The Evolution of Energy Landscape

Future of Smart Grid

Global Perspective

Dr Eng. Bartosz Wojszczyk
Global Director, Smart Grid Technical Solutions
General Electric
USA

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Problem Statement

Why Everyday People Need Us To Move Forward

- **We need more power**
  - By 2030, more than 60% of the global population will live in cities
- **Power must remain affordable**
  - Double-digit price increases are already commonplace
- **Sustainability must be achieved**
  - More than 40% of our current emissions are from electric generation
- **Industrialized nations are living on borrowed time**
  - Over the next 10 years, over 50% of T&D infrastructure needs to be replaced
- **Decreasing workforce**
  - Over 50% of skilled workforce are expected to reach retirement age in 5-10 years
- **Increasing customer expectation**
  - EPRI estimates that power outages and power quality disturbances cost businesses in the U.S. more than $120 billion a year

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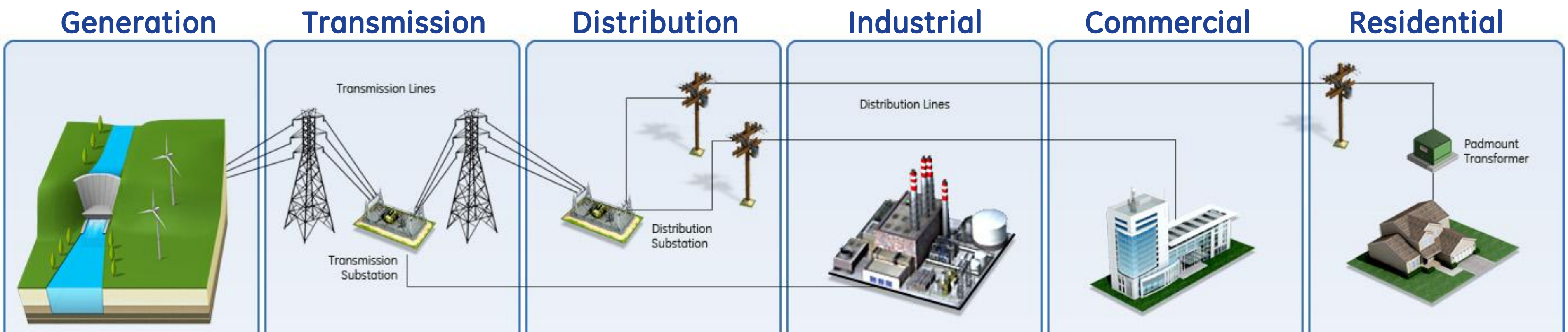
2
Smart Grid
Technology Transformational Journey

Smart Grid…many definitions…

Solution, emerging functionalities, complexity, added value



Wide-area monitoring, protection & control (WAMPAC)

Building / home automation

Large-scale renewable generation

Distributed Energy Resources Management / Microgrids

Adaptive Protection / SPS

EV charging infrastructure

Advanced automation

Energy management systems

Active voltage & reactive power management

Advanced Metering Infrastructure (AMI)

Demand response

Energy Storage

Smart appliances

Communication Infrastructure, Cyber Security

EMS/DMS/OMS, Geospatial Asset Management, Optimization & Diagnostics, Work Force Management, Integration Platform

Smart Grid…technology transformational journey

Solution, emerging functionalities, complexity

Distribution Grid ~ Transmission Grid

Category

Prevention & Healing
(Anticipation and restoration)

Performance
(Dispatch and Efficiency)

Negotiation
(With all energy stakeholders)

Enablers

- ✓ Cross-boundary observability and controllability
- ✓ Situational awareness
- ✓ Fast simulation and modeling
- ✓ Dynamic remedial actions
- ✓ Real-time stability and performance analytics
- ✓ Big data management
- ✓ Advanced computing
- ✓ Intelligent alarming

Solution Trends

✓ **Hyper-intelligent decision making optimizing reliability and performance**

- At a glance, visualization…human factors
- High-fidelity control & operations migrates down to distribution system

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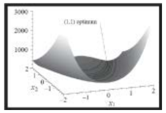
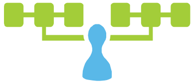
Hyper intelligence components

	Federated Data…	Real-time caching, references to (distributed) data Industry Standards & Security Adapters to legacy applications.
	Large Amount of Data…	The ability to collect, store and process very large data sets… quickly
	Advanced Analytics…	Advanced algorithms for prognostics Intelligent alarming Predictive analytics & Decision Support
	Optimization…	Advanced Optimization techniques for performance management
	Knowledge Mgmt…	Configurable Domain Expertise & BI KPIs Contextual Data: Right info, right time
	Distributed Intelligence…	Put intelligence at the optimal layer/location of the grid
	Visualization…	"At a Glance" visualization tied to analytics

Smart Grid hyper intelligence vision

Y=f (x1..xn)

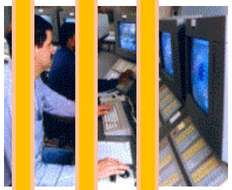
- ✓ *Decisions made at optimal location*
- ✓ *Distributed Logic / architecture*
  - *Generation – Meter*
- ✓ *Only propagate usable data*
- ✓ *Self learning & autonomous*

Advanced Visualization (KPI's)

Knowledge & Learning

Enterprise Solutions
Decision Support

Optimization & Reliability
Grid Management



Storage & Manipulation

Interoperability
Analytics, Data integration

HAN, AMI, FAN, MAN, WAN
Communication Networks

Collecting & Integration

Meters, Relays, IED's, Smart Appliances
Data Acquisition

Voltage, Current, Watts, VAR's., measurements
Sensors

Integrated, End-to-End Solution Approach

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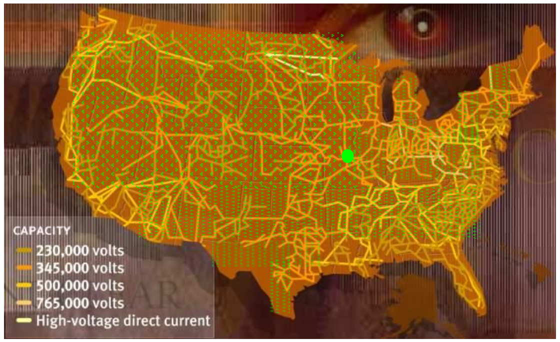
Smart Grid…technology transformational journey

Fast simulation & modeling: Entire grid perspective

The Controllable Grid

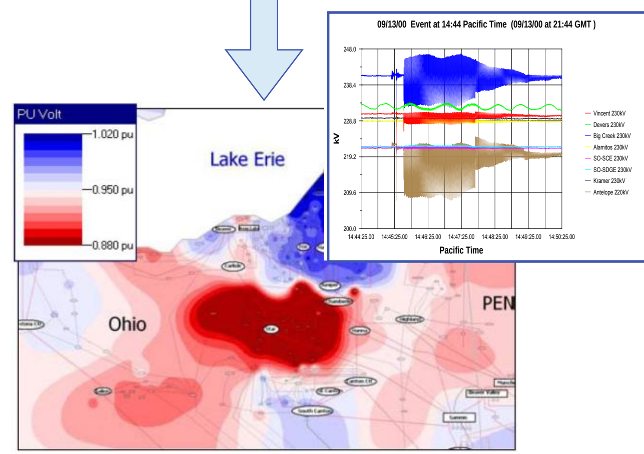


Distribution

Transmission

Synchrophasor Measurements

Real-Time State Estimation



Data Reduction & Visualization

Dynamic State

Supervising Center (Manual settings)

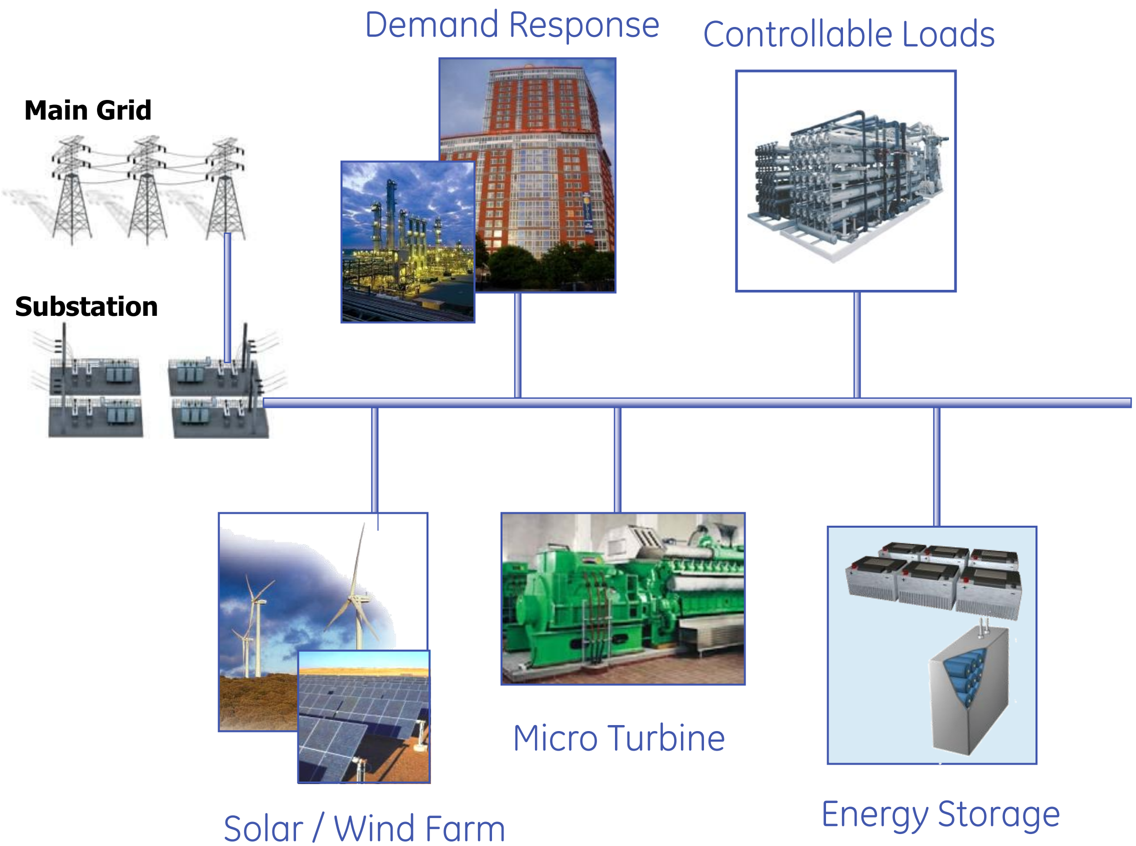
Control & Adaptive Settings

Fast Simulation & Modeling

Real-Time Contingency Analysis

Smart Grid…technology transformational journey

Microgrid / Islanded operation



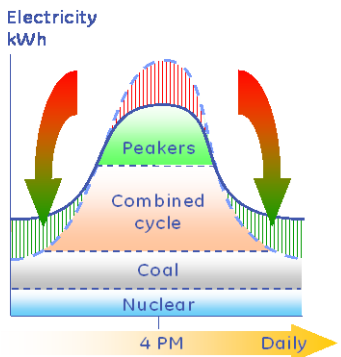
Technology Challenges

- 12 Million DER attachments expected in the next 20 years
- Advanced asset controls and protection required
- Energy Management:
    - Optimization of generation, storage and load operation
    - Intermittency management
    - Aggregate dispatch
- Advanced controls for transition between grid-parallel and island operation
- Cost-effective electrical and thermal energy storage

Smart Grid…technology transformational journey

Grid operation support beyond demand response

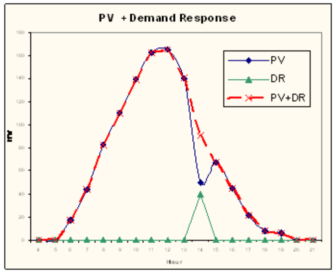
Peak Shifting



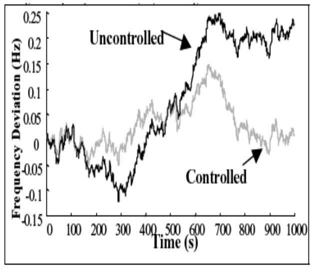
Today

Contingency Response

Spinning Reserves



Frequency Regulation



Tomorrow

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Smart Grid…technology transformational journey

Virtual Power Plant Concept (VPP)

Business Need

Optimal balance (supply and demand) of distributed resources to enable reliable and economic operation.

Provide solutions and services to plan, forecast, schedule, and dispatch

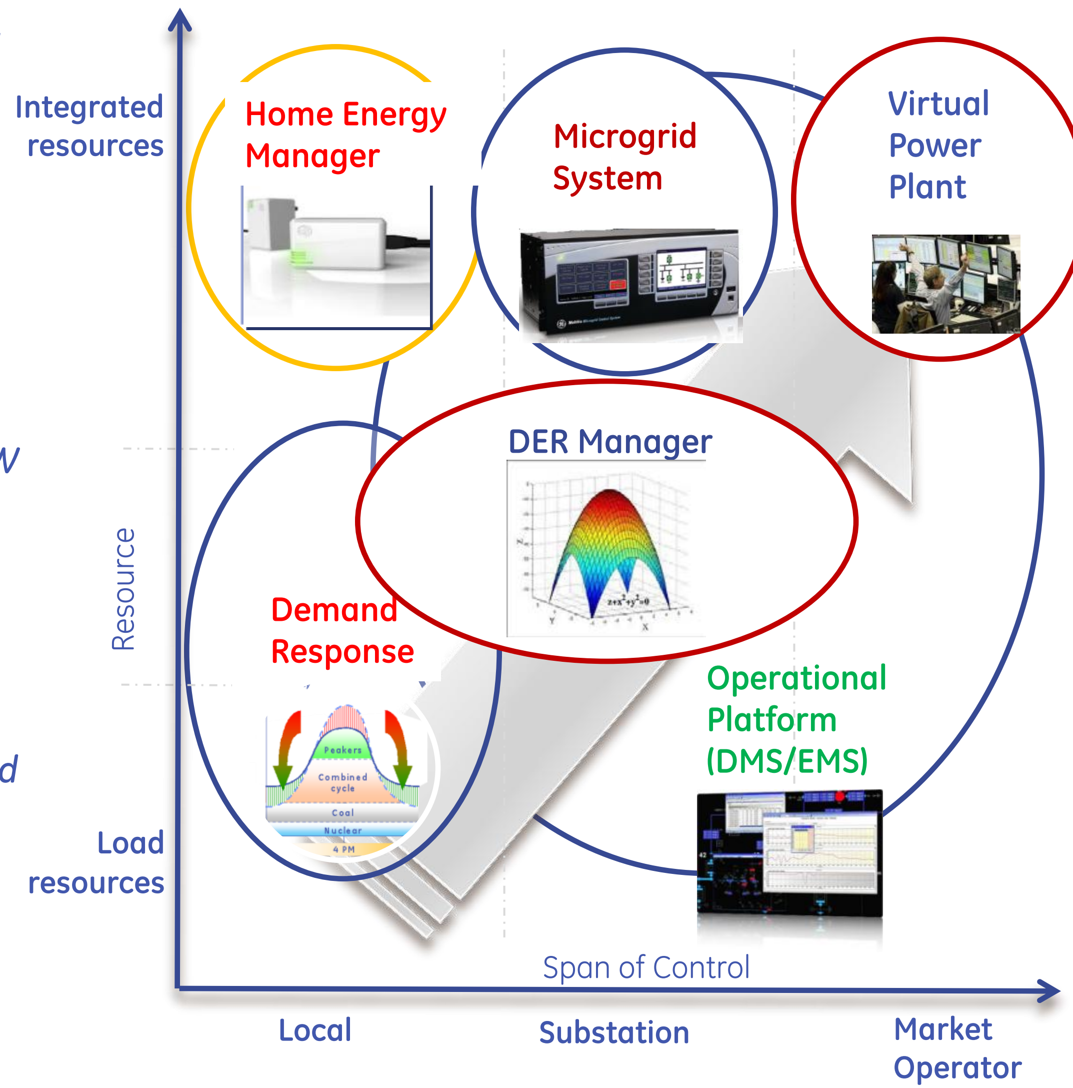
What

- ***Load resources–*** *dispatchable consumption*
- ***Distributed generation -*** *<10 MW renewable or non renewable generation*
- ***Integrated resources –*** *load and generation systems*

Where

- ***Local*** *– residential, commercial, and industrial*
- ***Substation /Feeder*** *– distribution system*
- ***Market Operator*** *– electricity and balancing market*

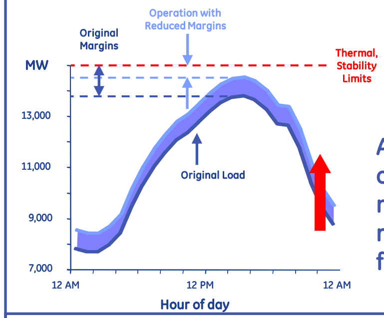
Concept

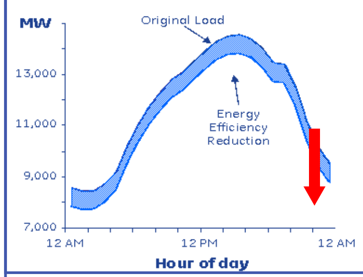
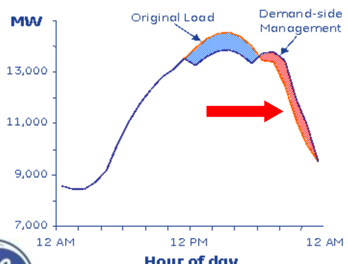


Smart Grid…technology transformational journey

Solution & Performance Scalability … today many technology pilot projects

	Technologies	Value & Performance	

Awareness & Control

 	
Allow load to increase by operating with reduced margins, leveraging reduced uncertainty and faster controls
	<u>Accurate Awareness</u>
	• Synchrophasors
	• Visualization
	• Wide-area Analytics:
	  • Real-time stability assmt
	  • Real-time contingency alsys
	  • Fault location ID
	<u>Advanced Control, Protection</u>
	• Wide area protection
	• Wide area controls
	• FACTS
		(Cost)
		<u>Awareness</u>
		• Up to 30% > power delivery over transmission system $_5$
			(Alternatives)
			Reliability Penalties
			Up to \$1 million per violation, per day$_1$

Load Reduction  Reduce loads at the distribution substation to relieve congestion	<u>Energy Efficiency</u> • Line-loss minimization • Distribution Voltage Regulation <u>DG Integration</u> • Solar PV • CHP	<u>Line-loss Min</u> ~20% < losses $_4$ = ~1% > energy <u>CHP</u> \$657/MW-yr$_7$ (bs)	**Generation Upgrade** • \$525K/MW-yr$_6$ (pk) • \$425K/MW-yr$_6$ (bs)
Load Leveling  Shift loads away from peak to flatten the load profile	<u>Demand Response</u> • Advanced Meters • Utility DSM signals (DLC, TOU, CPP, RTP) • End-user energy mgt • Smart appliances <u>Distributed Energy Resources</u> • Coordination controls for peak shaving with DER	<u>DSM</u> \$60K/MW-yr (EIA, ~11 GW/yr $_2$) <u>BESS</u> \$250K/MW-yr <u>Diesel</u> \$270K/MW-yr$_9$	**Transmission & Distribution Upgrade** • \$150K-\$1000K/MW-yr (EPRI for NYISO$_3$) • Ave: \$700/KW$_{3b}$ Rng: 0-\$1.8M/MW-yr

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3
Smart Grid
Business/Customer Transformational Journey

Smart Grid…business/customer transformational journey

Added value & sustainable performance

A. **Operating Model:** progressive and accelerated migration vs. defensive and incremental migration (innovative leader vs. fast followers)

B. **Utility vs. Customer Centric:** clear balance of customer/societal vs. utility/grid operation benefits (well-defined outcomes)

C. **Partnerships:** ensures a close 'marriage' of public and private partnerships and allows the utility and local city/communities to work in tandem for a 'better' outcome

D. **Business Case:** well-defined and justified business value

E. **Smart policies and regulations**

A. Utilities operation model must evolve

- ✓ Utilities must embrace new role as portfolio managers and service provider rather then “infrastructure owner”
- ✓ Utilities must identify and close talent gaps in core skill sets e.g: technical, marketing, IT/Comms, consumer outreach, etc.
- ✓ Utilities straying too far away from core competencies may meet with tax payer or regulator push back
- ✓ Utilities must push to get incentives aligned through regulatory reform
- ✓ Consumers will need to see value in a better choices and smarter consumption of a commodity like electricity
- ✓ Consumer education is key to industry/utility transformation
- ✓ Other

B. Smart Grid drivers…value

Economic competitiveness	Energy reliability & security	Empowerment-Consumer	Environmental sustainability
			

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B. Value driven approach

Enabler: Technology

	What	Why
Demand optimization	Peak management via control of power consumption	Defer upgrades and optimize generation
Distribution optimization	Reduce delivery losses in distribution systems	Reduce wasted energy and improve profit margins
Asset optimization	Prognostics for proactive equipment maintenance	Reduce CAPEX and risk of equipment failure
Transmission optimization	Wide area protection & control for improved visibility	Improve reliability and return on assets
Workforce Eng. & Design optimization	Productivity, planning, and design tools	Improve workforce productivity and reduce costs

B. Who are your customers?

Market assessment & segmentation

Select target markets

Focus groups

Conjoint analysis

Analyze & create plan

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C. Partnerships

Stakeholder alignment is at the heart of building a smart grid

Energy Smart Miami Partners

The City of Miami, Florida · GE · Cisco · FPL · Silver Spring Networks · Miami Dade College

Maui Smart Grid

Hawaiian Electric Company · Maui Electric Company, Ltd. · GE · University of Hawai'i

Partner Types

Political alignment

- Grid operators / Utilities
- Governmental organizations
- Cities
- Universities

Private sector engagement

- High-tech companies
- Financial institutions
- Transport / Waste
- Automotive

Citizen engagement

Citizens

Customers

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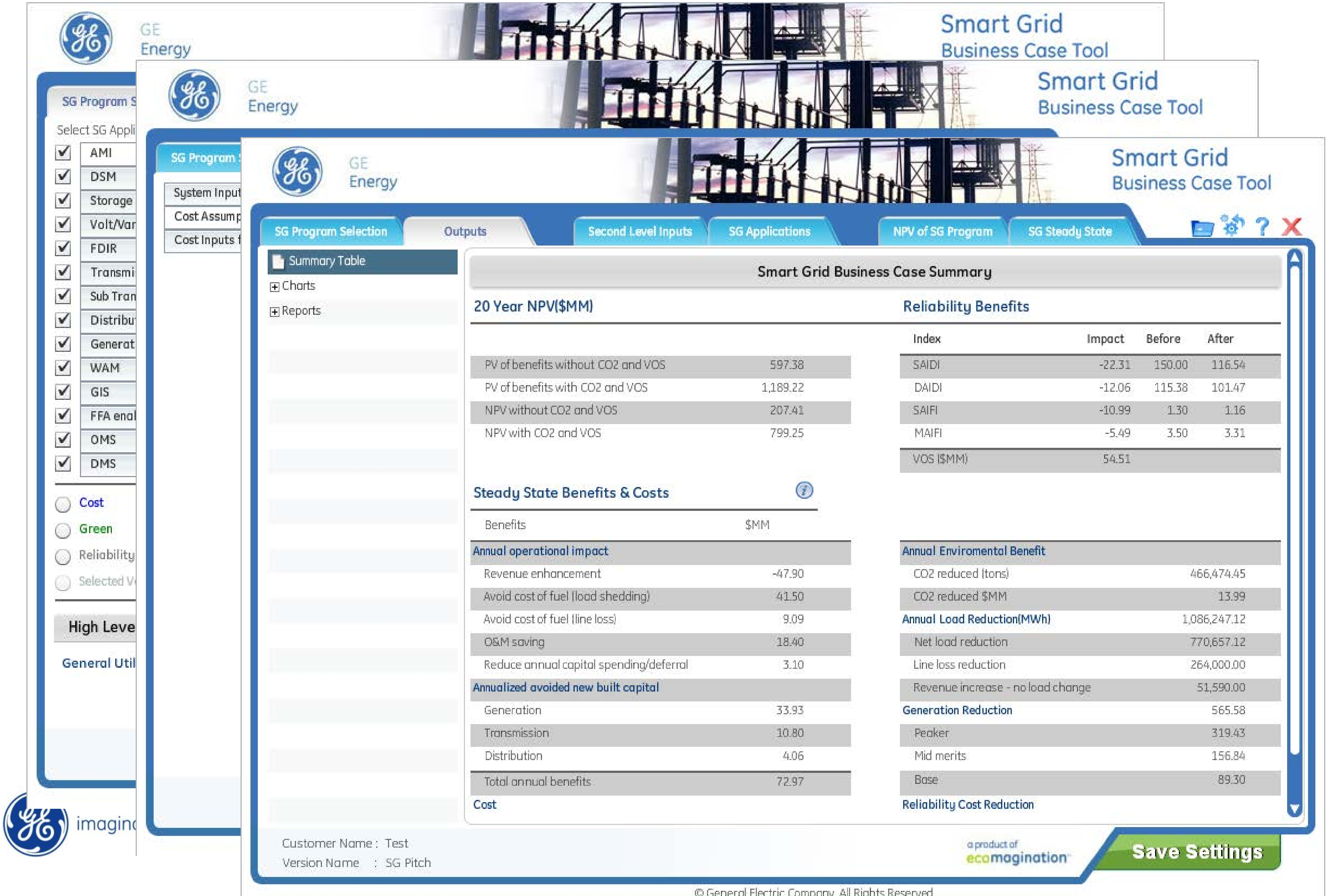
D. Business Case

Well-defined and justified business value



E. Smart policies help us move forward

Policymakers… establish the targets

1. Energy Efficiency resource standard
2. Peak load reduction standard
3. Clean energy standard

Regulators… provide the incentives

1. Cost recovery guidelines
2. Innovative rate designs
3. Equal treatment of demand-side resources

Questions…..

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