Harnessing the Power of the Sun

1 hour of sunlight contains more energy than the world’s population consumes in a year

$117\text{ B} \text{ Revenue in 2015}

300+\text{ k}+ \text{ Employees}

~180 GW PV capacity installed globally by 2014

Active in 170+ countries

~240 TWh generated by PV in 2015

120+ years experience in energy

If PV technology was 20% more efficient at converting solar energy into power, we’d only need to cover a land area about the size of Spain to power the entire Earth by 2030.

Energy Financial Services provide ~$10 B in cumulative global renewable energy commitments

More than 6.8 GW in solar Inverters, 2.3+ installed and 4.4+ in backlog

Levelized Cost of Electricity (LCoE) for PV has reduced by half over the past 4 years

1,000 m² of photovoltaic cells can reduce CO₂ emissions by around 69 tons per year.

34+ GW installed capacity in Renewables
1 hour of sunlight contains more energy than the world’s population consumes in a year.

~180 GW PV capacity installed globally by 2014.

~240 TWh generated by PV in 2015.

1/2 Levelized Cost of Electricity (LCoE) for PV has reduced by half over the past 4 years.

1,000 m² of photovoltaic cells can reduce CO₂ emissions by around 69 tons per year.

If PV technology was 20% more efficient at converting solar energy into power, we’d only need to cover a land area about the size of Spain to power the entire Earth by 2030.

117 $117 B Revenue in 2015.

300+ 300 k+ Employees.

170+ Active in 170+ countries.

120+ 120+ years experience in energy.

34+ 34+ GW installed capacity in Renewables.

6.8+ More than 6.8 GW in solar inverters, 2.3+ installed and 4.4+ in backlog.

~10 Energy Financial Services provide ~$ 10 B in cumulative global renewable energy commitments.
Contents

Industry overview .................................................................................. 7
GE Value .................................................................................................. 11
Key Differentiators ................................................................................ 12
Flexible Offerings .................................................................................. 13
  • Solar PV Power plant ........................................................................ 14
Standardized/Pre-engineered solutions
  • LV 5 Series solar inverter .................................................................. 16
  • Plant Control & Energy Dispatching ............................................... 20
  • Electrical Balance of System (BOS) .............................................. 21
  • Battery Energy Storage Solutions ............................................... 22
  • Grid Integration & Energy Consulting ........................................... 23
  • Integrated Power Plant Approach ............................................... 24
Technology Leadership
  • Future Solar PV Concepts ................................................................. 25
  • Hybrid Power Plant Solutions ....................................................... 26
Services across the project life-cycle
  • Commercial & Project Finance ....................................................... 28
  • Project Management ........................................................................ 30
  • Services ............................................................................................ 31
Our Success ............................................................................................. 32
Contact Us .............................................................................................. 33
The GE Store ........................................................................................... 34
When it comes to how we generate power, a lot has changed in the last 15 years. In 2000 renewable energy, excluding hydro, contributed to less than 2% of the global production of electricity, and by 2013 it constituted more than 6% with estimates predicting that by 2040 it will account for 18%.

Moreover, this shift over the last 15 years is even more significant since it occurred over a period during which global demand for power has grown by more than 50%.

As markets grow, and the population increases, the world will continue to need increasingly abundant, clean and flexible power.

Attention continues to grow for the use of power generation resources that also have a limited environmental impact, and nations have been developing and implementing stringent national targets to support the future development of renewable energy sources.

The installed capacity of renewables has grown by more than 100 GW per year over the past 4 years, with a record-high of 130 GW of new capacity installed in 2014. The result is that in 2014 renewables generated more than 5,400 TWh, accounting for approximately 40% more than the total annual consumption of electricity in the United States.

As a result of continuous attention to the environment and also to the decreasing cost of technology, it is easy to predict that renewables will become a mainstream fuel in the future.

When it comes to how we generate power, a lot has changed in the last 15 years. In 2000 renewable energy, excluding hydro, contributed to less than 2% of the global production of electricity, and by 2013 it constituted more than 6% with estimates predicting that by 2040 it will account for 18%.

Moreover, this shift over the last 15 years is even more significant since it occurred over a period during which global demand for power has grown by more than 50%.

As markets grow, and the population increases, the world will continue to need increasingly abundant, clean and flexible power.

Attention continues to grow for the use of power generation resources that also have a limited environmental impact, and nations have been developing and implementing stringent national targets to support the future development of renewable energy sources.

The installed capacity of renewables has grown by more than 100 GW per year over the past 4 years, with a record-high of 130 GW of new capacity installed in 2014.

The result is that in 2014 renewables generated more than 5,400 TWh, accounting for approximately 40% more than the total annual consumption of electricity in the United States.

As a result of continuous attention to the environment and also to the decreasing cost of technology, it is easy to predict that renewables will become a mainstream fuel in the future.

Despite the rapid growth of renewables, the 176 GW of solar PV installed capacity still generates only 1% of the global electricity output.

Compared to fossil fuels and other renewables sources such as hydro, which accounted for 16% of the total global electricity produced in 2013, it would seem that solar is still a very small niche. This, however, is far from the truth.

Firstly we must consider that in 2000 only 1 GW of solar power was installed globally. Since then, a global solar power capacity equivalent to more than 200 medium size gas-fired power plants has been developed.

Then consider that the last five years, in particular, were characterized by a growth of more than 30 GW of new installations per year. During this same 5 year period, a switch in the regional footprint has taken place.

While Europe has led the development of the industry over the decade (in 2011, Germany and Italy accounted for more than half of the capacity installed in the world), many other countries including Japan, China and the US, have invested heavily in Solar capacity over the past few years.
Solar PV Development Tomorrow

430 GW by 2020 – strong growth in utility scale

For the solar PV industry, it will mean that by 2020, the world will increase its cumulative global solar PV capacity from 176 GW to 430 GW, representing an increasing rate of 16% annually on average. More than half of the capacity growth is expected to come from the utility-scale segment.

The potential is huge, especially in those regions (e.g., Africa) having consistently higher solar radiation vs. Europe where the solar industry is already very well developed.

In the medium term future, Asia will more than likely drive the majority of growth in solar PV. China is planning to install 150 GW of solar PV by 2020 which will materialize in approx. 20 GW/year. China has also developed new legislative tools aimed at reducing the permitting procedures and devolving planning to provincial authorities. The grid connection availability for utilities remains the main constraint.

India has set the target of 100 GW by 2022 of solar energy, of which 40 GW through large and medium scale grid connected solar power projects.

Brazil is planning to have renewables sources covering 42.5% of its primary energy supply and 86.1% of its electricity generation mix by 2023.

Africa is expected to grow in Solar PV from 1 to 8 GW by 2020 mainly driven by South Africa and Egypt.

**250+ GW Additions in Solar PV by 2020**

**INSTALLED CAPACITY (GW)**

- 2014: 176 GW
- 2020E: 430 GW

Industry Challenge
Long-term visibility of CAPEX, OPEX and energy output

**LCOE IS THE KEY INDICATOR**

Levelized cost of electricity (LCoE) is the main indicator to drive investment decisions. Key drivers of LCoE for PV Systems are:

- Investment cost for system installation
- Cost of capital
- Operation and maintenance cost
- Average annual electricity yield (kW per year)

The market for solar PV is mainly driven by the continuous technology development which is improving the performance of the system and at the same time decreasing the cost. This has often been facilitated by attractive financing schemes and low contracted remuneration prices achieved in more markets. The PV cost of electricity decrease over the last years has driven more competition in the market and has stimulated more competitive application development. Higher conversion efficiency, lower material usage and more innovative manufacturing process are going to set a scene for the future market developments. The cost of generating electricity relies on long term visibility for project cost and grid planning and connection. But large cost variation also depends on the market segment, the business model chosen and financing availability.

**SOLAR PRICES CONTINUE TO DROP**

In 2010, the U.S. Department of Energy (DoE) has published a white paper “to stimulate a dialogue about technology pathways to achieve US$ 1/Watt PV Systems.” It was estimated that 5–6 US$ cents/kWh LCoE “would make solar PV competitive and would unlock the potential of the sun to provide low-cost, clean limitless electricity to the U.S. and the rest of the world, at the same cost of coal-based generation.”

**LOWER SIM I S YSTEM COST FOSTERS PPA**

Recent reports show that LCoE for solar utility scale PV power is already cost-competitive with other sources of electricity, meaning that the 2010 idea to achieve 5–6 US$-cents/kWh by 2020 is about to be reached now. System cost reductions are fostering power purchase agreements (PPA) between solar farms, selling a fixed amount of electricity per year, and utility companies who commit to buy at agreed price for 20 or more years.

**THE FALLING PRICE OF UTILITY SCALE PV PROJECTS**


---

5–6 US$-cents/kWh by 2020 (2010 goal)
Industry Challenge

Levelized cost of electricity (LCoE) is the main indicator to drive investment decisions. Key drivers of LCoE for PV Systems are:

- Investment cost for system installation
- Cost of capital
- Operation and maintenance cost
- Average annual electricity yield (kW per year)

The market for solar PV is mainly driven by the continuous technology development which is improving the performance of the system and at the same time decreasing the cost. This has often been facilitated by attractive financing schemes and low contracted remuneration prices achieved in more markets. The PV cost of electricity decrease over the last years has driven more competition in the market and has stimulated more competitive application development. Higher conversion efficiency, lower material usage and more innovative manufacturing process are going to set a scene for the future market developments. The cost of generating electricity relies on long term visibility for project cost and grid planning and connection. But large cost variation also depends on the market segment, the business model chosen and financing availability.

SOLAR PRICES CONTINUE TO DROP

In 2010, the U.S. Department of Energy (DoE) has published a white paper “to stimulate a dialogue about technology pathways to achieve US$ 1/Watt PV Systems.” It was estimated that 5–6 US$ cents/kWh LCoE “would make solar PV competitive and would unlock the potential of the sun to provide low-cost, clean limitless electricity to the U.S. and the rest of the world, at the same cost of coal-based generation.”

LOWERING SYSTEM COST FOSTERS PPA

Recent reports show that LCoE for solar utility scale PV power is already cost-competitive with other sources of electricity, meaning that the 2010 idea to achieve 5–6 US$-cents/kWh by 2020 is about to be reached now. System cost reductions are fostering power purchase agreements (PPA) between solar farms, selling a fixed amount of electricity per year, and utility companies who commit to buy at agreed price for 20 or more years.


Helping you to lower the cost of electricity, across the project life-cycle

EFFICIENT. PREDICTABLE. SUSTAINABLE.
Key Differentiators
Delivering solutions for solar PV power plants

GE has a proven track record, expertise and resources to meet specific customer needs with a portfolio of technology, products and services across the commonly used power generation methods and grid operations.

As the strong global growth of Solar PV power continues, the efficient and reliable conversion of solar energy into electricity will remain critical. Cost effective system design, highest energy output, efficient PV plant connection to the grid and long-term reliable solar plant operation are key to our customers’ success.

At GE we are always working to identify the best solution for our customers to help obtain higher energy yield at lower cost of electricity, thus enabling better investment performance.

BUILDING A SUSTAINABLE INDUSTRY
GE offers efficient and predictable solutions for cost-effective solar PV power by leveraging its broad capabilities to combine technology, products and services from the GE Store.

GE VALUE

COST-EFFECTIVE 1,500 VOLT PV SYSTEM DESIGN
- Max. Efficiency ... 1,500 Volt, up to 4 MW
- Capex Savings ... Up to 3% lower system cost
- OPEX Savings ... Up to 15% less maintenance cost

PRODUCTIVITY – INCREASE EQUIPMENT UPTIME
- Increasing plant yield and efficiency
- System availability 99+ %
- Integrated plant level control system with integrated storage option

GRID INTEGRATION & POWER QUALITY
- 20+ years proven grid integration capability
- Meet stringent grid code requirements in extreme conditions
- Advisory services for grid integration around the globe

LIFETIME SUPPORT – LONG-TERM AND LOCAL SUPPORT THROUGHOUT SOLAR FARM LIFE
- Long-term ... product support up to 20 years
- Local ... GE operating in 170+ countries
- Customized long-term services agreements

GLOBAL MANUFACTURING LOCATIONS & LOCAL CONTENT CAPABILITY
- Capacity to address the growing demand for solar PV inverters.
- Meet local content requirement to help to reduce lead time and cost.

BANKABILITY – MITIGATE RISK AND HELP TO IMPROVE INVESTMENT PERFORMANCE
- Energy consulting and project financing capability to support bankability and execution of projects
Flexible Offerings
Fulfill customer requirements

GE’s flexibility across the complete portfolio allows our customers to select products and systems that meet their specific requirements, while maintaining the key benefits of standardization and pre-engineering processes.

In addition, GE’s plant integrator approach can deliver added value across the full range.

From the basic engineering of core components to a turnkey PC or hybrid power plant approach, GE provides integrated offerings that enable efficient power plant operation:

- Faster, more efficient, sustainable PV solar power plant at lowest cost
- Manage intermittent energies with integrated hybrid solutions
- Improving grid productivity through energy storage systems

GE offers efficient and predictable solutions for cost-effective solar PV power by leveraging its broad capabilities to combine technology, products and services from the GE Store.

INTEGRATED POWER PLANT APPROACH

- LV 5 INVERTER
- SKID SOLUTIONS
- ELECTRICAL BALANCE OF SYSTEM (BOS)
- PLANT CONTROL & ENERGY DISPATCH
- ENTIRE PV PLANT APPROACH (EPI)
- GRID INTEGRATION SERVICES
Solar PV Power Plant

Leading technology – from standardized / pre-engineered solutions to integrated power plant approach
FLEXIBLE OFFERING: FROM INDIVIDUAL COMPONENT TO THE ENTIRE PV PLANT

- LV 5 Series solar inverter ................................................................. page 19
- Plant Control & Energy Dispatching ................................................. page 20
- Balance of System (BOS) ................................................................. page 21
- Battery Energy Storage Systems ..................................................... page 22
- Grid Integration and Energy Consulting Services .......................... page 23
- Integrated Power Plant Approach (EPI*) ......................................... page 24

Switchgear

Electrical Balance of System (BOS)

Grid Connection

Plant Controller SunIQ

Battery Energy Storage System

Turnkey Solution

Integrated Power Plant Approach (EPI)
GE was the first company to introduce 1.5 kV technology into the market. Our LV 5 builds on extensive manufacturing experience and a global installed base of over 34+ GW in renewables including 2.3+ GW in solar inverters.

**HIGHER DC VOLTAGE ARRAYS**

Solar panel technology is continually evolving to help lower the cost of energy production. The next step in this trend is the 1,500 Vdc panel. Inverter input voltages of 1,500 Vdc increase the output power by enabling a more efficient farm layout while significantly reducing investment costs for construction, cables, combiner boxes, fuses, inverters and transformers.

**IMPROVES GRID STABILITY 24/7**

Our LV 5 Inverter system offers advanced grid features and provides reactive power control day-and-night for grid voltage stabilization. It improves Power Quality by managing parameters to stabilize the grid such as frequency control, power factor management, power curtailment and power ramp rate control.

1.5 kV inverter enables lower system cost

<table>
<thead>
<tr>
<th></th>
<th>Capex Infrastructure</th>
<th>CAPEX AC</th>
<th>Capex DC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical 1 kV’ 2 MW</strong> (state of the art)</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE 1.5 kV’ 2 MW vs. typical 1 kV’ 2 MW</td>
<td>-1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE 1.5 kV’ 4 MW vs. typical 1 kV’ 2 MW</td>
<td>-3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE 1.5 kV’ 4 MW vs. GE 1.5 kV’ 2 MW</td>
<td>-2%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LV 5 Enables Lower LCoE

Building a sustainable industry

UP TO 3% LOWER SYSTEM COST

- Allows connection of 50% more modules in series
- Enables larger PV arrays and reduces the amount of strings
- Reduces DC losses due to higher voltage level
- Lowers the amount of electrical components (inverters, transformers, switchgear, combiner boxes, etc.)

UP TO 15% LOWER INVERTER OPERATING EXPENSES

- Reduced amount of inverter stations and MV transformers
- Increased system reliability
- Fewer components allow for lower Operation and Maintenance cost

HIGHER ENERGY OUTPUT

- Higher output due to reduced maintenance time
- Lower plant losses with 1,500 Volt

¹ Reference calculations for system comparison were made for 200 MW PV project on African continent.
² Up to 30% lower O&M cost of 1.5 kV 4 MW vs. typical 1 kV/2 MW system due to fewer components.
Fewer Components, Lower Cost
The 1,500 VDC advantage

1,500 Volt Inverter helps to reduce system cost by up to 3%, and lower O&M cost by up to 15% by using fewer components.

1,500 V (2 MVA) vs. 1,000 V (2 MVA)
- Fewer strings
- Up to 4.5% Reduction of string cable length
- Up to 27% Reduction of array cable length (for similar combiner box layout)
- Up to 58% Reduction of DC losses
- Up to 50% Reduction of combiner boxes

1,500 V (4 MVA) vs. 1,000 V (2 MVA)
- Up to 50% less transformers
- Up to 50% less switchgear
- Up to 50% less DC 240 mm² main cable length
- Reduction in cable trenches, compression works, pavement

Reference calculations for system comparison were made for 200 MW PV project on African continent.
LV 5 Series Solar Inverter

Efficient and proven technology, world class performance

- Fewer components, lower cost
- 1,500 VDC advantage

**Technical Data**

**TYPICAL CONFIGURATIONS**
- 1 MVA Inverter
- 2 x 1 MVA Skid solution
- 3 x 1 MVA Skid solution
- 4 x 1 MVA Skid solution

**DIMENSIONS**

LV 5-1507/1508/1510-SLR (outdoor & indoor):
- Width: 1,800 mm (2,800 mm*)
- Height: 2,000 mm (2,200 mm*)
- Depth: 600 mm
- Weight: <1,700 kg

**FEATURES**
- 1,500 Vdc voltage level
- Three-level inverter based on IGBT technology
- Liquid cooling system, indoor / outdoor models
- Interfaces: Ethernet, Modbus TCP
- UL / IEC compliance

**OPERATING VOLTAGE**
- 3 ph AC 400 V-550 V (+/-10 %)

**INPUT (DC)**
- DC MPPT: 650 to 1,300 V
- DC operating range up to 1,500 V

**OUTPUT (AC)**
- Power range: 725 to 4,000 kVA
- Frequency: 50 Hz/60 Hz
- Efficiency: >98 %
- Reactive power support: 0–1 ind. or cap.

*Cooling cubicle and plinths added for Outdoor application
Plant Control & Energy Dispatching
Predictable. Intelligent PV plant system design to improve serviceability

The GE Advantage

GE is transforming itself to become the world’s premier digital industrial company, executing critical outcomes for our customers. Based on decades of experience in the energy and asset management sector, GE can help you to drive greater asset reliability, lower operating costs, reduce risk and accelerate operational performance with our platform and software solutions.

INTELLIGENT PV PLANT SYSTEM DESIGN: IMPROVING SERVICEABILITY AND REDUCING LCOE

• GE’s Control System incorporates a full functioned SCADA system that provides high reliability, superior data integrity, open system access, and advanced data management.
• The system includes fully integrated, powerful and flexible web-based operator screens as well as a web-based solar plant level reporting system that allows operators, owners and other stakeholders to monitor and analyze historical solar plant operation and performance.
• GE offers both a supervisory plant level control and an operational data management system for a solar plant consisting of GE inverters.

Capabilities

SUN IQ PLANT LEVEL CONTROL SYSTEM
• Voltage control (AVR)
• Line drop compensation
• Power factor control, VAR control
• Power curtailment & ramp rate control
• Power frequency drop control
• Park shut-down/start-up

SCADA SYSTEM
• SQL database & standard communication
• Real-time data visualization
• Remote inverter control
• Weather Station & Substation interface
• Historical data analysis
• Automated reporting

CLOUD-BASED DATA
Optional capability to upload data to the cloud enables access with GE’s Predix platform to perform remote visualization and plant predictive diagnosis.

ENERGY MANAGEMENT SYSTEM

EMS – Intelligent Energy Management System to control hybrid operation.

EXAMPLE: VOLTAGE CONTROL

VOLTAGE WITHOUT PLANT LEVEL CONTROL

VOLTAGE WITH PLANT LEVEL CONTROL

Simulation: PV output variation over 12 hour period (10 MW plant)
Electrical Balance of System (BOS)

GE Store solutions for power collection and grid connection

SOLUTIONS FROM THE GE STORE

GE is a global leader in power generation, serving thermal, renewables, and distributed power plants and is helping to efficiently connect that power to the grid. The products and solutions that make this happen are commonly referred to as “Electrical Balance of Plant” (EBoP), and in the solar industry as electrical “Balance of System (BOS)”. The different pieces making up the core eBOS offering range from power collection equipment and auxiliary systems, to the high voltage switchyard and total system control room.

POWER QUALITY TECHNOLOGY TO STRENGTHEN GRID OPERATION

GE’s full range of power electronics based power quality devices include FACTS (flexible AC transmission systems), SVC (static VAR Compensator) and STATCOM (Static Synchronous Compensator). Each of these are specifically designed to ensure dynamic voltage control and increased power transfer capability. They are easy to integrate into both new and existing grid structures can help improve grid reliability, and avoid significant upgrade costs for grid connections.

KEY COMPONENTS BY GE ARE:

Power Collection Equipment
- ISO Phase Bus
- Gen Circuit Breaker
- Gen Step-Up Transformer
- Auxiliary Transformers
- Transformer Monitoring
- Protection & Control Equipment

High Voltage Switchyard/Substation Supplies
- HV Switchyard Equipment
- Communications
- SCADA
- Protection & Control

Auxiliary Systems
- MV/LV Switchgear
- MCCs
- Static Frequency Converter (SFC)
- Static Excitation Equipment (SEE)
- Communications
- Power Quality Devices (FACTS)

Electricals & Control Rooms
- Distributed Control System (DCS)
- MV/LV Electrical Distribution Equipment
- MV Feeder Protection
- Power Quality Analyzers
- MCCs & UPS
- Telecommunications
For over a century, the electrical grid has served its purpose, delivering power when and where it is needed. In recent years, several factors have converged that have heightened attention on the reliability and functionality of electric grids.

Utilizing the power of software, power systems, machine learning, and other advanced analytics and next-generation design and visualization techniques, GE is using its extensive knowledge of the grid to develop new solutions that will help utilities predict and prevent potential failures before they happen. GE’s portfolio of power-grid-based technologies enables the use of real-time information to improve the operation of the grid.

GE intermittency management and renewables integration technology also allow the grid to handle more renewable power without increasing wear and tear on utility equipment, while also enabling the efficient transfer of renewable power over long distances, helping to move power from sunny, windy areas to the places where people live and work.

Our dedicated expert group of engineers and business experts is specialized in complete power system analysis and simulation. Cross-business teams work to analyze and ensure the compliance of wind, solar and thermal power plant integration to the grid, keeping GE and its customers ahead of grid interconnection challenges.

The Global Power Projects team is made up of a core group of leading technical and business experts from GE who use cross-company resources to help you solve your most difficult challenges. Our team can help you with your renewables application issues, and we also can perform grid code testing of power generation equipment and sub-synchronous torsional interaction analysis and risk mitigation. Additionally, we have expertise in power system stabilizer application issues as well as utility IT and grid modernization projects.

### Key Differentiator | Services Across the Project Life-Cycle

#### Grid Integration & Energy Consulting

- Grid integration analysis and power systems operation & planning

### Higher System Flexibility

By its nature, renewable energies can sometimes produce too much, or too little energy. This unpredictability can be managed through battery storage, allowing excess power generated to be stored for use at a time when power demand is higher.

### Enhanced Prospects for Diverse Applications

When managing intermittent energies in renewable and/or decentralized power plants, requirements such as continuous energy supply during black-outs, cold start support or power demand control to avoid high peak tariffs are important to enable cost-effective plant operation.

### Improving Operational Efficiency in Cyclic Power Applications

GE’s standardized, modular and scalable solutions help you to flexibly manage plant energy conditioning. Our customized storage offerings allow plant operators to play in the balancing power market, and/or to buffer the energy output of renewable or decentralized power plants.

GE’s expertise in plant controls, power electronics, and a variety of battery and enclosure technologies help to improve operational efficiency across your range of power and grid applications, including:

- Energy Management: peak demand reduction, back-up, photo-voltaic (PV) self-consumption, power quality.
- Transmission And Distribution: capacity management, asset deferral, frequency regulation, harmonic suppression, voltage support, and power quality.
- Micro-Grid Applications: grid management, PV integration, and grid enhancement.
- Thermal and Renewable Power Generation: virtual spin (no emissions), ramp rate control, frequency regulation, time shifting, voltage support, curtailment avoidance.

### GE’s Battery Storage Offering

Designed to meet specific site needs for power management and grid connection, GE’s solutions include:

- Proven battery technologies e.g. on Li-ion with or without hybrid advanced lead-acid batteries
- Highly efficient 3-level low voltage inverters connecting DC battery blocks to AC
- Energy Management Systems (EMS) to integrate the battery management system (BMS) into a fully functional storage digital controller based on GE’s IT platforms, HMI, data logging, diagnostics and SCADA interface.
- Electrical balance of plant equipment.

GE’s tailored solutions help to address availability and reliability requirements of the total storage system capability over its entire lifetime, based on a total cost of ownership approach.
For over a century, the electrical grid has served its purpose, delivering power when and where it is needed. In recent years, several factors have converged that have heightened attention on the reliability and functionality of electric grids.

Utilizing the power of software, power systems, machine learning, and other advanced analytics and next-generation design and visualization techniques, GE is using its extensive knowledge of the grid to develop new solutions that will help utilities predict and prevent potential failures before they happen. GE's portfolio of power-grid-based technologies enables the use of real-time information to improve the operation of the grid.

GE intermittency management and renewables integration technology also allow the grid to handle more renewable power without increasing wear and tear on utility equipment, while also enabling the efficient transfer of renewable power over long distances, helping to move power from sunny, windy areas to the places where people live and work.

Our dedicated expert group of engineers and business experts is specialized in complete power system analysis and simulation. Cross-business teams work to analyze and ensure the compliance of wind, solar, and thermal power plant integration to the grid, keeping GE and its customers ahead of grid interconnection challenges.

The Global Power Projects team is made up of a core group of leading technical and business experts from GE who use cross-company resources to help you solve your most difficult challenges. Our team can help you with your renewables application issues, and we also can perform grid code testing of power generation equipment and sub-synchronous torsional interaction analysis and risk mitigation. Additionally, we have expertise in power system stabilizer application issues as well as utility IT and grid modernization projects.
Integrated Power Plant Approach

Enables faster turnkey installation

INTEGRATED POWER PLANT APPROACH (EPI*) –
FASTER. MORE EFFICIENT. SUSTAINABLE.

With advanced technology and BOS components, we are able to support turnkey projects and install entire PV plants at lower cost. A smart system design enables a quick and easy installation of ground-mounted solar PV plants instead of complicated construction processes.

LOWER CAPEX

- Lower installation cost: quick and easy module system transport and installation
- Reduced turn-key cost of ground-based solar power plants i.e. less steel, wiring and conjunction components needed

LOWER OPEX

- Higher space efficiency allows easy site access, simple cleaning and maintenance,
- Improved long term performance due to lower degradation of modules

HIGHER PRODUCTIVITY AND ENERGY OUTPUT

- Integrated yield optimizing technologies
- Higher area efficiency and comparatively constant energy generation over the day thanks to low angle alignment and east/west orientation
- Large volume scalability
- Reactive power day-and-night for grid voltage stabilization

* 3rd party scope: EPI – Engineering, Procurement, Installation (vs. EPC: Engineering Procurement, Construction)
Future Solar PV Concepts
Re-thinking traditional LV DC collection systems

STRIVING FOR 1 US$ / WATT PV SYSTEMS

At GE, we are committed to help our customers lowering cost of electricity. GE is driving developments to achieve 1 US$ / Watt PV systems and to help building a sustainable industry.

Aiming to help you lower LCoE, we are applying the science and systems of power conversion while combining technology from the GE Store to help reducing equipment cost.

MOVE FROM LV TO MV – THE NEXT STEP TO LOWER DC BOS COSTS

Solar PV plants are capital intense, but they use fuel at no cost. Since solar PV plants cannot generate power at night, it is most important to obtain the highest possible energy output during daylight hours of operation.

Keeping losses at a minimum level and maximizing efficiency of the plant are key requirements.

Historically, the PV systems operate at low voltage levels. Operating at higher voltage level allows reduce losses.

Moving the PV system towards higher DC voltage allows to operate the plant with lower losses, thus at higher efficiency, and it bears the potential to reduce system cost i.e. by using less and smaller equipment such as transformers and cables.

MV DC COLLECTION CONCEPTS

MVDC COLLECTION TOPOLOGY 1

MVDC COLLECTION TOPOLOGY 2

HIGHER EFFICIENCY

• No transformer losses in DC/DC converters at night
• Low switching frequency (no 60 Hz tracking + harmonics filtering)
• Smaller footprint due to compact system design
• Better efficiency due to multiple MPPTs
• Up to 2% better efficiency due to no DC/DC conversion
• Suitable for connection with energy storage system

LONGER LIFETIME

• Improved safety: no reverse power feeding PVs which helps to increase PV life time
• Short circuit protection by additional diodes or PV short circuit switch

REDUCES SYSTEM COST

• Reduced system cost due to smaller transformers, and less cable cost
• Only 1 connection point to the grid, customized to meet grid requirements, N+1 at low cost

MV = Low Voltage | MV = Medium Voltage | BOS = Balance of System
Hybrid Power Plant Solutions
Innovative systems beyond just power generation

THE CHALLENGE – INTEGRATING RENEWABLE AND CONVENTIONAL ENERGY GENERATION

Due to the increasing environmental consciousness around the globe, the amount of renewable energy generation is steadily increasing. Not only industry and utilities in the Western world aim at reducing their carbon footprint and their dependence on fossil resources, but also developing countries seek to include renewable energy generation into their portfolio to lower the costs of electrifying remote and off-grid regions. Thus, the smart integration of existing conventional and novel renewable power generation is a global challenge in energy systems.

The generation of conventional and renewable power – ideally – becomes integrated and is generated in spatial proximity to the customer.

Conventional energy is required to cover base-load demands and to compensate for fluctuations in renewable generation. Renewables are used to offset diesel fuel consumption. Storage devices gain increasing interest in assisting to flatten out seasonal but also daily production and demand peaks. Heat can be used to provide hot water and process heat, but also for cooling purposes in HVAC systems. Therefore, energy generation as commonly employed has to be rethought and adapted to integrated systems that are tailored to customer needs.

THE SOLUTION – HYBRID ENERGY CONCEPTS IN DECENTRALIZED LOCATIONS

From our perspective, hybrid power plants are of key importance to performing the shift towards the new world of energy generation. These decentralized power plants integrate renewable and conventional energy generation in tailored solutions. The storage systems flatten out daily production peaks of renewable energy sources, thus increasing the renewables share in the energy mix and further reducing fuel cost. At the same time, they can stabilize a grid through controlling energy and serve as critical power supply during grid downtime and load shedding.

As such, manufacturers can reduce their dependence on transmission grids and have more control over their energy costs, utilities can electrify remote areas without the need of installing new transmission lines while keeping the costs of fuel and fuel transportation low, and island (both energetic and physical) can reduce their reliance on fossil fuel which allows them to generate energy more cost-efficient. Especially in face of rising fossil fuel prices, these benefits are achievable at very short payback periods.

OUR VALUE

From individual components to a holistic solution for hybrid power generation, our flexible offering ranges from pre-feasibility studies to the commissioning of the final plant, including GE technology and service agreements.

Our commitment is a solution that is tailored to the customer’s needs by a deep understanding of the on-site setup. To be fast and flexible in implementation, GE divides hybrid energy solutions into modular building blocks to easily scale the projects while keeping overheads from individual layout efforts to a minimum.
GE’s Hybrid Power Plant
Turning an idea into reality

OUR SHOWCASE IN BERLIN / GERMANY

In answer to Germany’s energy transition policy, GE constructed a smart and fully integrated hybrid power plant in the country’s capital, Berlin, on the site of GE’s first German foothold.

The individual components are dimensioned based on the customer’s needs and aim at reducing the levelized cost of electricity, while still maintaining grid access to allow for a cost efficient energy portfolio generation.

A rooftop solar plant provides electricity during daytime, which is either directly consumed or stored in the battery and consumed later to offset grid demand and engine operation.

ELECTRICAL ENERGY GENERATION

The hybrid system is monitored and controlled by an intelligent management system. Crucial data is processed and displayed in real-time, such that every component of the plant is under steady supervision to make the system operate in the most efficient way.

ENERGY FLOWS

ELECTRICAL ENERGY GENERATION

PV System 621 kWp

Customer

Natural gas fired CHP 400 kWth

Distribution grid

Battery 200 kWh / 100 kW

THERMAL ENERGY GENERATION

Thermal buffer 440 kWh

Peak boiler

Customer

Natural gas fired CHP 490 kWth

UP TO 60 % AUTARKIC AND 0.015 EUR/KWH LOWER ELECTRICITY COST VS LOCAL UTILITY

The installation of a GE Jenbacher 312 offers the opportunity to produce base load electricity and heat at the same time. The CHP (combined heat and power) unit is driven by heat demand, where heat is consumed onsite and electricity is either used to cover local demand or is fed into the grid. The CHP also helps overcome the seasonal variation of PV generation, which decreases in winter times. While temperatures sink, the CHP load ramps up due to increasing heat demand and the cogenerated electricity covers the PV deficit.

Likewise to the battery, a thermal buffer allows for time-delayed generation and consumption of energy. Hence, energy generation can be performed more flexibly and responsively to meet demand.

The hybrid system is monitored and controlled by an intelligent management system. Crucial data is processed and displayed in real-time, such that every component of the plant is under steady supervision to make the system operate in the most efficient way.

UP TO 60 % AUTARKIC AND 0.015 EUR/KWH LOWER ELECTRICITY COST VS LOCAL UTILITY

The installation of a GE Jenbacher 312 offers the opportunity to produce base load electricity and heat at the same time. The CHP (combined heat and power) unit is driven by heat demand, where heat is consumed onsite and electricity is either used to cover local demand or is fed into the grid. The CHP also helps overcome the seasonal variation of PV generation, which decreases in winter times. While temperatures sink, the CHP load ramps up due to increasing heat demand and the cogenerated electricity covers the PV deficit.

Likewise to the battery, a thermal buffer allows for time-delayed generation and consumption of energy. Hence, energy generation can be performed more flexibly and responsively to meet demand.

The hybrid system is monitored and controlled by an intelligent management system. Crucial data is processed and displayed in real-time, such that every component of the plant is under steady supervision to make the system operate in the most efficient way.

UP TO 60 % AUTARKIC AND 0.015 EUR/KWH LOWER ELECTRICITY COST VS LOCAL UTILITY

The installation of a GE Jenbacher 312 offers the opportunity to produce base load electricity and heat at the same time. The CHP (combined heat and power) unit is driven by heat demand, where heat is consumed onsite and electricity is either used to cover local demand or is fed into the grid. The CHP also helps overcome the seasonal variation of PV generation, which decreases in winter times. While temperatures sink, the CHP load ramps up due to increasing heat demand and the cogenerated electricity covers the PV deficit.

Likewise to the battery, a thermal buffer allows for time-delayed generation and consumption of energy. Hence, energy generation can be performed more flexibly and responsively to meet demand.

The hybrid system is monitored and controlled by an intelligent management system. Crucial data is processed and displayed in real-time, such that every component of the plant is under steady supervision to make the system operate in the most efficient way.

UP TO 60 % AUTARKIC AND 0.015 EUR/KWH LOWER ELECTRICITY COST VS LOCAL UTILITY

The installation of a GE Jenbacher 312 offers the opportunity to produce base load electricity and heat at the same time. The CHP (combined heat and power) unit is driven by heat demand, where heat is consumed onsite and electricity is either used to cover local demand or is fed into the grid. The CHP also helps overcome the seasonal variation of PV generation, which decreases in winter times. While temperatures sink, the CHP load ramps up due to increasing heat demand and the cogenerated electricity covers the PV deficit.

Likewise to the battery, a thermal buffer allows for time-delayed generation and consumption of energy. Hence, energy generation can be performed more flexibly and responsively to meet demand.

The hybrid system is monitored and controlled by an intelligent management system. Crucial data is processed and displayed in real-time, such that every component of the plant is under steady supervision to make the system operate in the most efficient way.
Our goal is to offer our customers a complete commercial solution covering GE’s products, services and financing. More than 100 commercial finance experts in more than 25 countries provide you with financial advisory services through all stages of your project (acquisition, pre-bid, bidding, execution and negotiations) and support in structuring and arranging financial solutions using a variety of financial products, such as deferred payment, leasing, project- and export financing, contracting, equity and mezzanine funding.

The team works closely with and has access to local, global and alternative debt and equity sources, such as export credit agencies, commercial banks, multilaterals, policy banks, leasing companies, private equity and institutional investors. In addition, GE might consider investing in or providing financial support for strategic projects acting as a catalyst for third party debt and equity.
Our goal is to offer our customers a complete commercial solution covering GE’s products, services and financing. More than 100 commercial finance experts in more than 25 countries provide you with financial advisory services through all stages of your project (acquisition, pre-bid, bidding, execution and negotiations) and support in structuring and arranging financial solutions using a variety of financial products, such as deferred payment, leasing, project- and export financing, contracting, equity and mezzanine funding.

The team works closely with and has access to local, global and alternative debt and equity sources, such as export credit agencies, commercial banks, multilaterals, policy banks, leasing companies, private equity and institutional investors. In addition, GE might consider investing in or providing financial support for strategic projects acting as a catalyst for third party debt and equity.

**PROJECT FINANCING**
- Off balance sheet
- Cashflow based financing, limited recourse to sponsor
- Secured by project’s assets
- Agreements on risk allocation

**EXPORT FINANCING**
- On balance sheet
- Risk mitigation in difficult segments
- Longer/cheaper financing
- Requires approval process
**Project Management**

GE's offers cover at each step of your project, namely conceptual design, engineering, manufacturing, equipment transportation and commissioning of the plant. We will accompany you from the initial talks and sales pitches to the handover of the commissioned plant. With more than 1.7 GW installed base of solar inverters, GE can look back on a rich experience in Solar PV that allows a straightforward design and construction of your plant. From our perspective, experienced project managers are key to success – they coordinate the individual contractors, immediately perceive uprising challenges and manage them in a structured and well-organized manner.

GE offers training sessions for your employees, either on-site or at its manufacturing facility. They are held by experts to comprehensively convey the service and maintenance concepts. GE is passionate about customer satisfaction in each and every product and service offered. Long-term relationships are built with our customers by jointly contributing to their success.

<table>
<thead>
<tr>
<th>Services</th>
<th>Parts</th>
<th>Proactive Diagnostics</th>
<th>Contractor Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unscheduled Maintenance</td>
<td>Remote Support / Diagnostics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scheduled Maintenance</td>
<td>Remote Service Helpdesk &amp; Support (Central Telephone Available 24/7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Services &amp; Parts</td>
<td></td>
<td>Proactive Diagnostics</td>
<td></td>
</tr>
<tr>
<td>Obssolescence Manage / Advise</td>
<td>Replace as required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE offered Equipment Availability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE provided</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Spare Parts Package</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PHASES OF PROJECT MANAGEMENT**

- **Sales Pitches**
  - Layout & design

- **Order to Handover**
  - Engineering
  - Manufacturing & transport to site
  - Construction

- **Commissioning**

<table>
<thead>
<tr>
<th>Inquiry to order</th>
<th>Order to remittance</th>
</tr>
</thead>
</table>

**Customer**

**Planning Office**

**Project Manager**

- Application engineering
- Documentation
- Mechanical/electrical support
- Subsupplier

**Plant Construction Contractor**

*Project managers are key to a successful project by coordinating the individual stakeholders*
MEETING THE NEEDS OF YOUR OPERATIONAL MODEL

GE offers customized services to meet the needs of customers' individual operational and maintenance models (from daily operation, routine & scheduled maintenance, to outage services) comprising

- Remote monitoring & diagnostics
- Maintenance
- Spare parts & obsolescence management
- Warranty extensions
- Response time guarantees
- Availability guarantees

as risk sharing mechanisms.

FLEET DATA ANALYTICS AND PREDICTIVE MAINTENANCE

Through advanced digital platforms, we deliver expert onsite and remote 24/7 support, emergency interventions and all customized to meet unique customer requirements.

LONG TERM & LOCAL SUPPORT

We offer both on demand services and long term service contracts with a range of options from “Keep me running” to “Partnership”. With over 1,000 field service engineers, and operating in more than 170 countries GE has the organization to support customers wherever they may be.

ENHANCING ENERGY HARVEST ACROSS PROJECT LIFE-CYCLE

GE’s services help to support continuous plant operation, giving higher energy yield and therefore high return on investment across life-cycle. For equipment benefiting from GE long term service agreements, we expect up to greater than 99% inverter availability in the field.

REDUCING RISK, ENHANCING PRODUCTIVITY

GE offers services that address a broad range of activities that are necessary for utilities and farm operators to protect assets, keep critical processes running, to help decreasing risk and enhancing productivity while letting the owner/operator concentrate on their core business.

DELIVERING CUSTOMER VALUE WITH ENHANCED ASSET OPTIMIZATION AND IMPROVED AVAILABILITY

INCORPORATING OEM RECOMMENDED MAINTENANCE

### (TERM IN YEARS: UP TO 20)

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Keep Me Running</th>
<th>Partnership</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONTRACT MANAGEMENT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>REMOTE SERVICE HELPDESK &amp; SUPPORT (CENTRAL TELEPHONE AVAILABLE 24/7)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SCHEDULED MAINTENANCE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERVICES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PARTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PROACTIVE DIAGNOSTICS</td>
<td></td>
<td>CONTRACTOR OPTION</td>
</tr>
<tr>
<td><strong>UNSCHEDULED MAINTENANCE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REMOTE SUPPORT/DIAGNOSTICS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERVICES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERVICES &amp; PARTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>OBsolescence</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MANAGE/ADVERTISE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>REPLACE AS REQUIRED</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WARRANTED REACTION TIME</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REMOTE SUPPORT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FIELD SERVICE ENGINEER DEPLOYMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WARRANTED EQUIPMENT AVAILABILITY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TRAINING</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INITIAL SPARE PARTS PACKAGE</td>
<td>RECOMMENDED</td>
<td></td>
</tr>
<tr>
<td>CUSTOMER PROVIDED WAREHOUSE</td>
<td>RECOMMENDED</td>
<td></td>
</tr>
<tr>
<td>REMOTE ACCESSIBILITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ONSITE CUSTOMER SUPPORT DURING INTERVENTIONS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Included in fixed fee  
* Supplied as an extra fee  
* Customer to supply as Prerequisite
Our Success

2.3+ GW
Global installed base
in Solar Inverters

4.4+ GW
GW global backlog
in Solar Inverters

Contact Us
GE POWER CONVERSION HEADQUARTER
GE Energy Power Conversion Group SAS
103 rue de Grenelle
F-75345 Paris Cedex 07
France
www.gepowerconversion.com
renewables.powerconversion@ge.com

OUR CENTER OF EXCELLENCE FOR SOLAR PV:
GE Power Conversion GmbH
Culemeyerstrasse 1
D-12277 Berlin
Germany
Contact Us

GE POWER CONVERSION HEADQUARTER

GE Energy Power Conversion Group SAS
103 rue de Grenelle
F-75345 Paris Cedex 07
France

www.gepowerconversion.com
renewables.powerconversion@ge.com

OUR CENTER OF EXCELLENCE FOR SOLAR PV:

GE Power Conversion GmbH
Culemeyerstrasse 1
D-12277 Berlin
Germany
The GE Store

DRIVING COMPETITIVE ADVANTAGE ACROSS OUR BUSINESSES

We drive enterprise advantages that benefit the entire company, through what we call the ”GE Store”. It means that every business in GE can share and access the same technology, markets, structure and intellect. The value of the GE Store is captured by faster growth at higher margins – it makes the totality of GE more competitive than the parts. No other company has the ability to transfer intellect and technology as we can through the GE Store.
The GE Store

DRIVING COMPETITIVE ADVANTAGE ACROSS OUR BUSINESSES

We drive enterprise advantages that benefit the entire company, through what we call the “GE Store”. It means that every business in GE can share and access the same technology, markets, structure and intellect. The value of the GE Store is captured by faster growth at higher margins – it makes the totality of GE more competitive than the parts. No other company has the ability to transfer intellect and technology as we can through the GE Store.

ENERGY CONNECTIONS
- Electrification, controls & power conversion technology

RENEWABLE ENERGY
- Sustainable Power system & storage

OIL & GAS
- Services & technology – a first-mover in growth regions

TRANSPORTATION
- Engine technology & localization in growth regions

APPLIANCES & LIGHTING
- LED is gateway to energy efficiency

HEALTHCARE
- Diagnostics technology – a first-mover & anchor in growth markets

AVIATION
- Advanced materials, manufacturing & engineering productivity

POWER
- Combustion sciences & services, installed base

GE DIGITAL

GLOBAL GROWTH ORGANIZATION

CULTURE & SIMPLIFICATION

GLOBAL RESEARCH CENTER
Harnessing the Power of the Sun

Helping to lower the cost of electricity.

GE Power Conversion:
More efficient and sustainable solutions
for Cost-Effective solar PV power

www.gepowerconversion.com
renewables.powerconversion@ge.com

©2016 General Electric Company