System Planning with Smart Grid – Worksheet Slides for Committee Meeting

Presented at

Power System Planning & Implementation Committee

Calgary, Alberta, Canada

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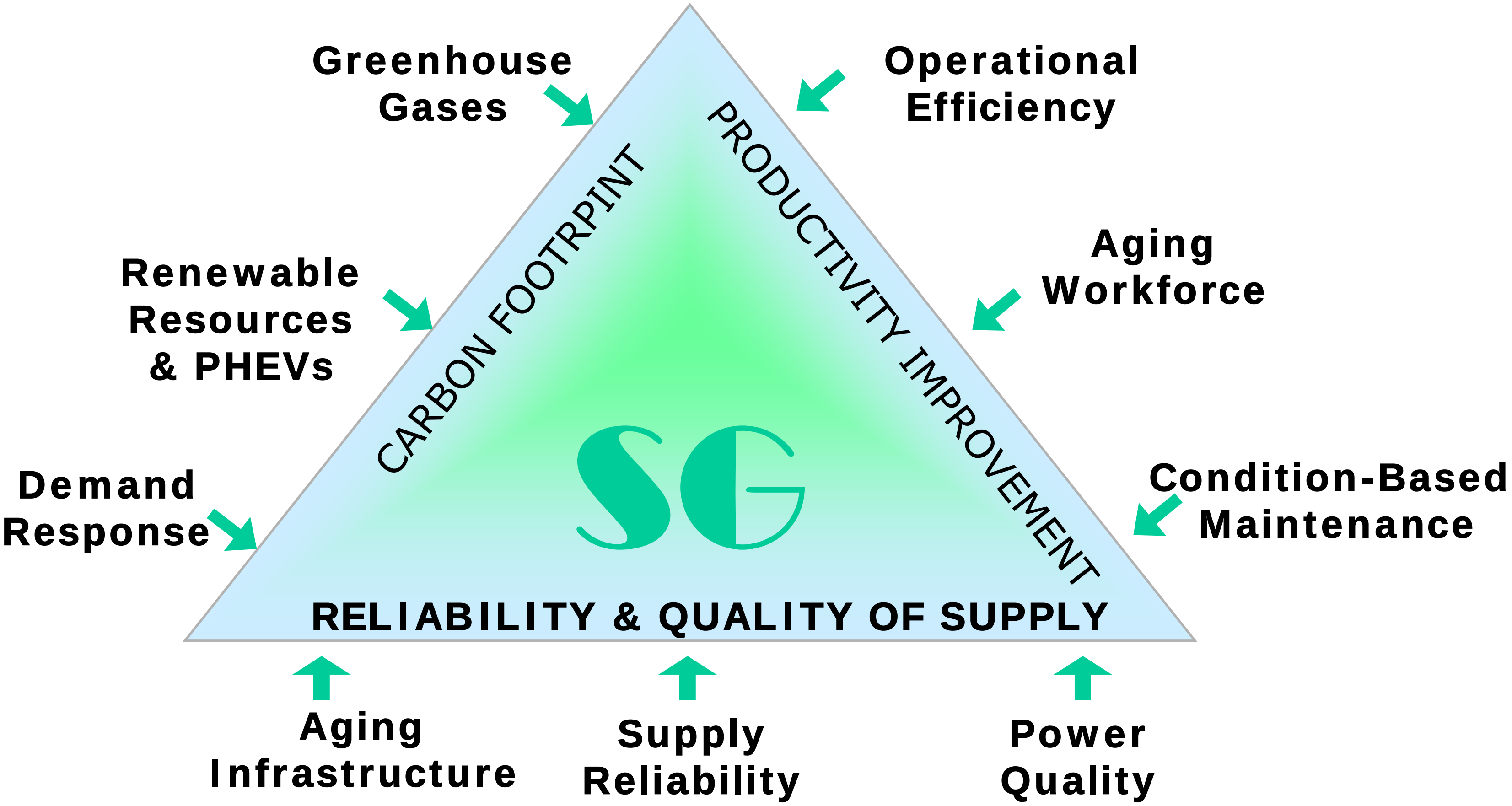
Smart Grid Business Drivers: New Business Environment



Greenhouse Gases

Operational Efficiency

Renewable Resources & PHEVs

Aging Workforce

Demand Response

Condition-Based Maintenance

CARBON FOOTRPINT

PRODUCTIVITY IMPROVEMENT

SG

RELIABILITY & QUALITY OF SUPPLY

Aging Infrastructure

Supply Reliability

Power Quality

Smart Grid is ….

- Overlay of Information Technology Infrastructure on Power Delivery Infrastructure to achieve:
  - System efficiency
  - Sustainability (green the grid)
  - Optimal utilization
  - Enhanced system reliability
- A Smart Grid is intelligent, efficient, accommodating, motivating, opportunistic, quality-focused, resilient and green
- Covers G, T, D and customer sectors
- Not a set of shrink-wrapped solutions; unique to each utility

The Smart Grid of The Future[1]

20th Century Grid	21st Century Smart Grid
Electromechanical	Digital
One-way communications (if any)	Two-way communications
Built for centralized generation	Integrates distributed generation & renewable and supports EVs or hybrids
Radial topology	Network topology; bidirectional power flow
Few sensors	Monitors and sensors throughout; High visibility
Manual restoration	Semi-automated restoration & decision-support systems, and, eventually, self-healing
Prone to failures and blackouts	Adaptive protection and islanding
Scheduled equipment maintenance	Condition-based maintenance
Limited control over power flows	Pervasive control systems; state estimator
Not much sustainability concern	Sustainability and Global Warming concern
Limited price information	Full price information to customers – RTP, CPP, etc.

[1] Modified from the Emerging Smart Grid: Investment And Entrepreneurial Potential in the Electric Power Grid of the Future, Global Environment Fund, October 2005

Translated into Requirements

- More visibility to the T&D system
  - Intelligent Electronic Devices (IEDs), AMI meters, Phasor Measurement Units (PMUs)
  - Real-time generation and emission
- More local intelligence control of the system
  - Communications infrastructure (e.g., Peer-to-Peer)
  - Interoperable devices
  - Cyber security
- Condition-based maintenance
- Optimal utilization of infrastructure capacity

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Translated into Requirements (cont’d)

- Integration of intermittent renewable (customer-owned and utility scale); standards to be defined
- Customers – AMI meters or ESCO interface units to grid for homes, high rises and office complexes with renewable & PHEV chargers; net zero energy buildings
- Distribution protection scheme for bidirectional power flow and micrograds

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Smart Grid Applications for Generation System

- Real-time heat rate calculation modules
- Continuous emission monitoring systems
- Continuous asset condition monitoring systems for CBM
- Integration of intermittent renewable resources with energy storage technologies

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Smart Grid Applications for Transmission Systems

- PMUs to provide time synchronized data on system dynamics
- Wide Area Protection System (WAPS) for improved system reliability
- FACTS to optimize the utilization of capacity
- Substation automation involving IEDs for protection and condition monitoring
- Closer integration in planning with distribution system planning

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Smart Grid Applications for Distribution Systems

- Feeder Automation
- Fuse Clearing via fast curves
- Remote monitoring of FCIs
- Real-time incipient fault prediction
- Integrated volt/var control
- Feeder & Sub Peak Load Management
- Equipment Condition Monitoring
- Distribution SCADA or DMS

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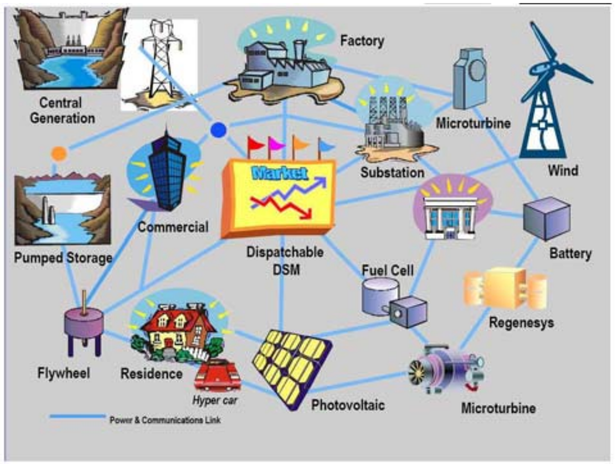
Smart Grid Applications for Distribution Systems (cont’d)

- Substation Automation
  - ❑ Data concentrators
  - ❑ Use of IEDs and Data Concentrators
  - ❑ Equipment Condition Monitoring with non-operational data
- Micro-grid management involving DGs, Renewable and PHEVs



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Smart Grid Applications for Customers

- AMI Systems for suburb/rural area customers that participate
  - ☐ AMR
  - ☐ Outage detection
  - ☐ Remote Service Connect/Disconnects
  - ☐ Integrate DER resources
  - ☐ PHEV charging
  - ☐ Netmetering

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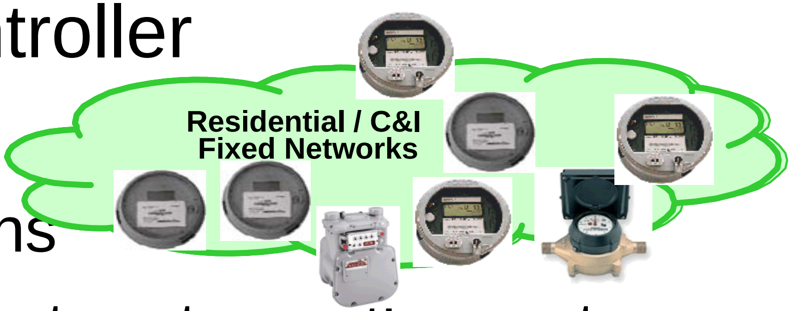
Smart Grid Technologies for Integrating DERs

- AMI System/Smart Controller
  - AMI meters with HAN
  - Zigbee for communications
  - Home energy management system with smart charger system for PHEVs
  - Smart appliances & smart thermostats
  - Microgrid interface controller; real-time adaptive settings for protective relays
- Customer Portal Systems for energy management



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Integration with Net Zero Energy Buildings and Microgrids

- Demand Response (DR) shifts peak load
    - Direct control of end-use loads (e.g., AC, WH)
    - Critical Peak Pricing/Real-Time Pricing/TOD Rates
- Renewable (wind, solar PV) & DGs with energy storage
- PHEVs as energy supply sources for customers
- Becomes Net Zero Energy Buildings with these DERs

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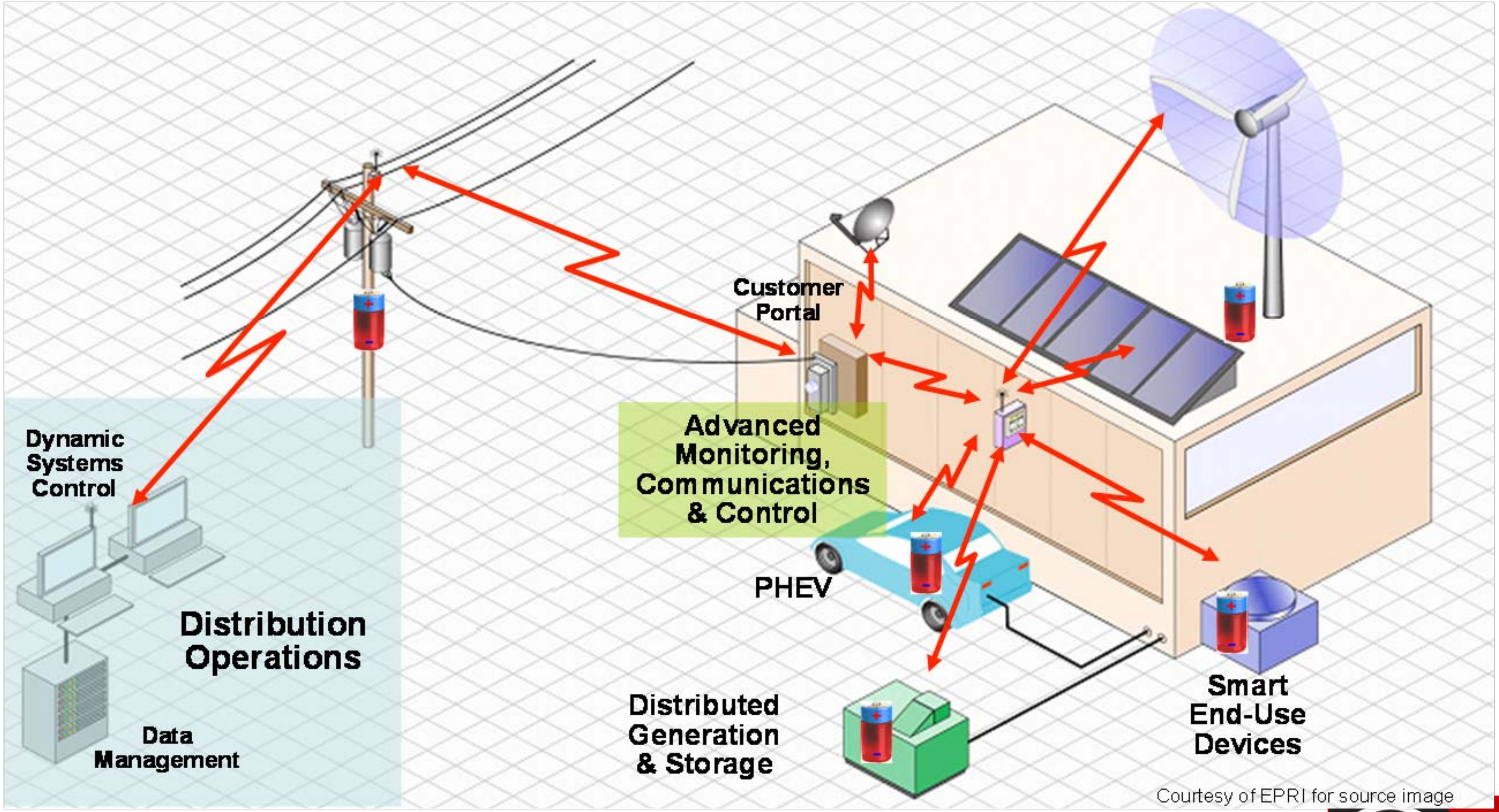
Integrating DERs

Energy Storage

Advanced Monitoring, Communications & Control



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Smart Grid Business Drives & Applications

Smart Grid Applicatoins	Power System Integrity	Powem System Reliability	Peak Demand Management	Energy Efficiency	Cost Efficiency	Carbon Footprint Reduction	Integrate Renewable	Revenue Enhancement
Generation System								
Equipment Condition Monitroing (ECM)					x			x
Continous Emission Monitorinng System (CEMS)						x		x
Wind Farm Intgration			x			x		
Transmission System								
Equipment Condition Monitoring		x			x			
Phasor Measurement Units (PMUs) & WAPS	x				x		x	x
FACTS	x		x	x		x	x	
Distribution System								
Fault Location, Isolation & Service Restoration (FLSIR)		x						
Distribution Management System (DMS) with IVVC, Peak Demand Management & GIS	x	x	x	x	x	x	x	
ECM		x			x	x		
Customers								
Load Control/Demand Response (LM/DR)	x	x	x		x	x		x
Metered Load Data Utilization								
Electric Vehicles (EV) with Smart Chargers			x			x	x	

Smart Grid leverages on enablers

- “Sensors”
- Communications Infrastructure
- Enterprise Information Integration
- Open interoperability
- Corporate Culture: A Holistic Approach

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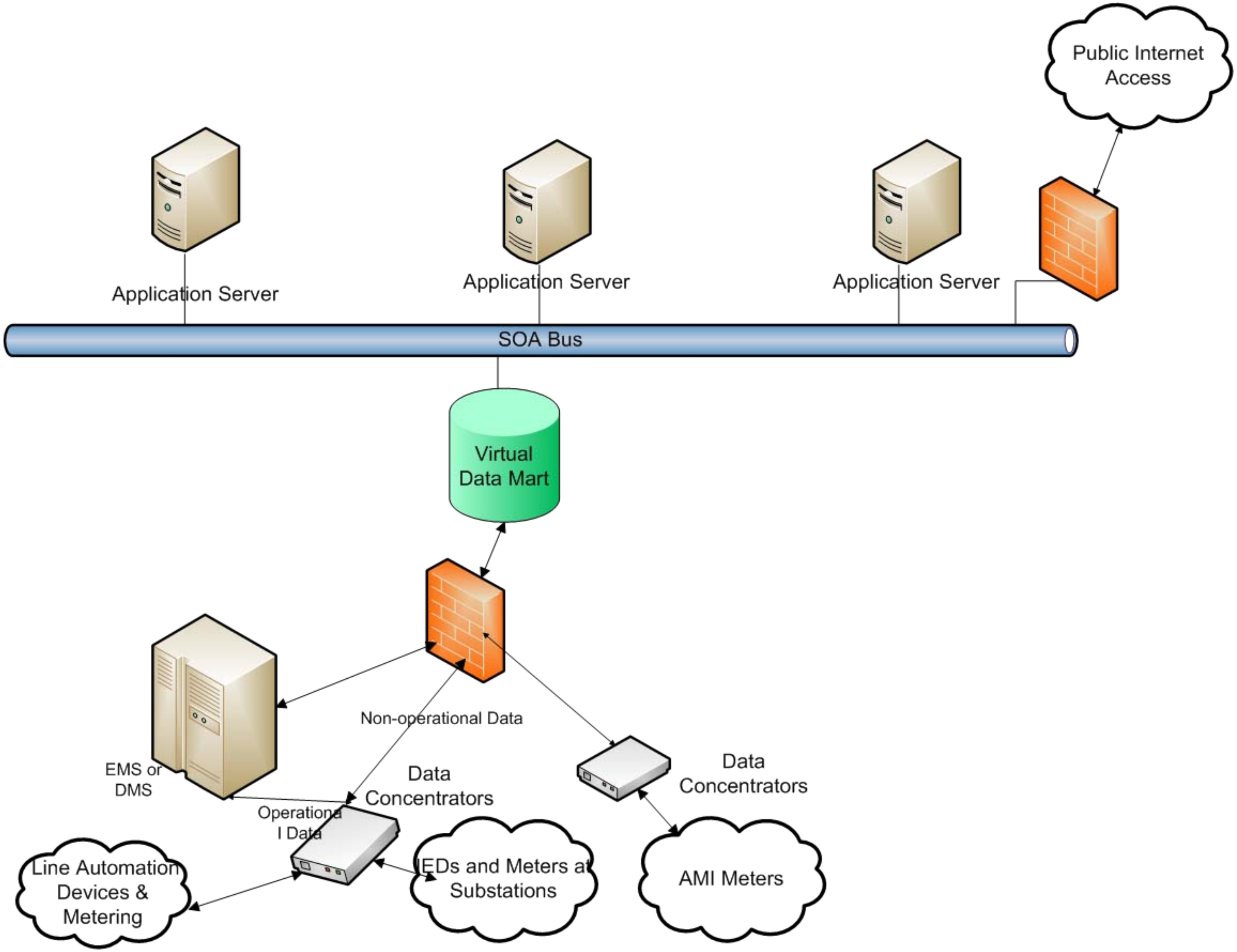
Integrated Data Management System



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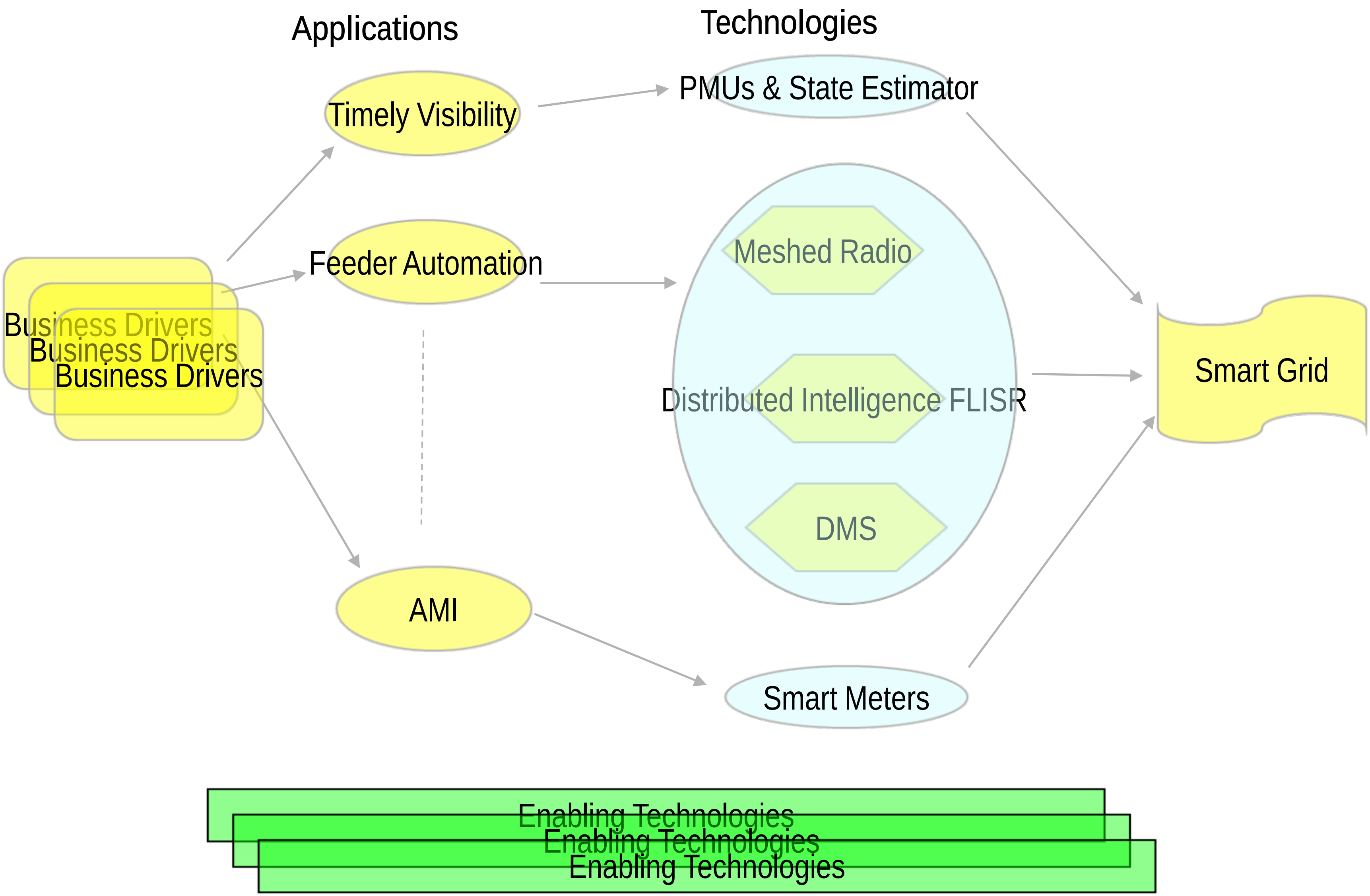
Smart Grid ....



Applications

Technologies

Business Drivers
Business Drivers
Business Drivers

Timely Visibility

Feeder Automation

AMI

PMUs & State Estimator

Meshed Radio

Distributed Intelligence FLISR

DMS

Smart Meters

Smart Grid

Enabling Technologies
Enabling Technologies
Enabling Technologies

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Impacts on G & T System Planning

- Integrated G&T planning
  - Optimal capacity and siting in relation to the optimal mix of renewable, storage and conventional generation
    - Under competitive energy market
    - Under non-competitive market
    - Carbon trade market or valuation of carbon reduction
- Who is the planner? Gaming?
  - ISO/RTO for the region?
  - Individual utility for integrating renewable to meet RPS mandate
  - IPPs and/or merchant transmission lines?
- Planning tools? How about risk management?
- For utilities trying to integrate wind and solar,
  - Technologies for combating resource intermittency; impacts on ACE and dynamic instability problems
  - Integration with utility scale storage technologies (e.g., CAES, Pumped Storage, battery storage, FACTS and LVRT)

Impacts on G & T System Planning (cont'd)

- PHEV integration impacts
  - Used for the ancillary service market if load can be a source
  - To receive full carbon footprint results if EV batteries are charged by renewable sources
- Asset condition monitoring for CBM
- Integration of smart grid technologies with advanced infrastructural technologies (e.g., superconducting cables, IUTs)
- ……

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Integrating Intermittent Renewable Resources…

- Modeling of intermittent resources; EMTP model to evaluate impacts of types of wind turbines; and then run PSLF to investigate system impacts
- Use RTDS to simulate how FACTS controllers should be designed and to test how WAMPACS software works
- Optimal mix of utility-scale and distributed storage resources for the distribution system

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Planning for Distribution System involving Smart Grid

- Integration of DGs and DERs along feeder lines and at distribution substations, and DRs, PHEVs and DERs at customer premises to optimize capacity and reliability planning; especially wind resources
- Spatial load forecasting
- Include feeder automation, substation automation, etc. to optimize the capacity utilization in conjunction with AMI system
- Minimize losses on lines
- Incorporate microgrids into planning and operations, including relay coordination
- Impact of PHEVs on distribution system planning
- What degree of renewable penetration do we have to be concerned? What to be concerned? System protection?
- Asset condition monitoring for CBM
- ……………….

Customer Service Planning under Smart Grid

- What products and services likely to be offered under Smart Grid infrastructure?
- What type of rate tariffs will really help the DR program proliferation?
- What infrastructure at customer sites is required for PHEVs?
- ……………..

Sessions for T&D, GM2010 and PSCE

T&D at New Orleans, 4/19-22. 2010	**GM2010 at Minneapolis, 7/xx/2010**	**PSCE at XXX April 2011**
Energy Supply WG		
Transmission WG	Green Planning Merchant Transmissinon Planning	
Distribution WG		
Customer WG		
Asset Management WG		

Tranmsission Group

- Speical publications & webinars
- Reactive Grid Planning ?

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Thank You!

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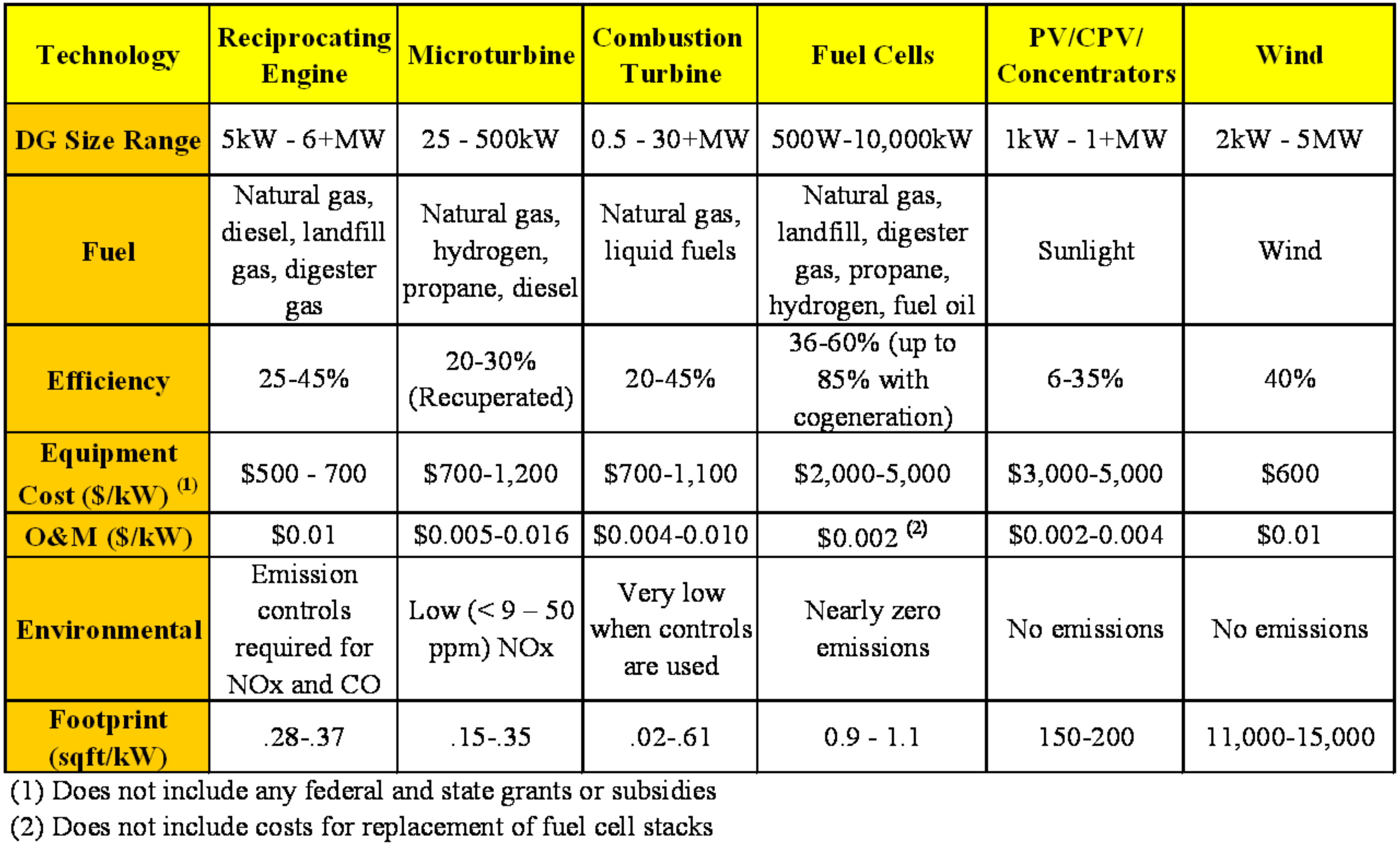
Integrating Distributed Generation

Distributed Generation: Technology Summary



Technology	Reciprocating Engine	Microturbine	Combustion Turbine	Fuel Cells	PV/CPV/ Concentrators	Wind
DG Size Range	5kW - 6+MW	25 - 500kW	0.5 - 30+MW	500W-10,000kW	1kW - 1+MW	2kW - 5MW
Fuel	Natural gas, diesel, landfill gas, digester gas	Natural gas, hydrogen, propane, diesel	Natural gas, liquid fuels	Natural gas, landfill, digester gas, propane, hydrogen, fuel oil	Sunlight	Wind
Efficiency	25-45%	20-30% (Recuperated)	20-45%	36-60% (up to 85% with cogeneration)	6-35%	40%
Equipment Cost ($/kW) (1)	$500 - 700	$700-1,200	$700-1,100	$2,000-5,000	$3,000-5,000	$600
O&M ($/kW)	$0.01	$0.005-0.016	$0.004-0.010	$0.002 (2)	$0.002-0.004	$0.01
Environmental	Emission controls required for NOx and CO	Low (< 9 – 50 ppm) NOx	Very low when controls are used	Nearly zero emissions	No emissions	No emissions
Footprint (sqft/kW)	.28-.37	.15-.35	.02-.61	0.9 - 1.1	150-200	11,000-15,000

(1) Does not include any federal and state grants or subsidies

(2) Does not include costs for replacement of fuel cell stacks

Distributed generating units from 100 kW up to 10,000 kW (IEEE 1547) are being installed on the distributed feeders

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DG Impact on Distribution System

An Interconnecting DG has a System Impact Determined By:

- **The size and type of DG design:** (the power converter type, unit rating, unit impedance, relay protection functions, interface transformer, grounding, etc.)
- **Type of DG prime mover:** (wind, PV, ICE, CT, etc.)
- **Intended DG operating mode(s):**
  (such as peak shaving, base-load CHP, power export market, etc.)
- **Its interaction with other DG or loads**
- **Its location on the distribution system and the characteristics of the distribution system such as:**
  - network, auto-looped, radial, etc.
  - System impedance at connection point
  - Voltage control equipment types, locations and settings
  - Feeder grounding design (3 wire delta, 4 wire multigrounded neutral)
  - System protection equipment types, locations, and settings
  - Various other factors

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Common Radial System DG Interconnection Requirements of Utilities

Requirement Description	Very Small DG less than 10 kW	Small DG 10 to 100 kW	Intermediate DG 100 kW-1000 kW	Large DG >1000 kW or > 20% of feeder load
Disconnect switch or device	✓	✓	✓	✓
Protective relays for Islanding Prevention and Synchronization	✓	✓	✓	✓
Overcurrent Protection	✓	✓	✓	✓
Unbalance Protection and other protection modes	maybe	maybe	✓	✓
“Utility Grade” protective relays with input test ports	maybe	maybe	✓	✓
Dedicated Transformer	maybe	maybe	✓	✓
Ground fault contributions may require a grounding impedance			Maybe	Often
Special monitoring and automation requirements		Sometimes	✓	✓
Transfer/remote Trip		Almost Never	Occasionally	Often
Detailed Feeder Impact Studies			Sometimes	✓
Feeder Upgrades			Maybe	Likely

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Integrating Energy Storage

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Energy Storage Technologies

- Low Voltage Ride-through
- Battery (regular and EV)
- Flywheel
- Superconducting magnetic energy storage
- Compressed air energy storage
- ……

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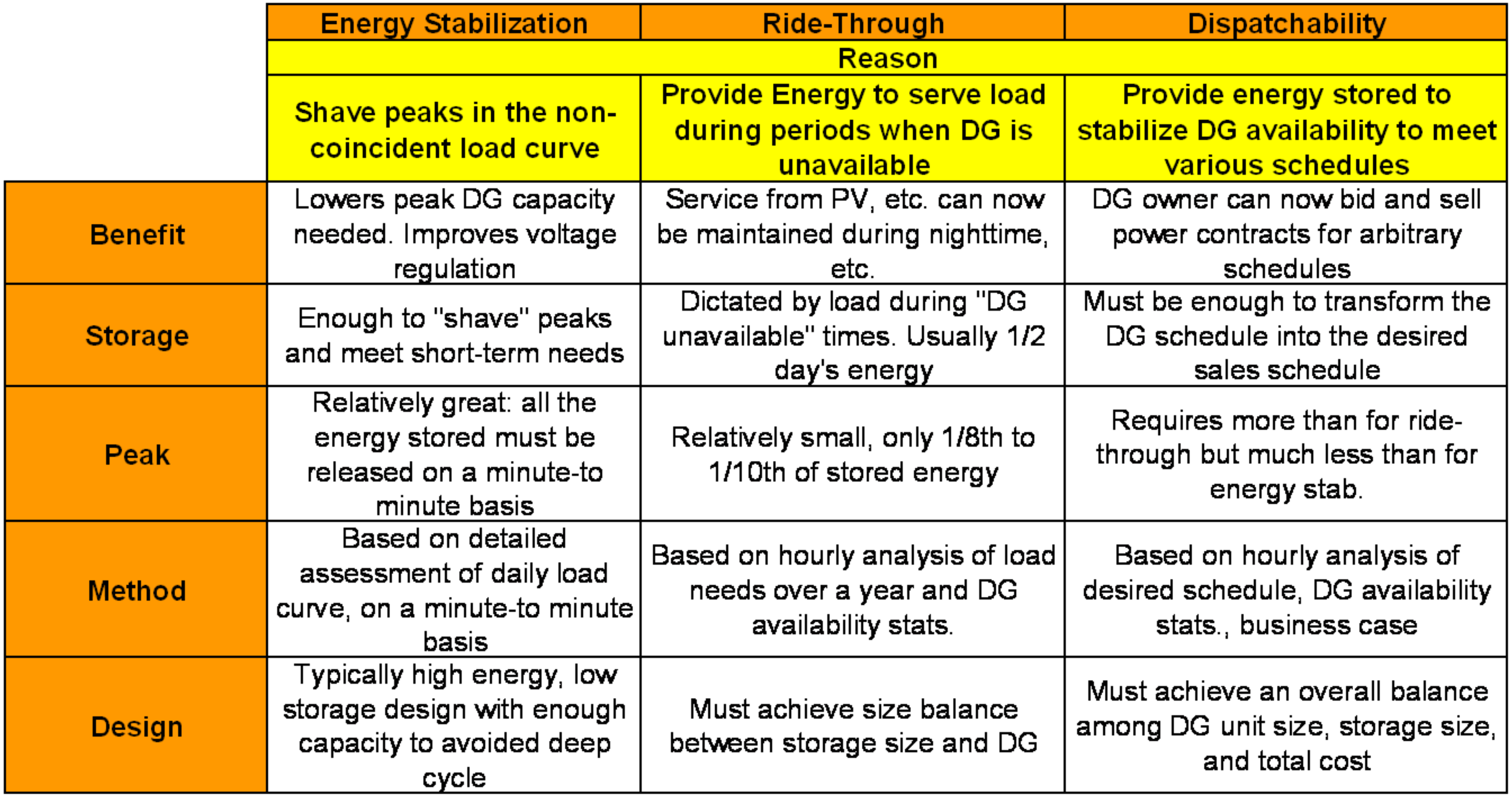
DG and ES: DG Outlook



	Energy Stabilization	Ride-Through	Dispatchability
	Reason		
	Shave peaks in the non-coincident load curve	**Provide Energy to serve load during periods when DG is unavailable**	**Provide energy stored to stabilize DG availability to meet various schedules**
Benefit	Lowers peak DG capacity needed. Improves voltage regulation	Service from PV, etc. can now be maintained during nighttime, etc.	DG owner can now bid and sell power contracts for arbitrary schedules
Storage	Enough to "shave" peaks and meet short-term needs	Dictated by load during "DG unavailable" times. Usually 1/2 day's energy	Must be enough to transform the DG schedule into the desired sales schedule
Peak	Relatively great: all the energy stored must be released on a minute-to minute basis	Relatively small, only 1/8th to 1/10th of stored energy	Requires more than for ride-through but much less than for energy stab.
Method	Based on detailed assessment of daily load curve, on a minute-to minute basis	Based on hourly analysis of load needs over a year and DG availability stats.	Based on hourly analysis of desired schedule, DG availability stats., business case
Design	Typically high energy, low storage design with enough capacity to avoided deep cycle	Must achieve size balance between storage size and DG	Must achieve an overall balance among DG unit size, storage size, and total cost

Full benefits of DG + DS integration can be accomplished by implementing advanced automation

DG and ES: Utility Outlook

	Mid-term Scenarios	Long-term Scenarios **“Smart Grid” Concept**
Power dispatch (integrated into AGC)	Pre-defined generation dispatch based on peak/off-peak time	Active/adaptive power sharing
Congestion management	Peak shaving	Real-time power flow optimization
Volt./Var control	Reactive power compensation	Interactive voltage control/regulation
Reliability enhancement	Planned-islanding	Microgrids (volt/freq. control)
Power Quality	Load balancing	Active filtering

Full benefits of DG + DS integration can be accomplished by implementing advanced automation

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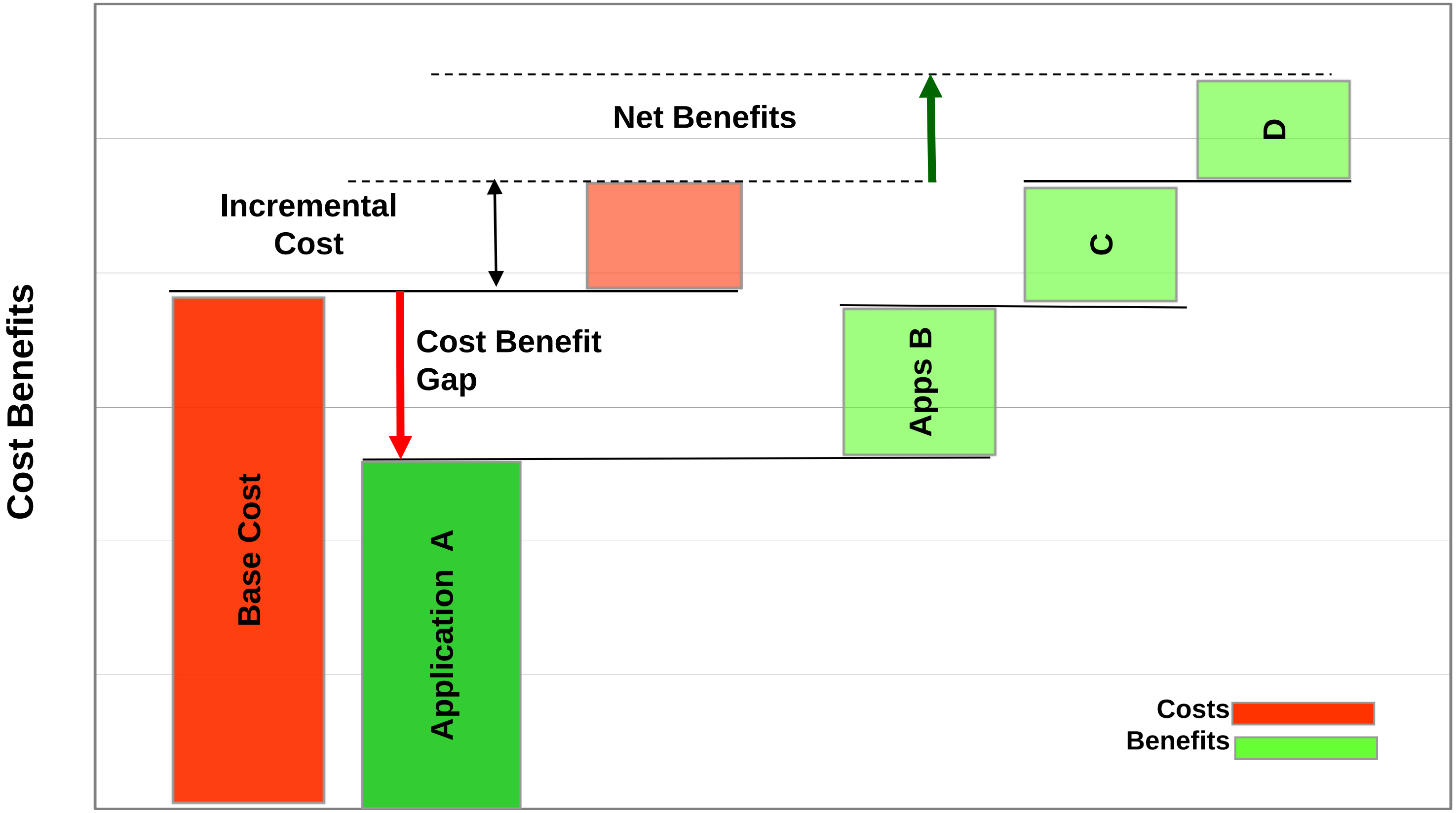
Smart Grid Requires a “Holistic” View



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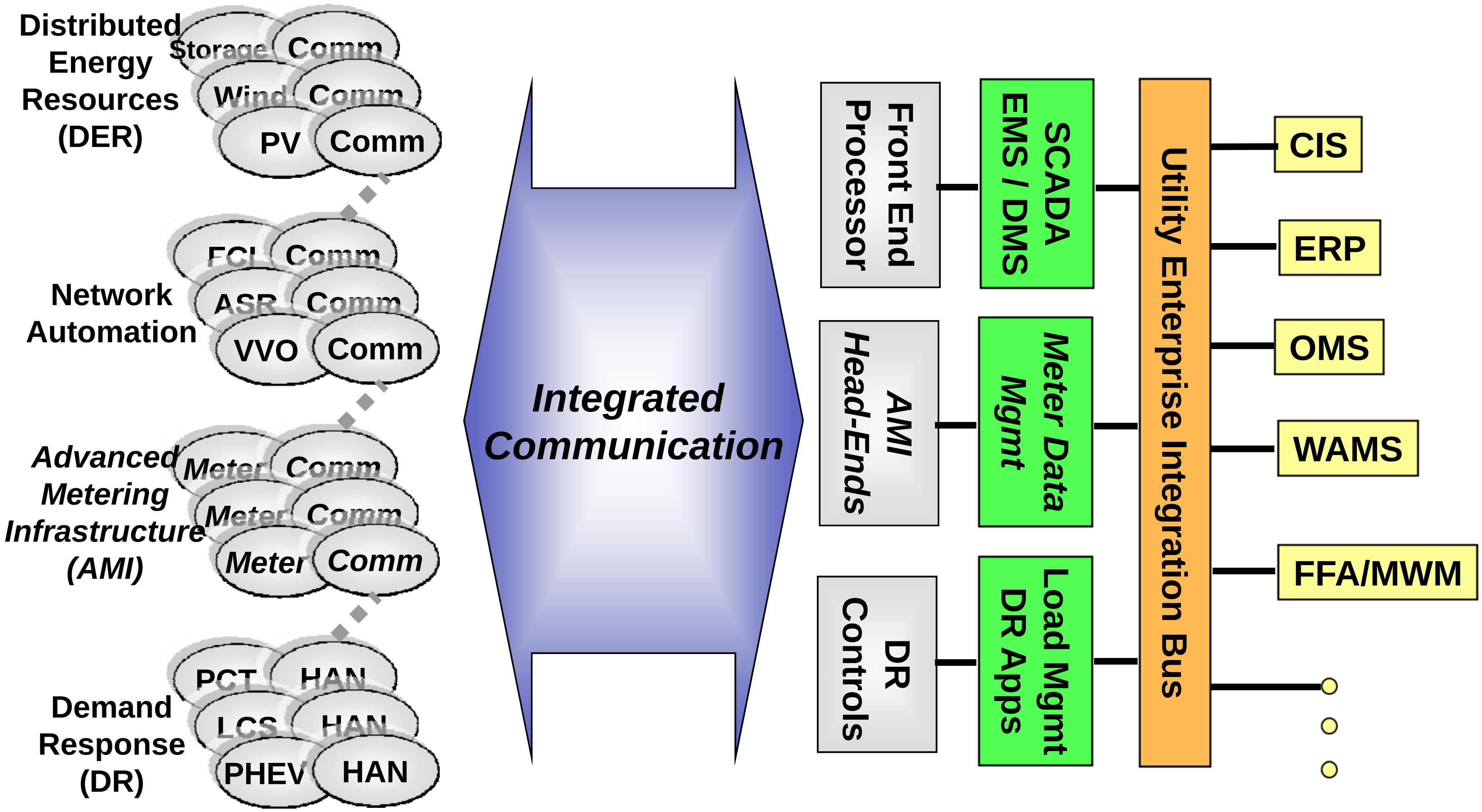
Major Smart Grid Components



Distributed Energy Resources (DER)
- Storage – Comm
- Wind – Comm
- PV – Comm

Network Automation
- FCI – Comm
- ASR – Comm
- VVO – Comm

Advanced Metering Infrastructure (AMI)
- *Meter* – *Comm*
- *Meter* – *Comm*
- *Meter* – *Comm*

Demand Response (DR)
- PCT – HAN
- LCS – HAN
- PHEV – HAN

Integrated Communication

- Front End Processor – SCADA EMS / DMS
- *AMI Head-Ends* – *Meter Data Mgmt*
- DR Controls – Load Mgmt DR Apps

Utility Enterprise Integration Bus

- CIS
- ERP
- OMS
- WAMS
- FFA/MWM

Technology/Infrastructure Deployment

Enterprise Integration