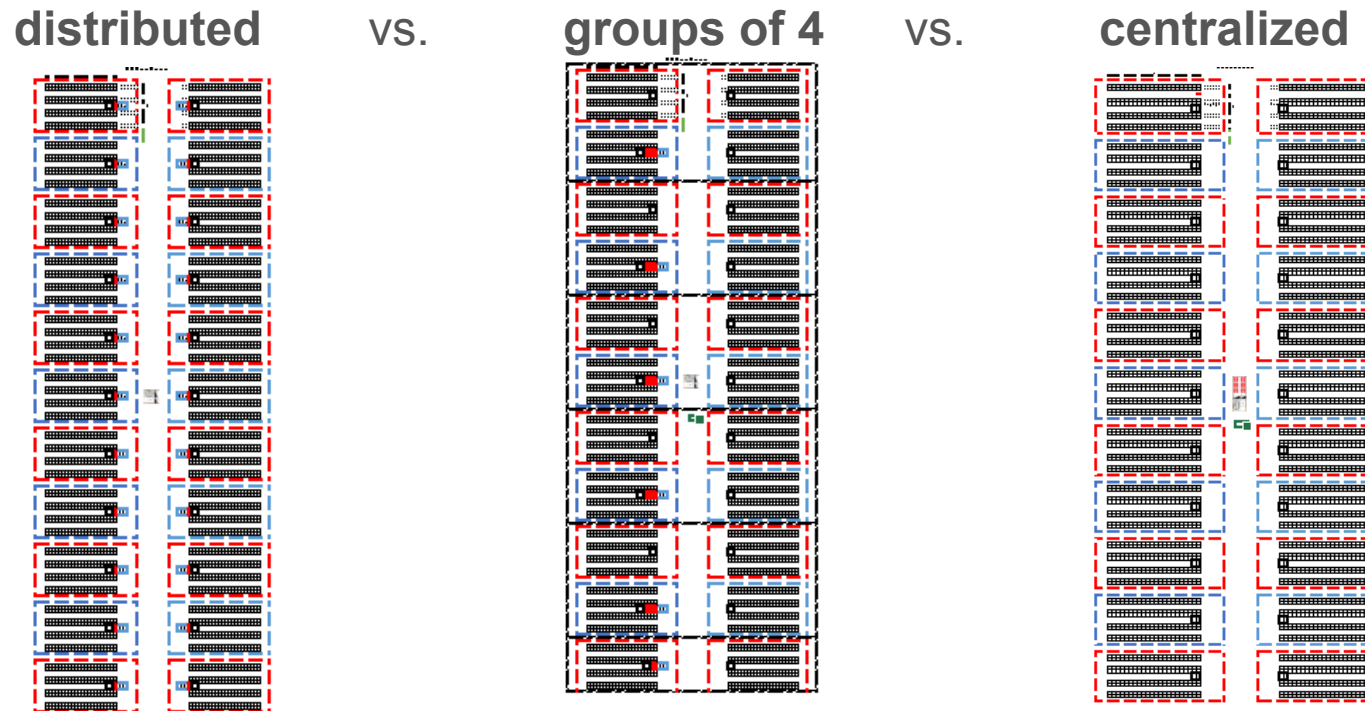
Description

- Input: Fuse holder / screw terminal up to 16 mm²
- Output: Distribution block 35 ... 120 mm² Cu / Al
- With several SPD options
- France: with integrated DC switch and MC4



Why single MPPT input?

Comparison of different string inverter installation concepts



Comparison of CAPEX for field installations

System	distributed	grouping by 4 inverters	String inverters in central position
BoS in field	159%	127%	100%

- the centralized string inverter concept allows savings for installation in field
- The centralized approach allows to fully benefit from the future REFUsol NextGen inverter suitable for 1500V DC.
(simulations with Bluesol 3.0)

Comparison central and string inverters

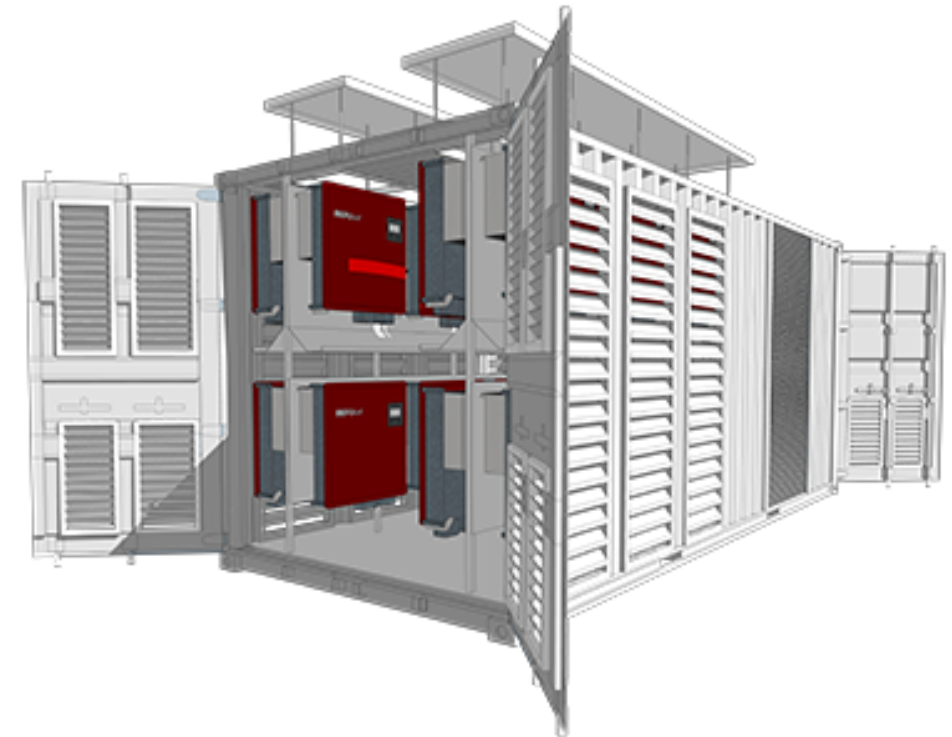
Advantages of string inverters

- LESS RISK - Easy replacement in case of failures
- HIGHER YIELDS - More MPPTs, less auxiliary consumptions
- LOWER OPEX – Less maintenance; Don't require maintenance contracts, no air condition
- MORE FLEXIBILITY – Adapts to all conditions

Advantages of central inverters

- FAST DEPLOYMENT – Independent DC and MC cabling, then install container
- LOWER BoS – Benefits fully from DC - AL cables AC distribution in field
- EASIER MAINTENANCE – Inverters concentrated in one place
- LOWER CAPEX - Lower over-all system cost

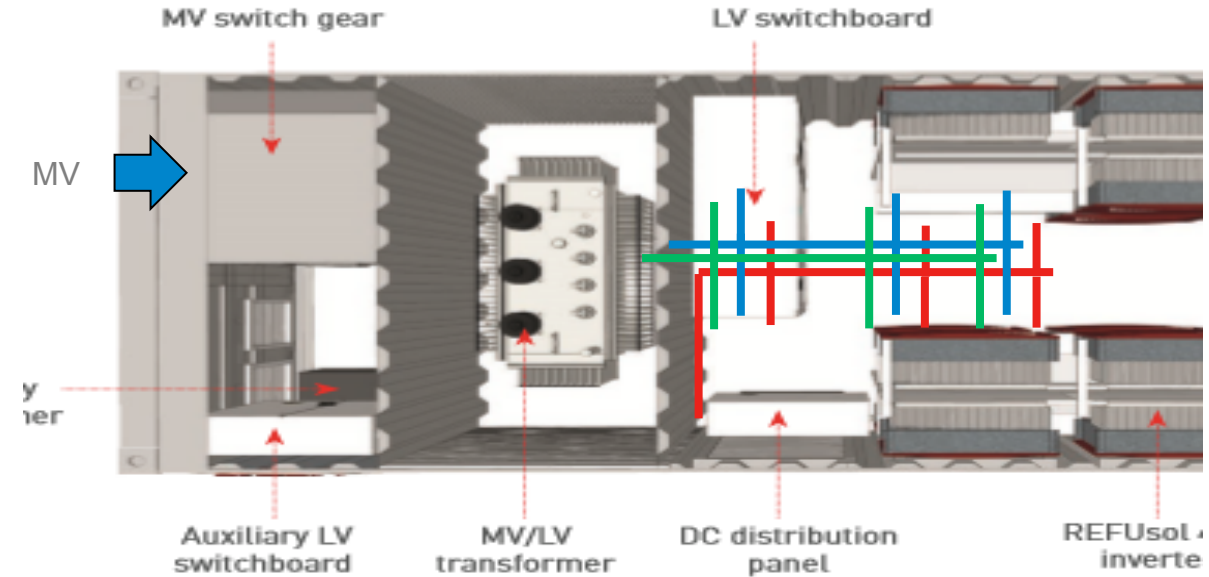
Our answer



REFUcube

Description

- Power classes 1 MVA, 1.6 MVA, 2 MVA, 3 MVA
- String inverters, MV/LV Transformer, MV Switchgear, LV switch board, DC connection panel, Auxiliary transfer and auxiliary switch board, grid protection relay installed in a 20ft / 40ft container
- Plug&Play solution, All components pre-cabled and tested
- Intelligent passive cooling system – maintenance –free (no fans)!
- Suitable for all climate types
- More flexibility



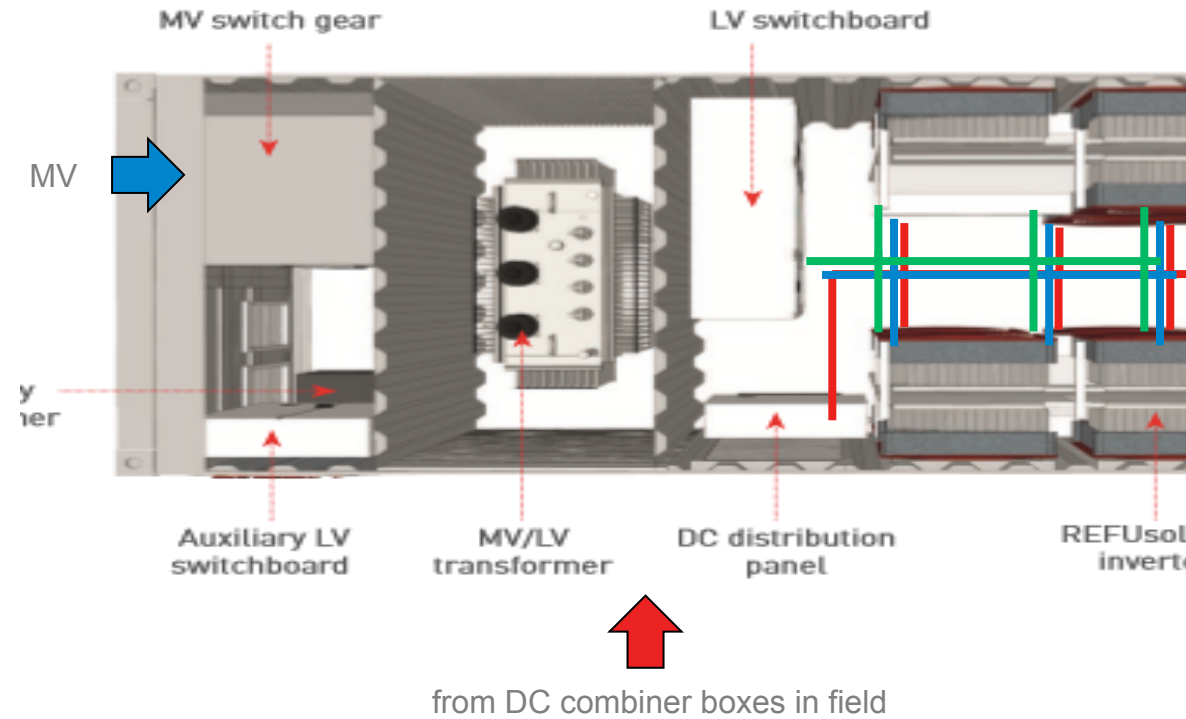
from DC combiner boxes in field

— DC
— AC
— Ethernet

REFUcube

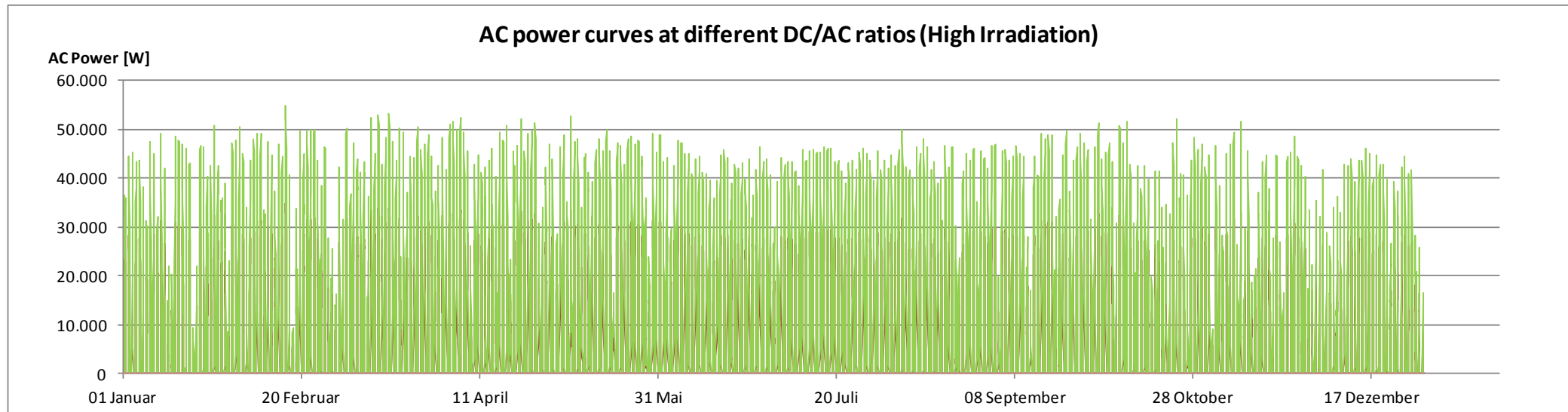
Your benefits

- Less risk
- Fast deployment
- Higher yields
- Lower BoS
- Lower CAPEX
- Lower OPEX
- Easier maintenance
- More flexibility



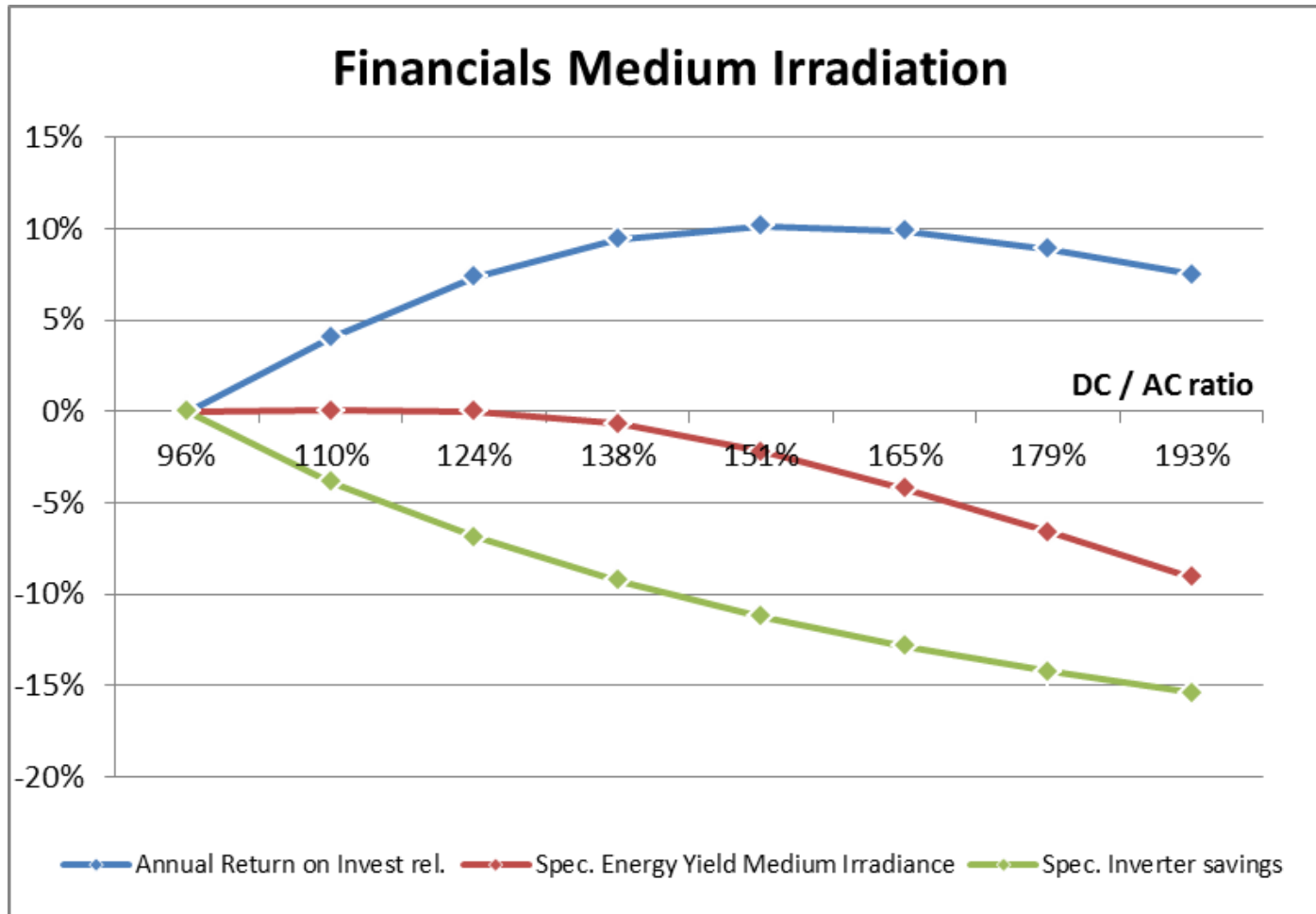
Other important features of REFU sol inverters: high DC/AC ratio

Example: Spain DC/AC=150% (3,2% less energy respect to DC/AC = 100%)



The losses are **relatively low compared to the benefits** deriving from lower installed AC power

Benefit of a high allowed DC/AC ratio: better economic performance

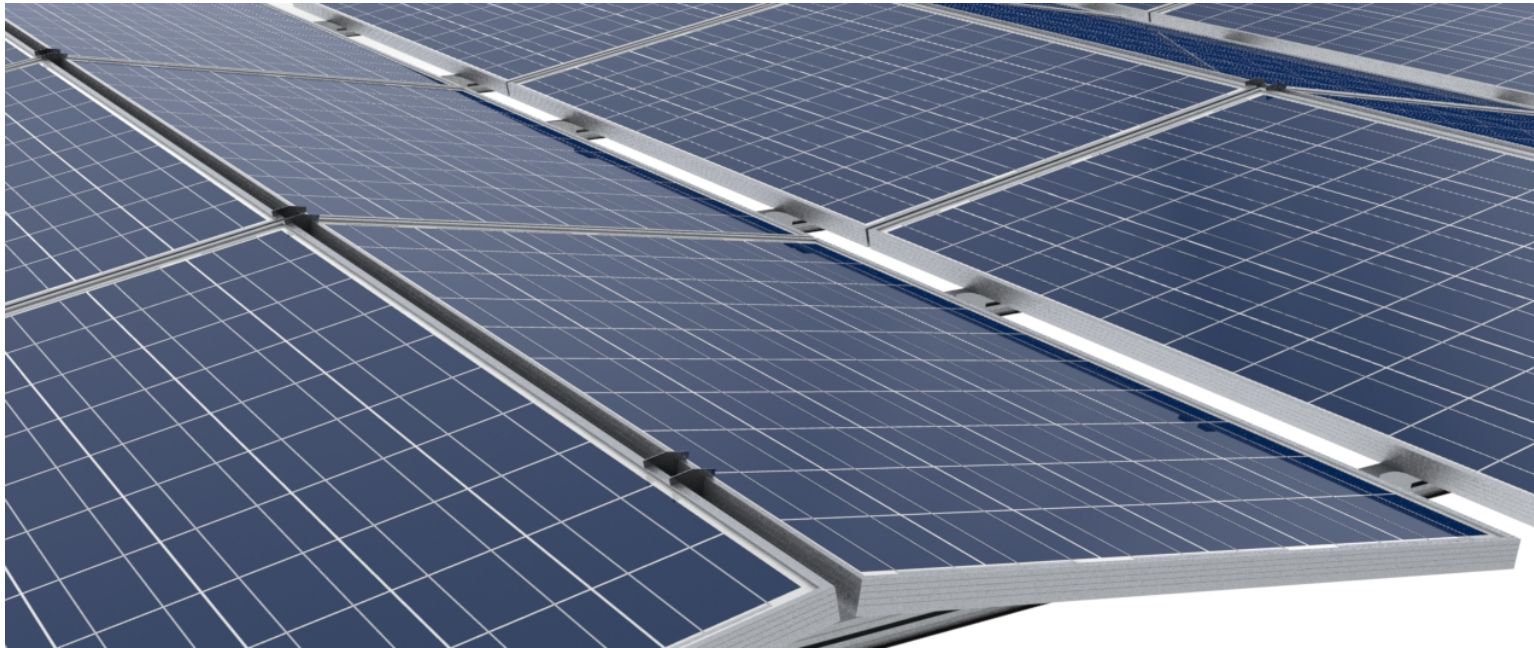


Example: DC/AC 150%

Losses 3%
Savings 13%

Overall benefit 10%

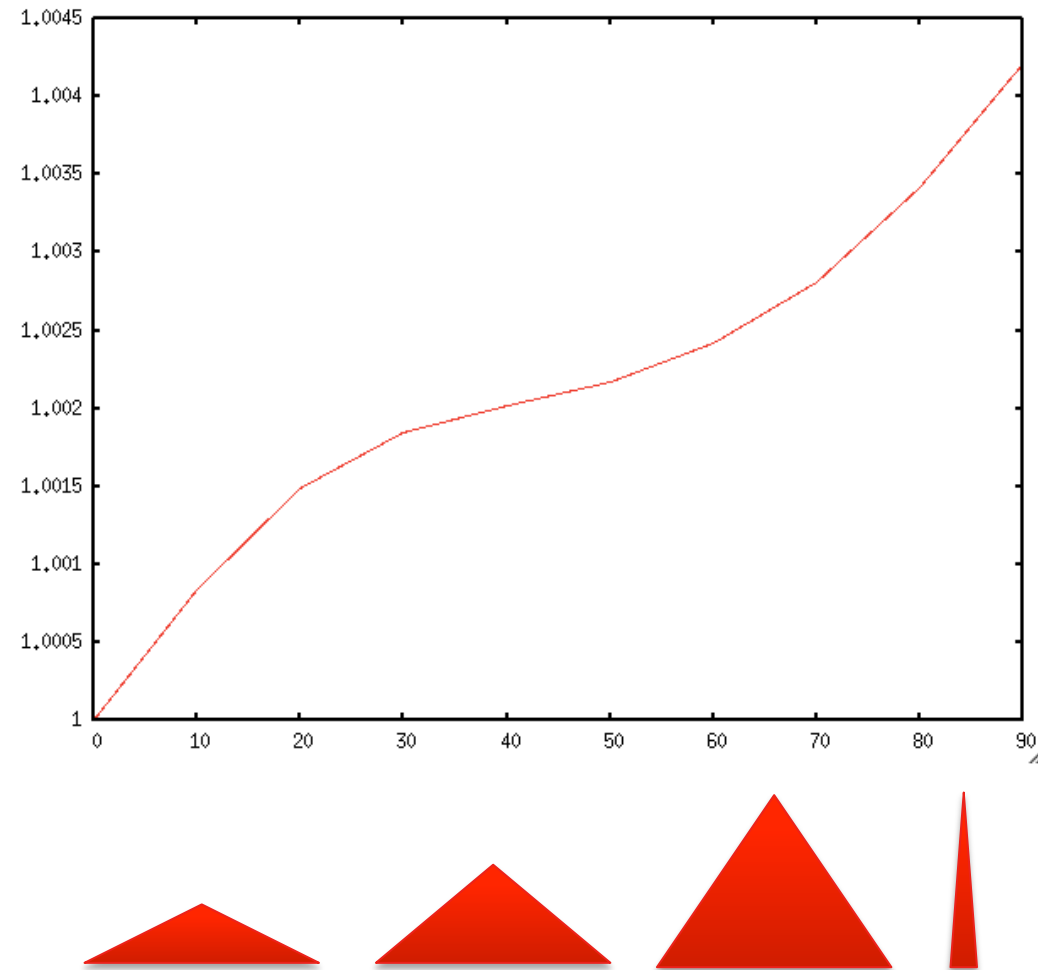
Other important features of REFUsol inverters suitable for east-west roofs



Advantage of single MPPT: all configurations possible incl. east-west

Normalized yield benefit
in % in comparison to a
single MPPT depending
on the inclination
 $\ll 0,5\%$

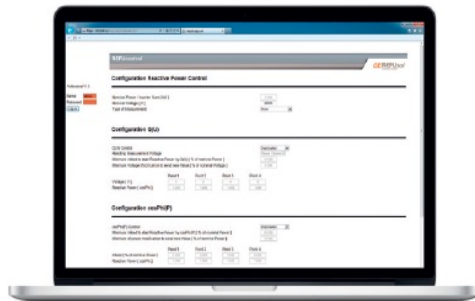
**One MPP tracker
inverter is well suited
for east west systems**



REFUsoI – tools for solar inverters

REFUdesign Planning Tool

www.refu-design.com



- Automatic online planning tool
- Including battery system
- Real hourly simulation
- Solar panel and weather database included

REFUlog Monitoring

www.refu-log.com



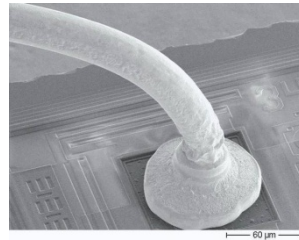
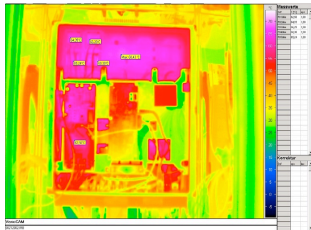
- Professional monitoring portal
- Direct data collection from inverter
- Remote firmware update
- Analysis features

Criteria for inverter selection

- MAXIMUM OVERALL ENERGY YIELDS
- SAFE OPERATION
- INTELLIGENT MONITORING
- SUITABILITY FOR EXTREME INSTALLATION ENVIRONMENTS (HEAT/DUST)
- FLEXIBILITY AND RAPIDITY OF INSTALLATION
- **RELIABILITY**

German Engineering

- Power electronic competence since 1965
- Solar inverter competence since 1998
- REFUsol String inverters are designed for a service life of 20 years
- qualification and selection of high-quality components
- Simulation of heat flow, mechanical stress etc.
- Type tests during R&D process (see next slide)



Product Testing

A comprehensive list of test items are taken care of during the development process of our products.

- Electrical safety: i.e. IEC 62109-1
- Temperature: thermal imaging, power derating, performance tests
- EMC emissions: conducted and radiated emissions, i.e. FCC Part 15, CISPR 22, harmonics
- EMS disturbances: radiated immunity, conducted immunity, electrostatic discharge, transients, surge withstand tests, voltage dips
- Functionality: short circuit, earth fault etc.
- Environment: humidity, temperature cycle, salt test, dust and sand
- Efficiency, MPP Tracker
- Vibration, Shock, Free fall, acoustic pressure
- Accelerated Life testing etc

Production Quality

1. Isolation resistance and dielectric withstand test
2. Dipole input voltage
3. DC switch (manual)
4. identifying Power board
5. temperature sensors
6. Firmware check / firmware update
7. Clock setting
8. Check Udc link balance
9. Udc link monitoring adjustment

Our Storage Product Portfolio

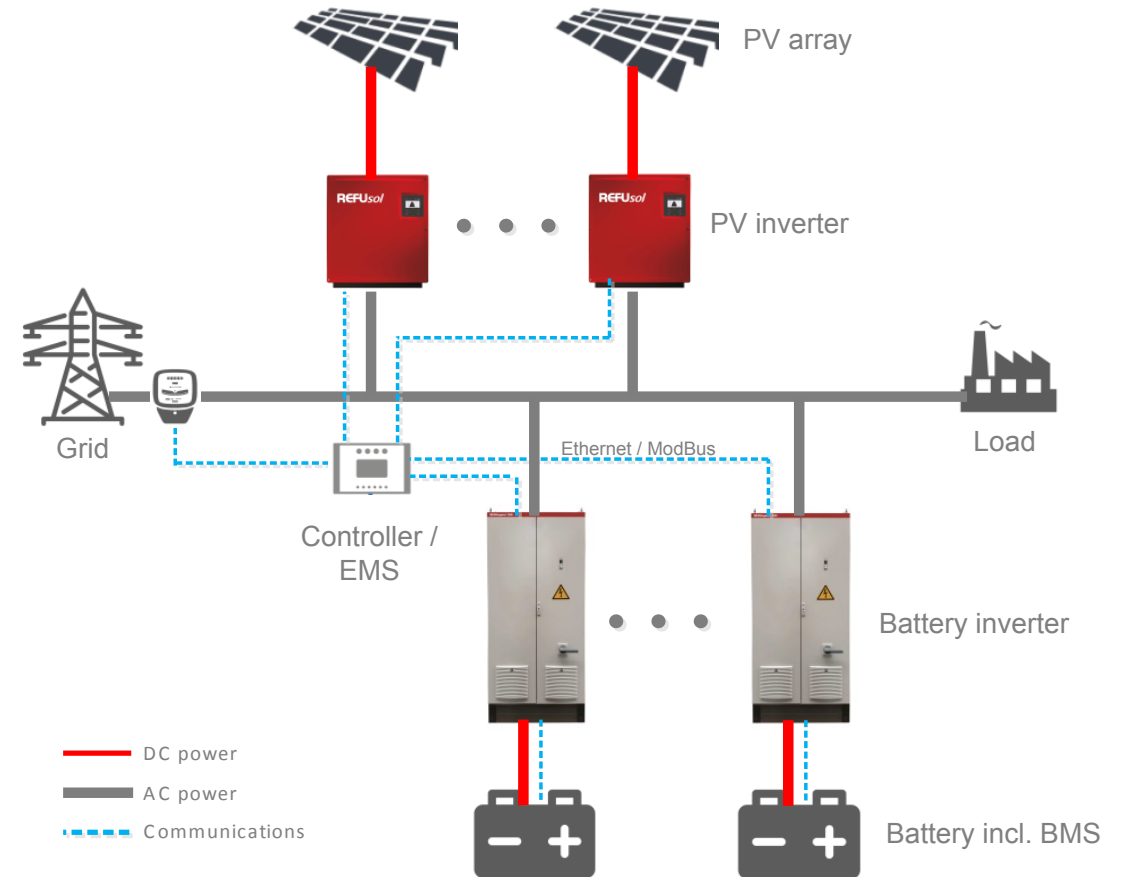
AC - coupled storage solution (grid or diesel generators)

Description

- Two separate inverters for PV and battery (REFUsoI 08K ...46K paired with REFUhybrid 100)
- Battery rack by REFU or third-party
- Individual control/EMS solution through REFU partners

Your benefits

- Independent sub-systems for solar and storage
- Independent design, installation, operation & maintenance
- High voltage design up to 800V
- Can be easily extended and retrofitted
- Individual controls through REFU partners
- Turnkey system for solar plus storage



Our References

70 MW, Germany



2550 x REFUsol 20K
38 x REFUsol 333K

Commissioning 2011

www.refu.com

13 MW, United Kingdom



227 x REFUsol 46K

Commissioning 2015

www.refu.com

10 MW, Germany



500 x REFUsol 20K

Commissioning 2014

www.refu.com

5 MW plant, Turkey



136 x REFUsol 40K
1 x REFUsol 20K

Commissioning 2016

www.refu.com

4.6 MW, Belgium



312 x REFUsol 10K,13K,17K

Commissioning 2011

www.refu.com

1.5 MW, Germany



65 x REFUsoL 20K

Commissioning 2012

www.refu.com

3 MW, India



120 x REFUsol 23K

Commissioning 2013

www.refu.com

1.7 MW plant, Italy



75 x REFUsoI 12K
267 x REFUsoI 17K

Commissioning 2011

www.refu.com

1 MW plant, Germany



22 x REFUso! 20K

Commissioning 2011

www.refu.com

1 MW plant, Turkey



20 x REFUsol 40K

Commissioning 2016

www.refu.com

400 kW System on Lake, Korea



20 x REFUsol 40K

Commissioning 2016

www.refu.com

Why working with REFU?

Why working with REFU?

- As part of the PRETTL Group, we are a strong partner with **inhouse R&D, PCB and assembly**
- High bankability and **long track record** the in solar business
- **Expert knowledge** since 1965 in the field of inverters, from 1998 solar and renewable energy
- Maximum revenue through **top efficiency products** – proven by independent Photon tests
- Focus on Commercial and Utility systems
- **Innovative Products** for Energy Storage Systems
- Comprehensive software and **online tools available** (REFUlog, REFUdesign, REFUset)
- Field experience: more than **250,000 inverters operating** in the field
- **Service partners** / Parcel replacement service

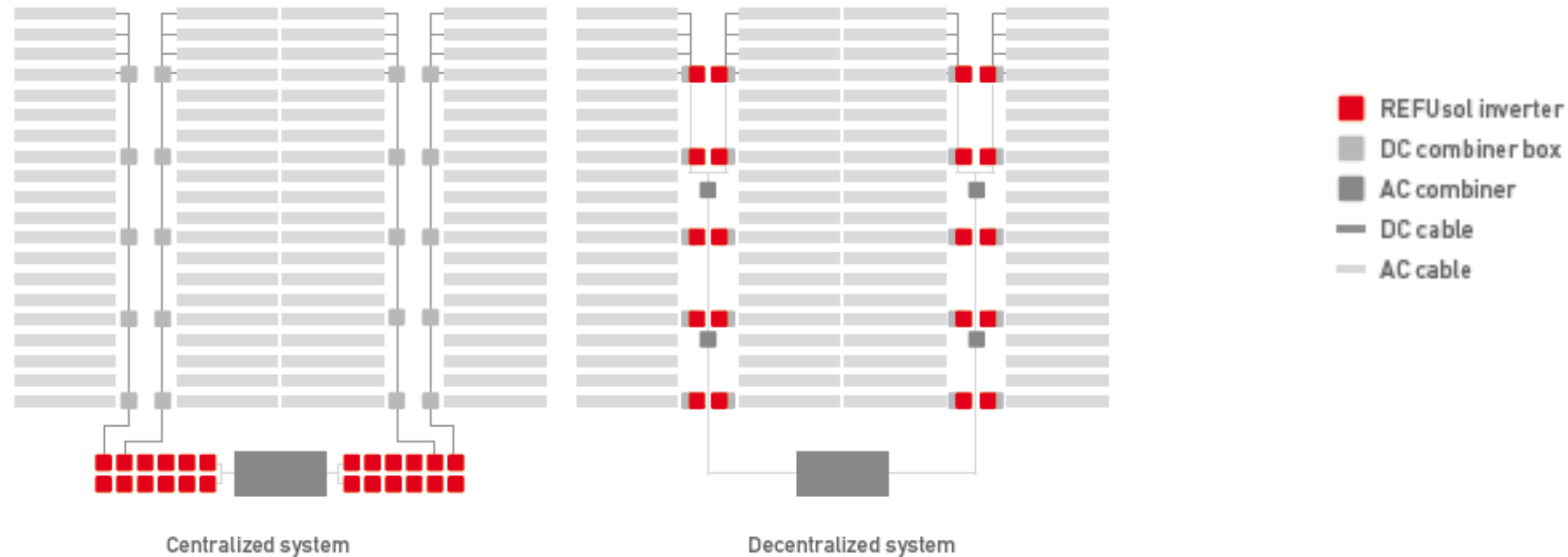
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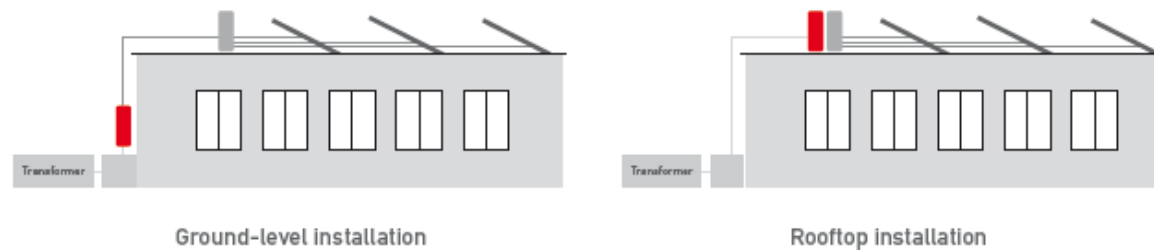
Backup

REFU provides... flexible system design with Gen2

GROUND MOUNTED SYSTEMS

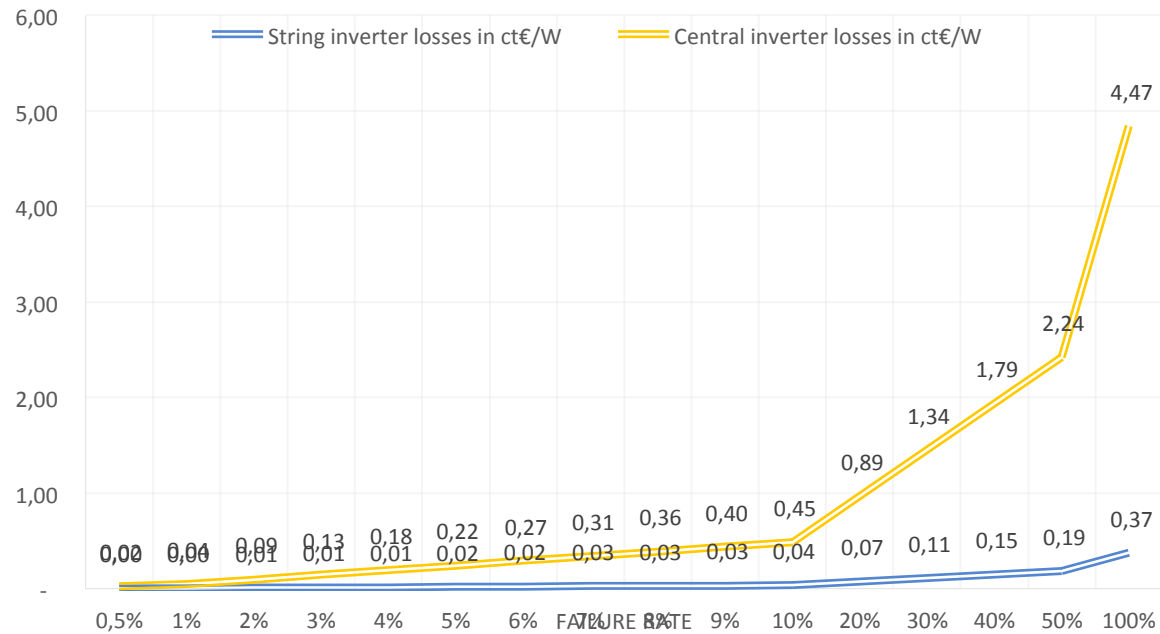


ROOFTOP SYSTEMS



Advantage of string inverters – low MTTR

LOSSES DUE TO FAILURES CT€/W



Assumptions:
 30MWn
 MTTR string 4h
 MTTR central 48h
 Value kWh 10ct€/kWh