

Distribution Energy Solutions

Future of Energy

*Roda KUM
Grid Solutions Service
November 24, 2018*



Energy Transformation

Ecosystems transform rapidly as technology advances



Can be difficult to predict the pace of change, but we can see what is coming...

Powerful trends shaping the nature of electricity



DECARBONIZATION

By 2026, **RENEWABLES** will represent **40%** of global installed generation capacity*

IMPACT

- Growing share of renewables an increasing challenge to the traditional power system model

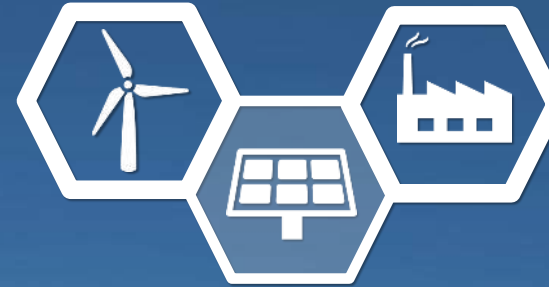


DIGITIZATION

EXPONENTIAL GROWTH of connected devices & smart sensors

IMPACT

- Real time decision making becomes possible ... new software solutions open breakthrough optimization



DECENTRALIZATION

GROWING PENETRATION of Distributed Energy Resources

IMPACT

- End users become active actors of the power system ('prosumer') ... growing grid complexity



ELECTRIFICATION 2.0

ELECTRIFICATION OF ENERGY-INTENSIVE USES

IMPACT

- Step increase in electricity consumption ... accelerating Decentralization

Our future will look very different

- Zero carbon, near-zero variable cost generation... at lifecycle parity
- Battery storage... balancing supply & demand, eliminating peaking capacity
- Rapid growth of electric vehicles... the end of ICE's
- Rapid growth of autonomous vehicles... change the paradigm of vehicle ownership
- Electrification of everything... as means to deep decarbonization
- Peer-to-peer energy trading

Supplier-centric, centralized power system to meet varying load requirements



Consumer-centric, participatory digital network that intelligently balances load and available supply

At what pace will the transformation occur?

Tailwinds

- Rapid cost reductions in solar & storage
- Digital technology & AI
- Connected smart-devices growth
- Consumer choice & engagement
- EV lifecycle cost parity + value to grid
- Autonomy improves costs, time, safety, land usage

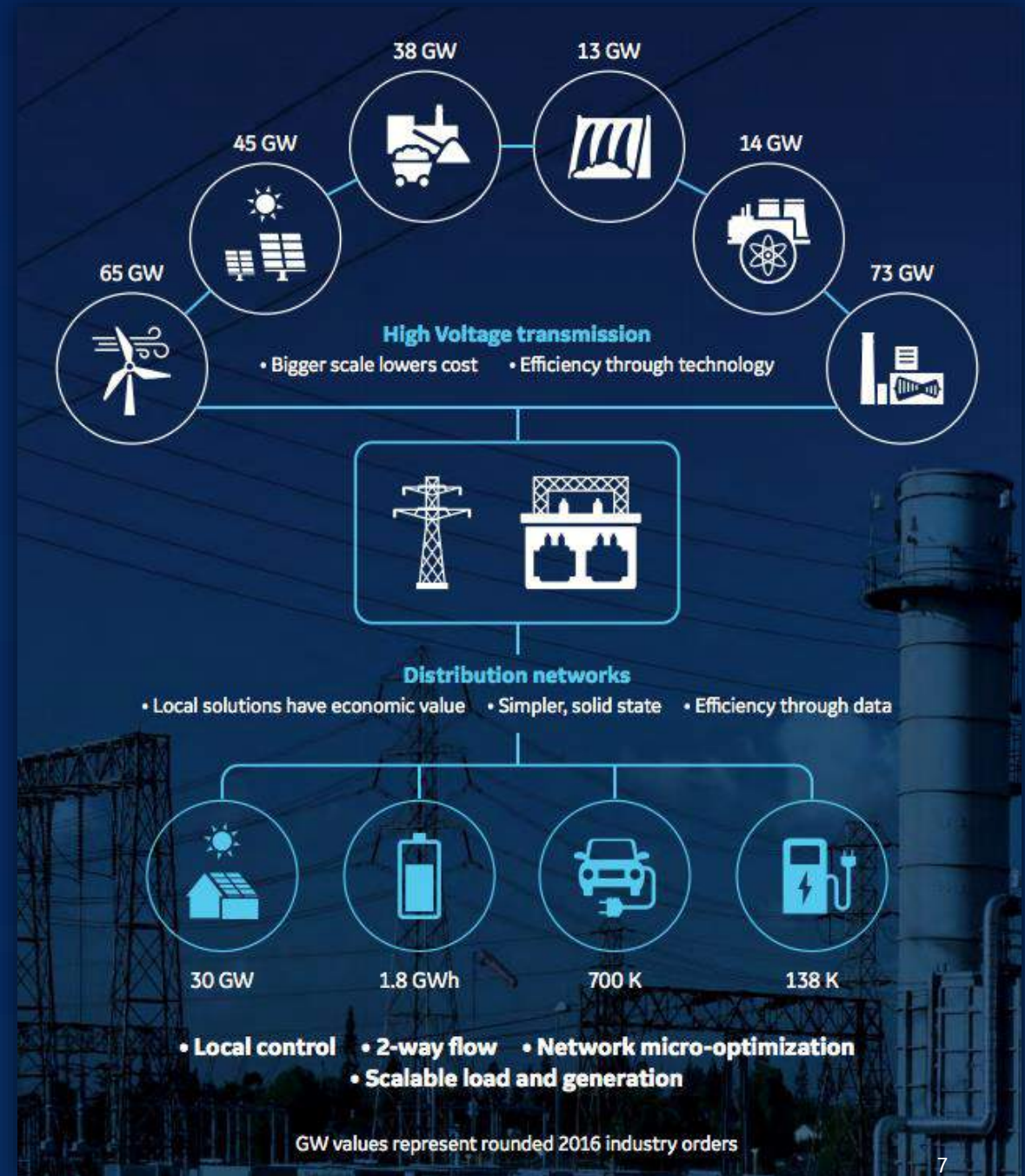
Headwinds

- Massive disruption to jobs drives policy barriers
- Energy burden left on lower-income families
- Saturation of peak afternoon solar decreases PV value faster than cost decline

Power System Transformation

- Distributed power technologies creating the need for two-way power flows.
- New technologies such as batteries are providing opportunities throughout the T&D network.
- Transformative applications such as electric vehicle platforms are creating new synergies.
- Baseload power options—coal, gas and nuclear power continue to expand.

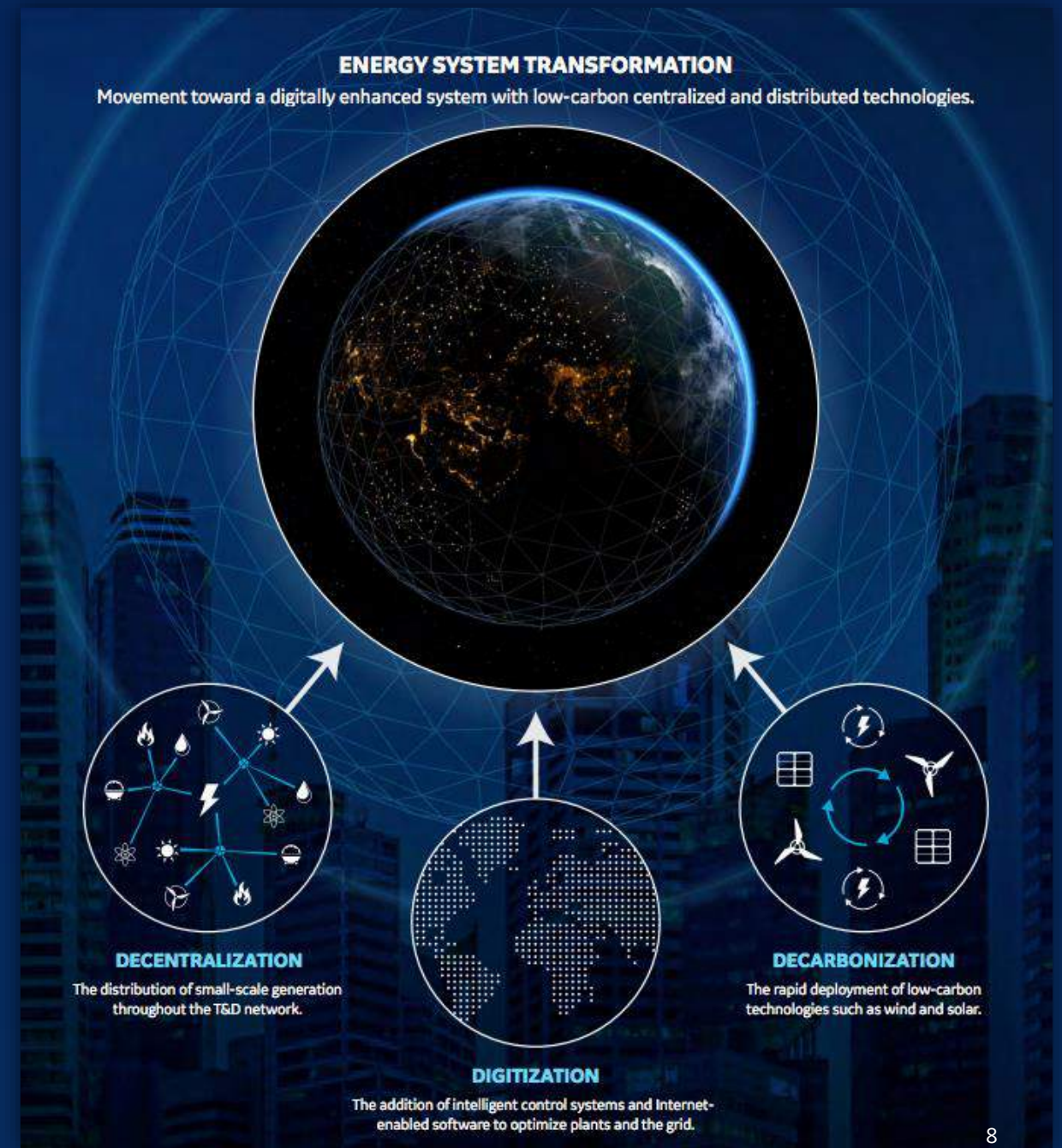
A two-way, intelligent and electric power network is emerging.



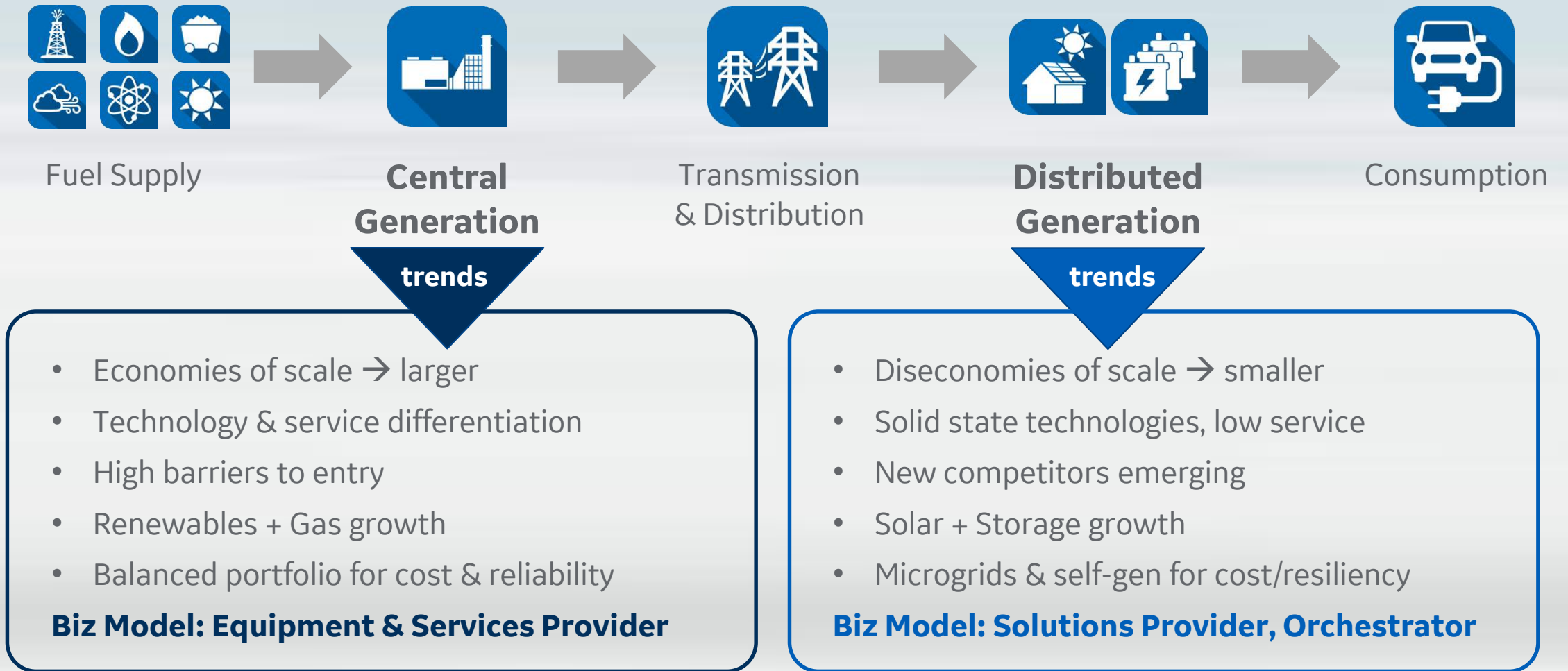
Reimagining Electricity

- **Decentralization:** Economically competitive small, distributed power systems are being installed in increasing numbers.
- **Decarbonization:** Low-carbon technologies are exceeding growth expectations.
- **Digitization:** Asset, facility and fleet level, Internet-enabled applications are proliferating.

These factors are transforming the global electric power system, creating new challenges and opportunities.



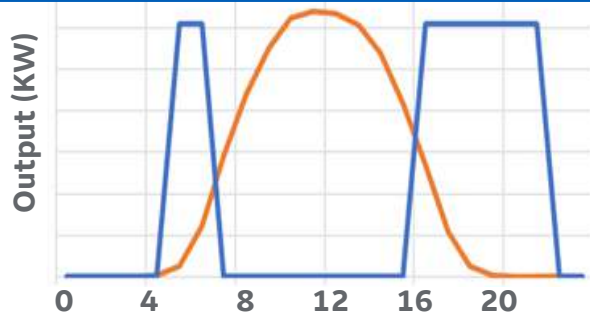
Market Trends



Future will be combination of central & distributed ... must have strong capability in both

New solutions are needed - examples

Kaua'i Island Solar



12MW Solar + 60MWh ES

- Store & Shift ~100% of solar during peak hours
- Use energy offset fuel burn during shoulders
- Avoid curtailment of other renewables on the grid

World's First Battery-Gas Turbine Hybrid

- GE 10MW ES + 50MW LM6000 gas turbine
- Enhances flexibility, reliability and response time to customer's energy demands
- Allows more effective use of renewables and faster response to changing demands



Philadelphia Navy Yard Microgrid

- Full energy plan to meet present and future needs of growing commercial center
- High efficiency & reliability
- Combines GE microgrid management software and equipment offerings

Integrating storage, software, and system design to deliver new customer value

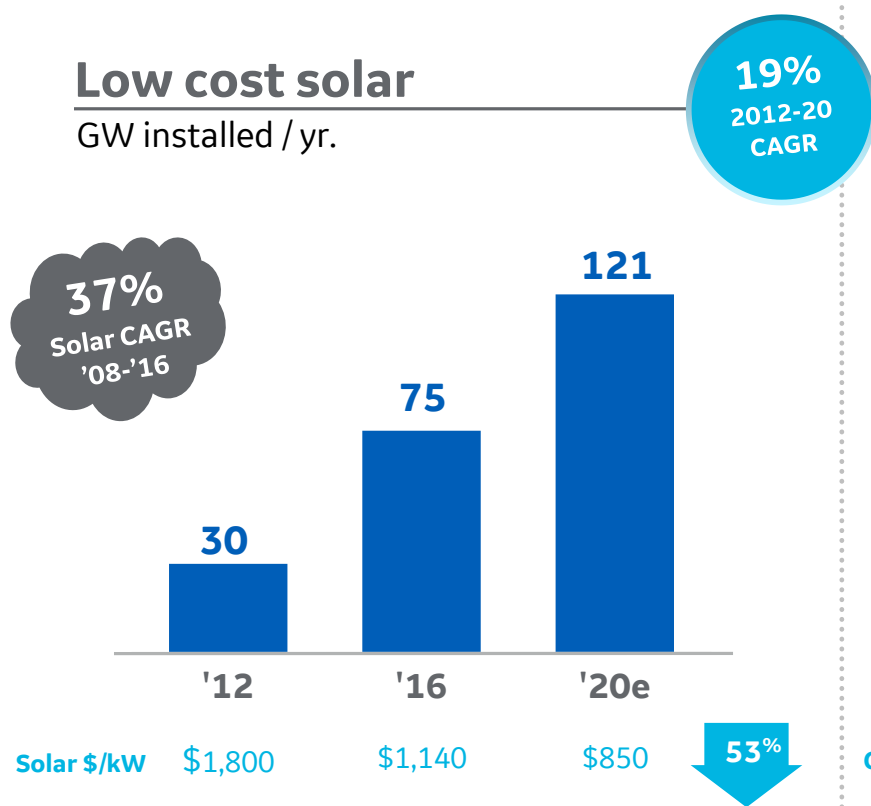
Capabilities required for the future of energy

- Deep technical & market domain expertise
- Strong digital capabilities & analytics
- Access to data on consumption behaviors & patterns
- Controllable loads and assets under management
- Artificial intelligence & machine learning capabilities
- Blockchain experience & peer-to-peer trading schemes
- New business models
- Strong partnerships across multiple industries

Energy transition underway ... driven by rapid economic shift

Low cost solar

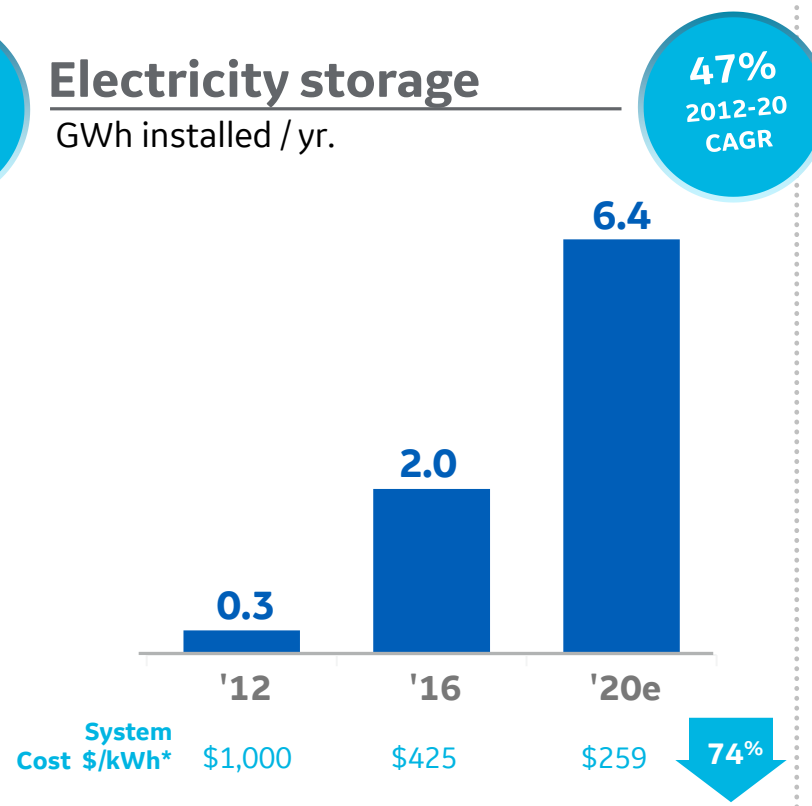
GW installed / yr.



19%
2012-20
CAGR

Electricity storage

GWh installed / yr.

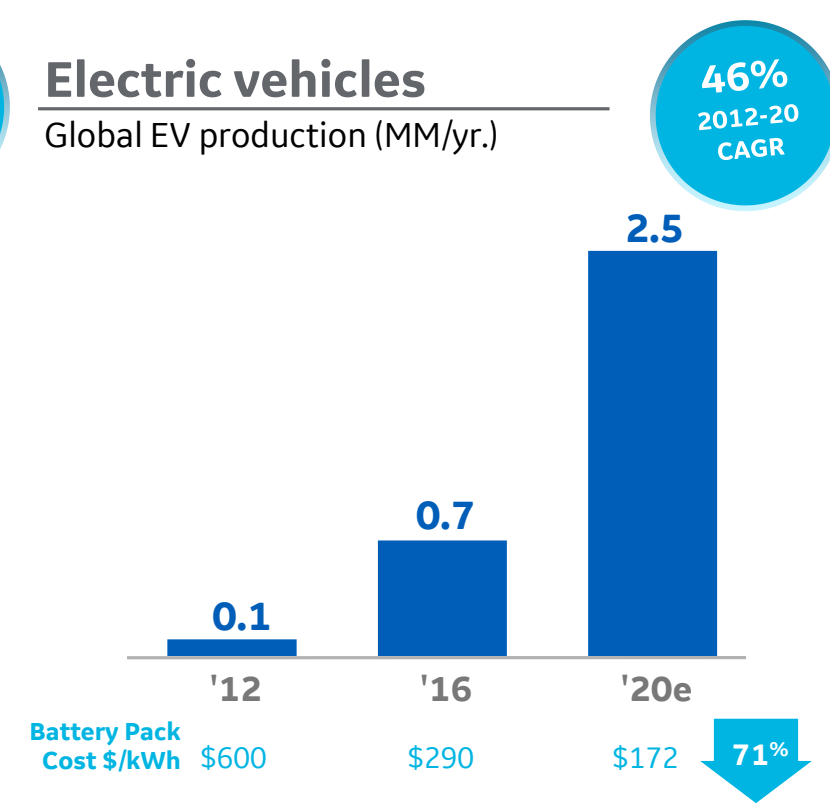


* 4 hour system

47%
2012-20
CAGR

Electric vehicles

Global EV production (MM/yr.)



Distributed and electrified solutions at competitive cost



Source: GTM, BNEF, GE Analysis

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GE Power



ABOUT GE —

GE drives the world forward by tackling its **biggest challenges**:

ENERGY and TRANSPORTATION— THE ESSENTIALS OF MODERN LIFE.

By combining **world-class engineering** with **software** and **analytics**, GE helps the world work more efficiently, reliably, and safely. For more than 125 years, GE has invented the future of industry, and today it leads new paradigms in additive manufacturing, materials science, and data analytics.

GE people are **global, diverse** and **dedicated**, operating with the highest integrity and passion to fulfill GE's mission and deliver for our customers.



GE POWER FACTS

GE technology delivers **1/3 OF THE
WORLD'S ELECTRICITY**

GE technology can be found in **90% OF
UTILITIES WORLDWIDE**

40% of the world's energy is managed by
our software



How GE powers the world



~5,900

Gas turbines



~9,900

Generators



~1,000

Boilers



~300

Heat recovery
steam generators



>35000 WT capacity installed
globally



~1,600

Aeroderivative
gas turbines



~2,600

Utility steam
turbines



~3,400

Industrial
steam turbines



85 MW capacity installed at 92 sites



19k GE personnel
in **60+** countries

50+ repairs centers
in **25+** countries

28k+ power generation
assets installed globally

~140 MW & 180 MWH of grid
storage projects awarded globally

~1.6 TW of installed capacity ... providing 1/3 of the world's power supply

GE Power Facts

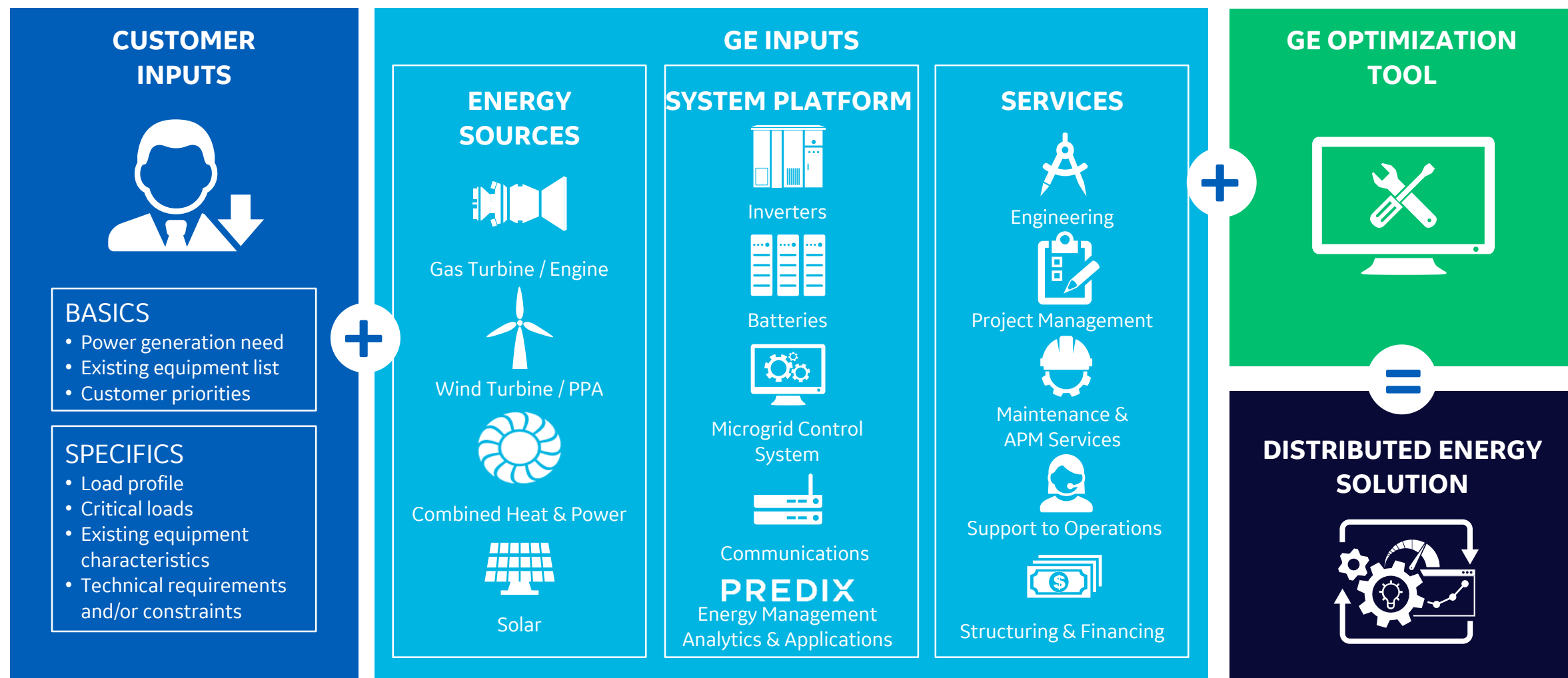
- 125 years old ... ~80,000 Employees
- GE technology delivers **1/3 OF THE WORLD'S ELECTRICITY**; each day GE's Power capacity supports an additional 100,000 people worldwide
- **~1,600+ GW** installed base
- **260+ MILLION** operating hours on GE's gas turbine fleet
- GE technology can be found in **90% OF UTILITIES WORLDWIDE**
- **25+** of the world's leading power producers have signed up as Predix™ customers
- **40%** of the world's energy is managed by our software
- GE's Greenville, South Carolina site (U.S.) is the **WORLD'S LARGEST** gas turbine test facility



- GE's H-class turbine now operating in 5 countries with 90k+ operating hours and **GUINNESS WORLD RECORDS** for combined cycle at Chubu Electric and EDF Bouchain
- GE's F-class turbines account for the **WORLD'S LARGEST FLEET, W/>1,100 INSTALLED** units and **64 MILLION** operating hours
- GE's E-class turbines account for **>3,000 INSTALLED UNITS W/143 MILLION COMBINED** operating hours
- 1st w/advanced ultra-supercritical coal-fired power technology achieving **>47% efficiency** (vs. global avg. of 34%)
- GE's Boiling Water Reactor technology is utilized in approximately **45 REACTORS GLOBALLY**
- **35,000 GE GAS ENGINES** deployed, enough to **POWER >25 MILLION HOMES** in the U.S.
- **92,000 DIGITAL ASSETS** under management through the Industrial Internet
- **40%** of the world's power generation assets serviced by GE

Distributed Energy Solutions Offering and Methodology

GE Distributed Energy Solutions approach



GE Power – World-class Technology and Business Capability



**DISTRIBUTED ENERGY
SOLUTIONS**



GAS POWER SYSTEMS



SOLAR



ENERGY STORAGE



GRID



FUEL



FINANCING



RESEARCH / CORPORATE



ENERGY CONSULTING



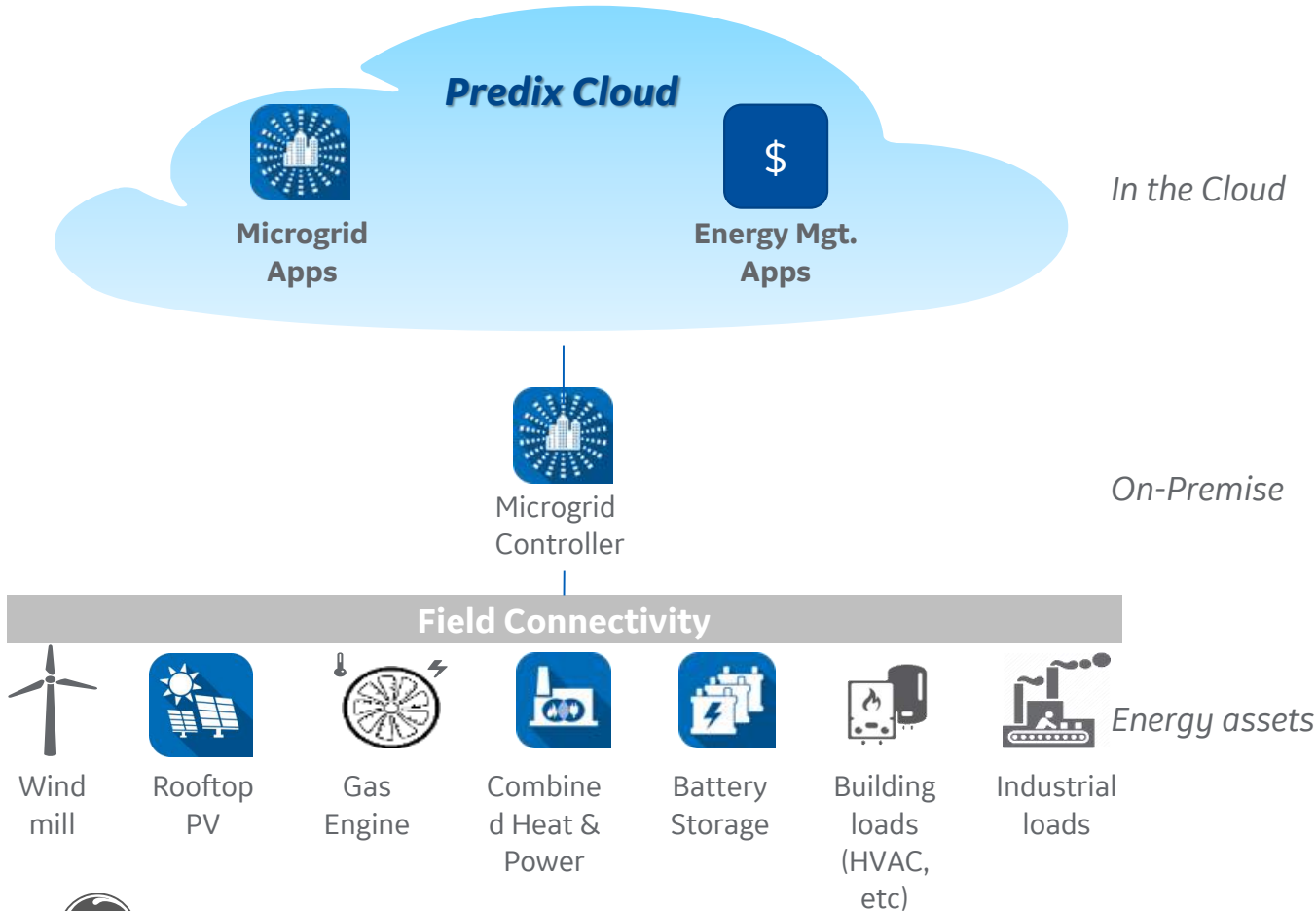
PARTNERS

Utilizing GE's strength and reach... positioned to deliver customer value



Focus on microgrid platform

Microgrid and Energy Management High-Level Architecture



Benefits and High-Level Approach

Key benefits:

- Industrial-grade Products
- Secured Connectivity
- Modular offering
- Tailored by customer and by site

High-level approach:

- Pre-feasibility phase: 3-4 weeks
- Detailed Study and Business Case: 4-6 weeks
- Implementation Phase: 12-18 months
- Running phase: up to 10 years

Remote Network Operation Center



GE's Microgrid References



AMERICAS

- Philadelphia Navy Yard – Microgrid / DERMS
- University of Ontario – Microgrid Automation
- Portsmouth Navy Yard – Microgrid Islanding
- 29 Palms – Marine Base Microgrid
- RNEST + P67, P70, P68, P71 – Petrobras, Brazil



EUROPE / MIDDLE EAST

- NiceGrid – Microgrid / DERMS
- Issygrid – Community Energy Management
- FEDA – Andorra, Community Energy Mgmt
- Eco2charge – EV smart charging
- Emirates Global Aluminum Industrial Energy Mgmt



ASIA / PACIFIC

- Singapore – REIDS microgrid pilot
- Singapore – Nanyang Technological University Microgrid
- Australia – ICHTHYS offshore platform and FPSO



Microgrid Controls Architecture

Microgrid Portfolio Management System (MPMS)
R-NOC: Remote Network Operation Center



Microgrid Energy Management System (MEMS)

Operations Planning	Forecasting	Scheduling	Asset Performance Management	Visualization & Reporting	Operation Dashboards
Weather Services	Portfolio Optimization	Dispatch		Meter Data Management	Billing & Accounting

Microgrid Automation Control System

Data Communication Gateways

Integrated Protection & Controls



Switch

Substation Bus Bar

Switch



Seamless Islanding & Reconnection

Volt- VAR & Frequency Regulation

Substation Switch Yard



Electric Grid

CHP

Steam Production

Chilled Water

Hot Water

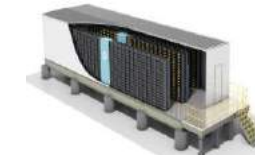
Electric Energy

Solar PV



Ground Mount PV

Storage



MW Scale Battery Energy Storage



Philadelphia Navy Yard Microgrid

Commercial & Industrial Park owned and operated by the City of Philadelphia



Project purpose

- **Infrastructure:** Upgrade 1930s vintage system to be resilient, reliable, and distributed without expanding city infrastructure
- **Business Model:** Savings, forecasts, tariffs, incentives, procurement, & O&M
- **Building owner opportunities:** Demand response programs & partnerships, Distributed Generation, and Energy Efficiency
- **Test-bed outreach / R&D:** Campus for energy innovation, DOE support

Focused on sustainability and consumption efficiency

- **Dense urban area:** 7.6MM ft³, 150+ companies, and 13,000+ people
- **Critical energy demand in constrained area:** 25 MW peak load
- **Comprehensive energy solution**



Gas power
6 MW



Solar
1 MW



Energy Storage*
2.5 MW/5 MWh



Microgrid
control room



↑ Resilience

↓ Capex

↓ Opex

↑ Local Capacity

Economic Development



* In progress

As the world becomes more sensitized to CO₂,
hyperconnected, distributed and electrified...

GE has a comprehensive energy offering for companies to



Create system benefits locally and scale globally at the speed of business

*System Design
Development*

*Local control & grid integration
Financing*

*Leading technology
Monitoring & maintenance*

GE Distributed Energy Solutions



Electrifying transportation

Transportation evolving...

>2M

EVs on the road today
>10x vs. 180k in '12

~1M

EVs in China in '20
12M on road = 120 GW V2G potential

>150

New EV models released by '25
GM, VW, Volvo, others electrifying

>\$50B

Infra. & battery spend through '21
"make ready" grid, >700k stations

~17X

GWh deployed vs. stationary
~1,300 GWh vs. 75 GWh ('16 -'24)

>300 GW

Controllable load from V2G in '25
Buses & delivery 1st opportunity

... converging with electricity

GE'S RESERVOIR STORAGE UNIT ... Up to 4 MWh Capacity



Enhanced to reduce installation cost and shorten project schedule

UP TO 15% EXTENDED BATTERY LIFE
UTILIZING PROPRIETARY BLADE
PROTECTION UNITS

**UP TO 50% REDUCED
CONSTRUCTION TIME** WITH FACTORY
BUILT & TESTED SOLUTION

IMPROVE SAFETY BY REDUCING FAULT
CURRENT BY **UP TO 5X**

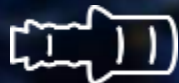
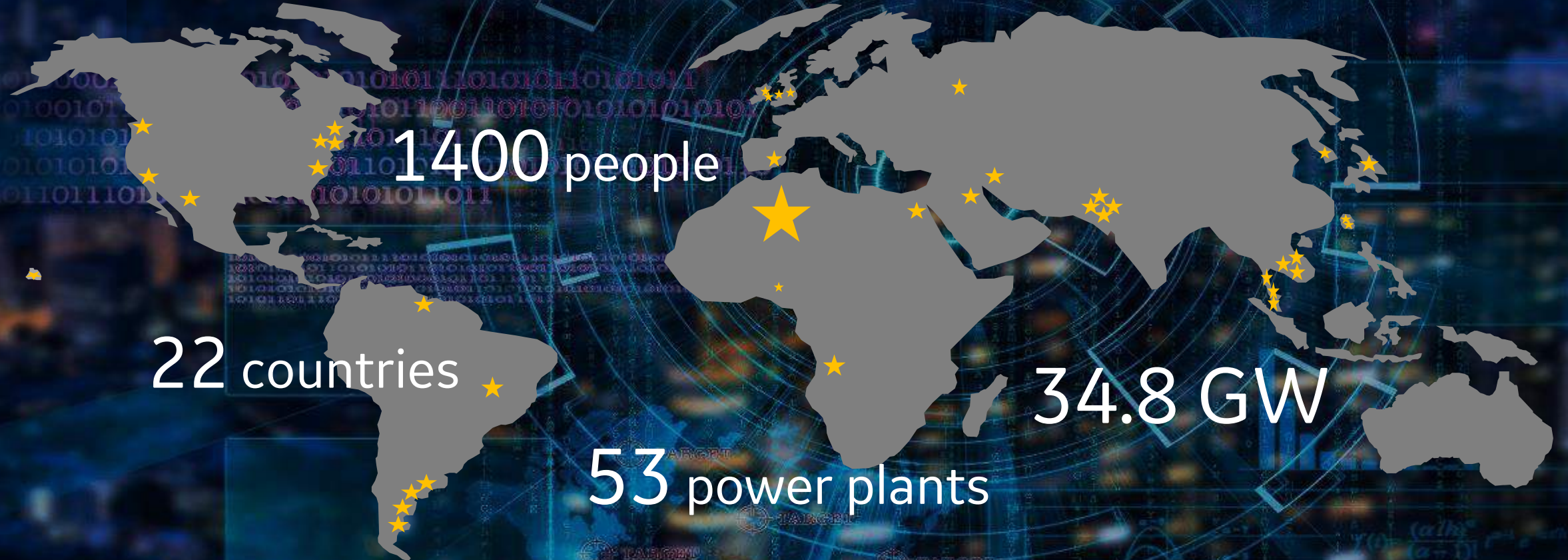
**IMPROVE INTEGRATION AND
MAXIMIZE UTILIZATION OF CONNECTED
GENERATION**





GE O&M sites globally – Fast growing

ALL TECHNOLOGIES: H, F, E, B, GT 11 | GT24 | GT26 | AERO | STEAM | SOLAR



GAS TURBINE



STEAM
TURBINE



GENERATOR



HRSG



BOP



COAL



BIOMASS



SOLAR



OEM



Case Studies

Portsmouth Naval Shipyard Microgrid

US Navy Facility – 10 MW onsite CHP

- Seamless Islanding & Fast load-shed
- Successfully live tested seamless islanding twice in 2016
- Frequency Regulation with BESS

Technology/Methodology Description

○ MCS / FLS

- GE C90 Plus
- F35 Feeder Protection Relays
- D400 Remote Terminal Unit
- GPS Controlled Clock
- MODBUS via Ethernet and Fiber



○ BESS

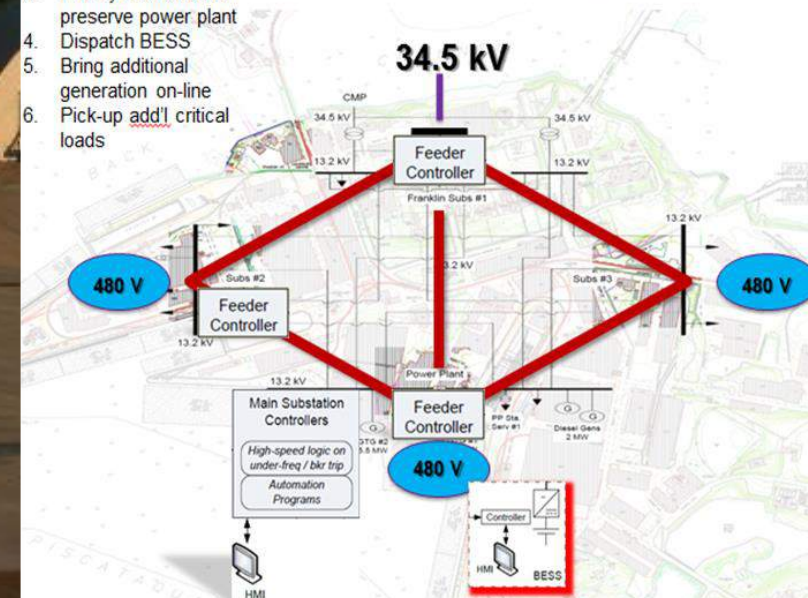
- Battery, 580 kWh Li-Ion
- Inverter, 500 kW Bi-Directional
- Site Controller
- MPLS Network, ISO Router & RTU



Fast load-shed & BESS

1. Monitor all sources and loads
2. Loss of Utility
3. Priority load shed to preserve power plant
4. Dispatch BESS
5. Bring additional generation on-line
6. Pick-up add'l critical loads

Technical Approach



Military



Universities

APPLICATION
CAMPUS

PROJECT
UNI. OF ONTARIO INSTITUTE
OF TECH.

LOCATION
CANADA

Challenge

Reduce electricity costs on campus while maximizing renewable sources, and provide a seamless transition between grid connection and on-site generation for critical loads during grid failures.

Solution

Campus-based microgrid system with monitoring and control capabilities delivering:

- Active system to optimally control Battery Energy Storage System (BESS) and other energy storage sources based on different forecasting engines, providing a seamless transition in case of grid failure
- Simulation tool to evaluate the performance of the control system when faced with different load and electricity prices
- Monitoring system to provide status, event, and alarm management with remote data access



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Energy Storage*
2.5 MW/5 MWh



Microgrid
control room



↑ Resilience

↓ Capex

↓ Opex

↑ Local Capacity

Economic Development



* In progress



Island

Airports

Malpensa - Italy

20 million passengers / year

- ✓ Control solution for power distribution and generation systems from Malpensa Airport
- ✓ Technical requirements: high availability and open connectivity
- ✓ Solution: GE HMI/SCADA, GE Historian, PACSystems RX7i (redundant configuration) and VersaMax IO
- ✓ 25 redundant controllers connected via reflective memory network, ensuring the highest availability and performance of the system
- ✓ Over 170.000 tags



imagination at work



Airports

More Success Cases

- ✓ MSP: Minneapolis, EUA – Runway Lighting, Transportation System
- ✓ PHL: Philadelphia, EUA – Runway Lighting
- ✓ STL: St Louis, EUA – Runway Lighting
- ✓ ZRH: Zurich, Switzerland – Runway Lighting
- ✓ PAR: Paris, French – Transportation System



Istanbul Atatürk – Turkey

28 million passengers / year

- ✓ Control solution applied for power generation and climatization systems
- ✓ Natural gas power plant with a generating capacity of 9.9MW – 40% of all airport consution
- ✓ Software solution for power management system: GE HMI / SCADA and GE Historian Analytics
- ✓ High availability redudant control solution with PACSystems RX3i and VersaMax



imagination at work



ion at work



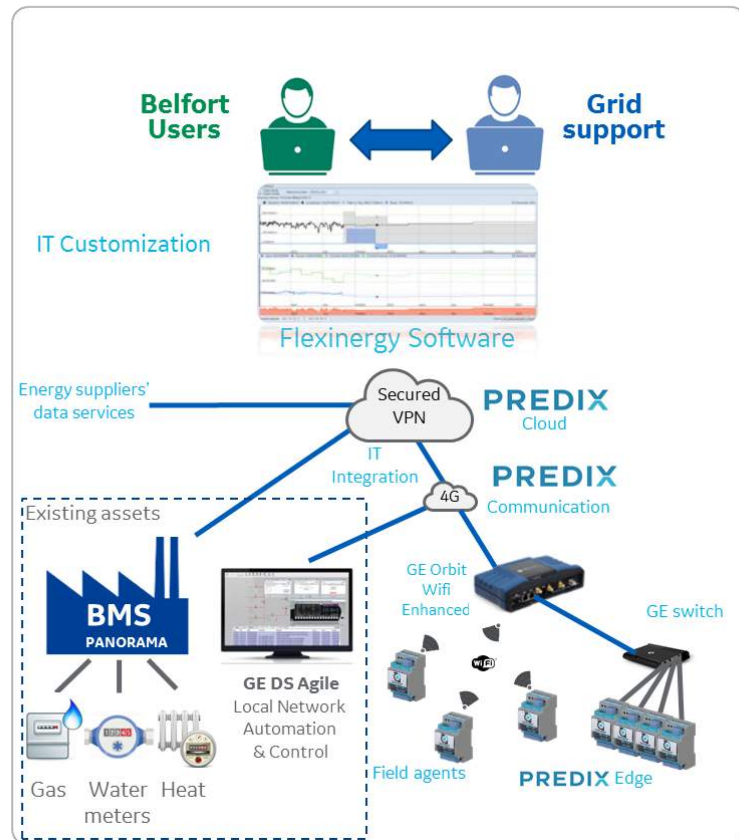
Airports

Industry



Digital Infrastructure Belfort Project Scope

Multi-energy management



Scope

Grid Support
Operate SaaS
Energy efficiency
consulting

5 year contract

SaaS license

Infrastructure
Field agents,
private 4G
network

Field agents deployment



Energy as a Service Contract Project key features

- Project aims at identifying energy savings opportunities, and implement them
- Multi-energy consumption monitoring & management
- Performance-based contract with bonus/malus scheme for service provider

Port Facilities & Operations

Smart Grid



- **Control System**
 - GE Digital Energy Microgrid Controller (Heart of the Control System), Volt/VAR
- **Controller**
 - GE Digital Energy IEDs - Interfacing with individual Distributed Energy Resources
 - Smart Meters at Load Points
 - Communications
 - GE MDS Wireless WAN, Ethernet switches for LAN
- **HMI – Enervista or PMCS or equivalent**
- **Instrument Transformers**
- **Auxiliary equipment**
- **Primary Equipment – ATS, PSGG**
- **Services – Microgrid configuration studies, control settings, commissioning support, site testing support, system integration**

GE is developing a smarter grid at the Port of Rotterdam Distribution Park (Distripark)

The Distripark consists of several companies in distribution, storage, logistics and cooling.

By first investigating energy profiles at individual sites our team is optimizing the energy flow by combining generation, distribution and consumption of the entire site.



Ports



imagination at work