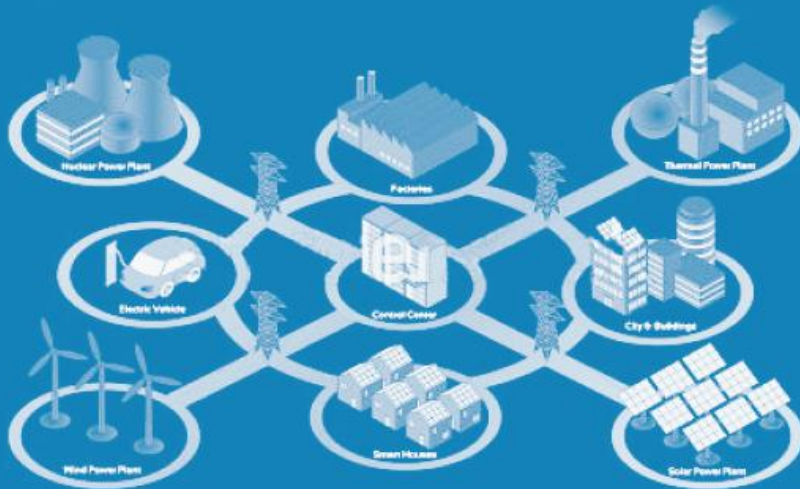


THE ADVANCED SMART GRID

EDGE POWER DRIVING SUSTAINABILITY

SECOND EDITION



**ANDRES CARVALLO
JOHN COOPER**

THE ADVANCED SMART GRID

*EDGE POWER DRIVING
SUSTAINABILITY*

Andres Carvallo
Founder & CEO
CMG Consulting LLC
www.512cmg.com



Carvallo's Bio



University of Idaho



Borland®

PHILIPS



digital





Who is CMG?

- **CMG is a strategy consulting and advisory company focus on enabling smarter Cities, Enterprises, Utilities, and Vendors. CMG builds ecosystems for its clients.**
- Our consulting services include the development of **Strategy, White Papers, Reports, Assessments, Gap Analysis, Benchmarking, Designs, Architectures, Road Maps, Business Models, Business Cases, Go-to-Market Plans, IT/OT Management, Product Innovation, Funding, and M&A.**
- The results of our involvement are proven to Increase Value, Reduce Risk, Accelerate Adoption and Delight Customers.



CMG Solutions

- **Strategy and Scenario Planning (SSP) Framework**
- **Business Optimization and Transformation (BOT) Framework**
- **Smart Grid Roadmap (SGR)**
- **Smart Grid Governance (SGG)**
- **Smart Buildings (SB) Framework**
- **Big Data (BD) Framework**
- **Internet of Things (IoT) Framework**
- **Cloud Computing (CC) Framework**
- **Distributed Energy and Microgrid (DEM) Planning Framework**
- **Virtual Power Plant (VPP) Planning Framework**
- **Smart Cyber Security & Compliance (SCSC) Framework**
- **Distribution Management System Lifecycle Management Framework (DMSLM)**



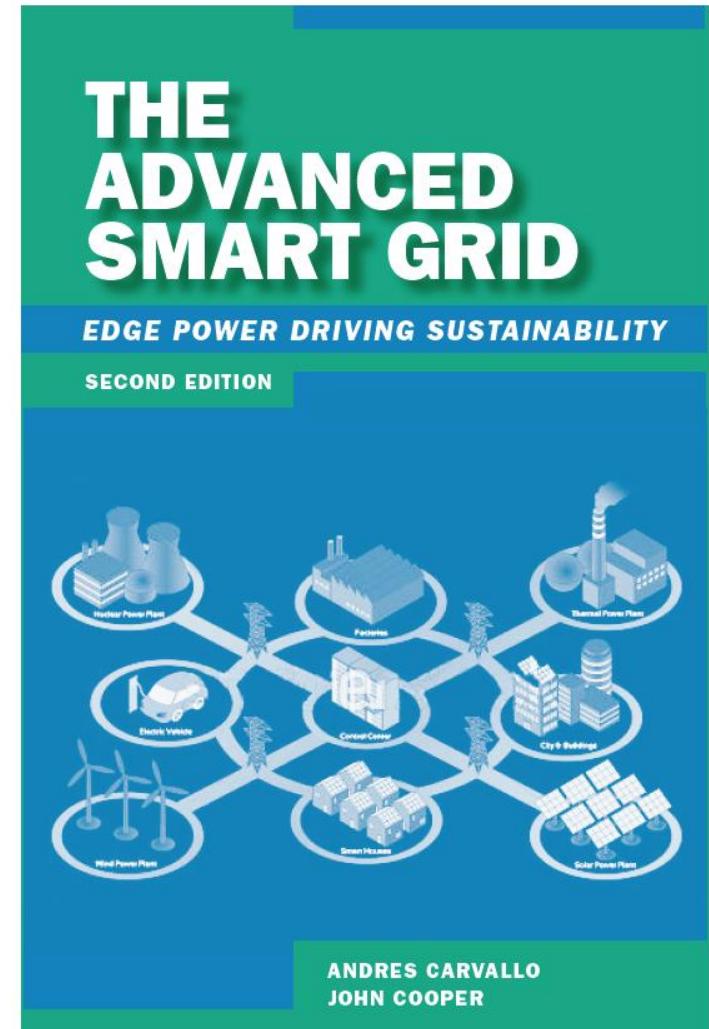
Key Customers





The Advanced Smart Grid

- The Inevitable Evolution of Smart Grids. The Rationale for an Advanced Smart Grid. Vision, Planning, and Initiative. Smart Grid 1.0: From Power Plant to Meters. The National Perspective on Smart Grid. Interfacing with Distributed Energy Resources (DER). Smart Grid 2.0 Emerges: An Integrated, Advanced Smart Grid. The Potential of Advanced Smart Grids. Fast Forward to Smart Grid 3.0
- <http://www.512cmg.com/services/book/>

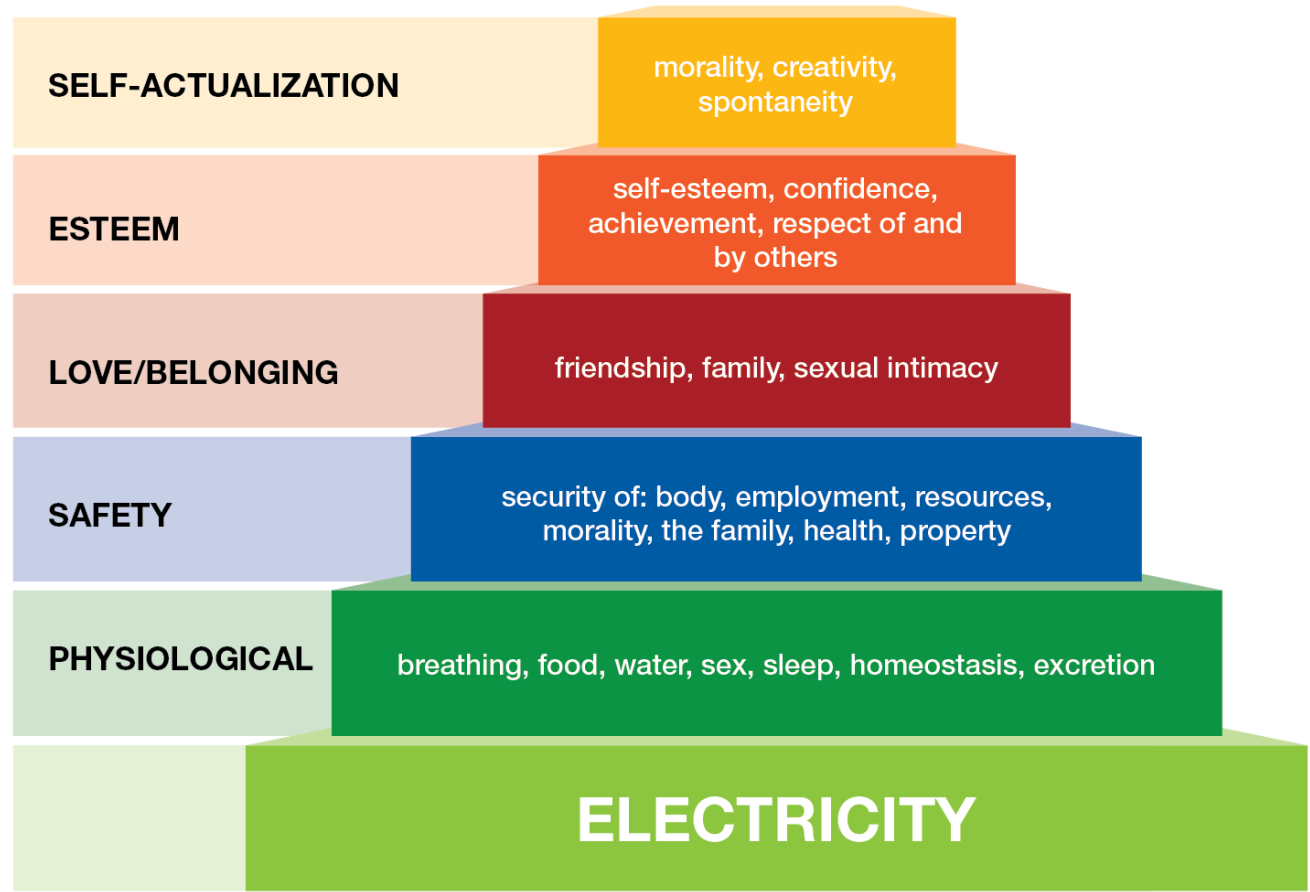




Electricity Drives All Modern Life

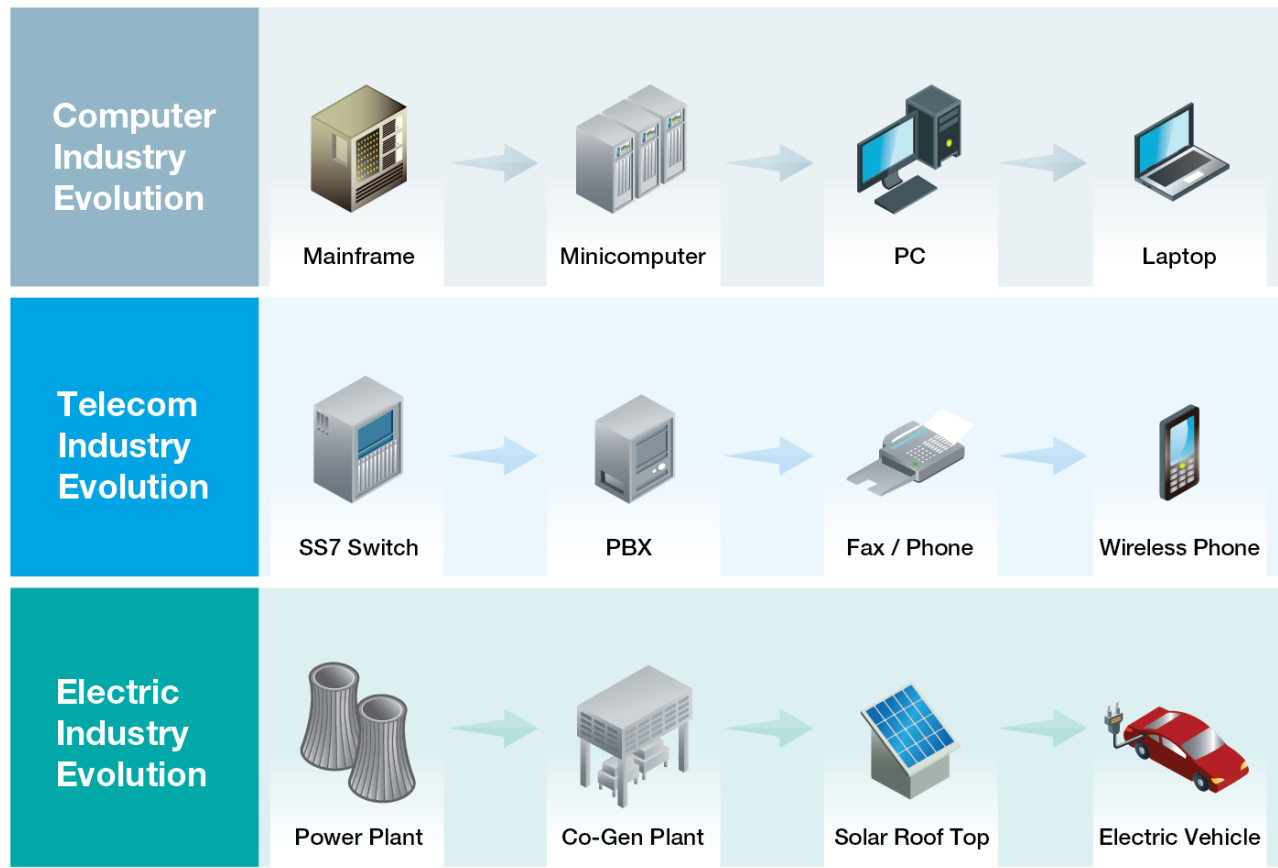
The Grid has become the fundamental infrastructure that provides the quintessential essence of our modern lives: electricity

Without electricity, we lose modernity, as we rapidly revert to a more primitive state, focused on survival and our most basic physiological and safety needs.





We Have Been Here Before



The Grid must be upgraded to become an Advanced Smart Grid because the nature of technology is to evolve over time to empower individuals at the edge.

The electricity industry will follow similar trend lines described by evolution in the IT and telecom industries.



The Inevitable Emergence of The Smart Grid

- EDISON and Tesla's inventions have lasted 135 years almost unchanged, since Pearl Street Station in NYC in 1882 to today.
- DC power dominated until 1890. AC power took over since.
- Samuel Insull invented the winning business model in 1897 offering two tier rates to Chicago Citizens.
- Central Generation, Load Factor (Avg.Load/PeakLoad), Copper Wires, and Tier Rates are at the core of the business model.
- First DCS by Honeywell in 1975. First SCADA and Modbus by Modicon in 1979. And first EMS by most vendors in 1981.
- Demand Response was introduced by IEEE in 1980.
- First Smart Meter (GE) with two way network deployment (Metricom) deployed by Southern California Edison in 1986.
- Power Grid has remained blind from substation to meter and beyond all this time.



What drove the Smart Grid in Austin, Texas in 2003?

- **Best Managed Utility in the US**
 - Created Strategic Plan in June 2003 (revised every 2 yrs.)
- **2010 Goals**
 - Get AA bond rating
 - Get to 83% in customer satisfaction index
 - Get SAIDI to 40, SAIFI to 0.5 and SALTPI to 3
- **2020 Goals**
 - Get to 800 MW of energy efficiency
 - Get to 35% mix of renewable energy in our generation (now 65% since Aug 2014)
 - Get to 200 MW of Solar (now 800 MW – Aug 2014)



AE Smart Grid Program 2003 - 2010



- First deployment of 127,000 smart meters in 2003
 - One way RF network built in 2003 and Fiber to every substation
- Built Strategic Plan and Technology Governance in 2004
 - PMO, EAC, DRC, TSC, EDC
- Enterprise Architecture deployed in 2006
 - Portal, Enterprise Service Bus, Data Warehouse, Business Intelligence, Cyber Security, IT Management Tools, Fiber backbone
- 2-way RF network upgrade plus more Fiber to support two wind farms, a solar farm, a CHP natural gas power plant, two cogeneration power plants, and two district cooling microgrids in 2007 - 2010
- Nodal Market Tools deployed plus Storm Center in 2008
 - New GMS, New Network Model, SCADA/EMS Upgrades, New Maximo and PowerPlan
- All 420,000 smart meters installed in 2009
- New Meter Data Management System deployed in 2010
- 120,000 smart thermostats installed (25% of homes in Austin)
 - Started in 2003, 80k residential, 6k commercial, double by 2015
- New Billing System replacement in April of 2011
 - RT/TOU Pricing, Pre-pay, Web2.0, TXT/SMS, Self-service
- New Distribution Management System in January of 2012
 - Piloted with 500 sensors in 2009. Grow to 20,000 sensors by 2020.



What is the Smart Grid 1.0 (SG1)?

It is the automation of the entire Utility Grid

- **Smart Grid 1.0 = GA + TA + SA + DA +AMI**
- Smart Grid 1.0 (SG1) monitors, controls and manages the creation, distribution and consumption of energy, AND has dynamic visibility and control of the distribution assets, including meters.
- This step requires the logical integration of SCADA/EMS with DMS with GIS with AMI/MDM in a new way.



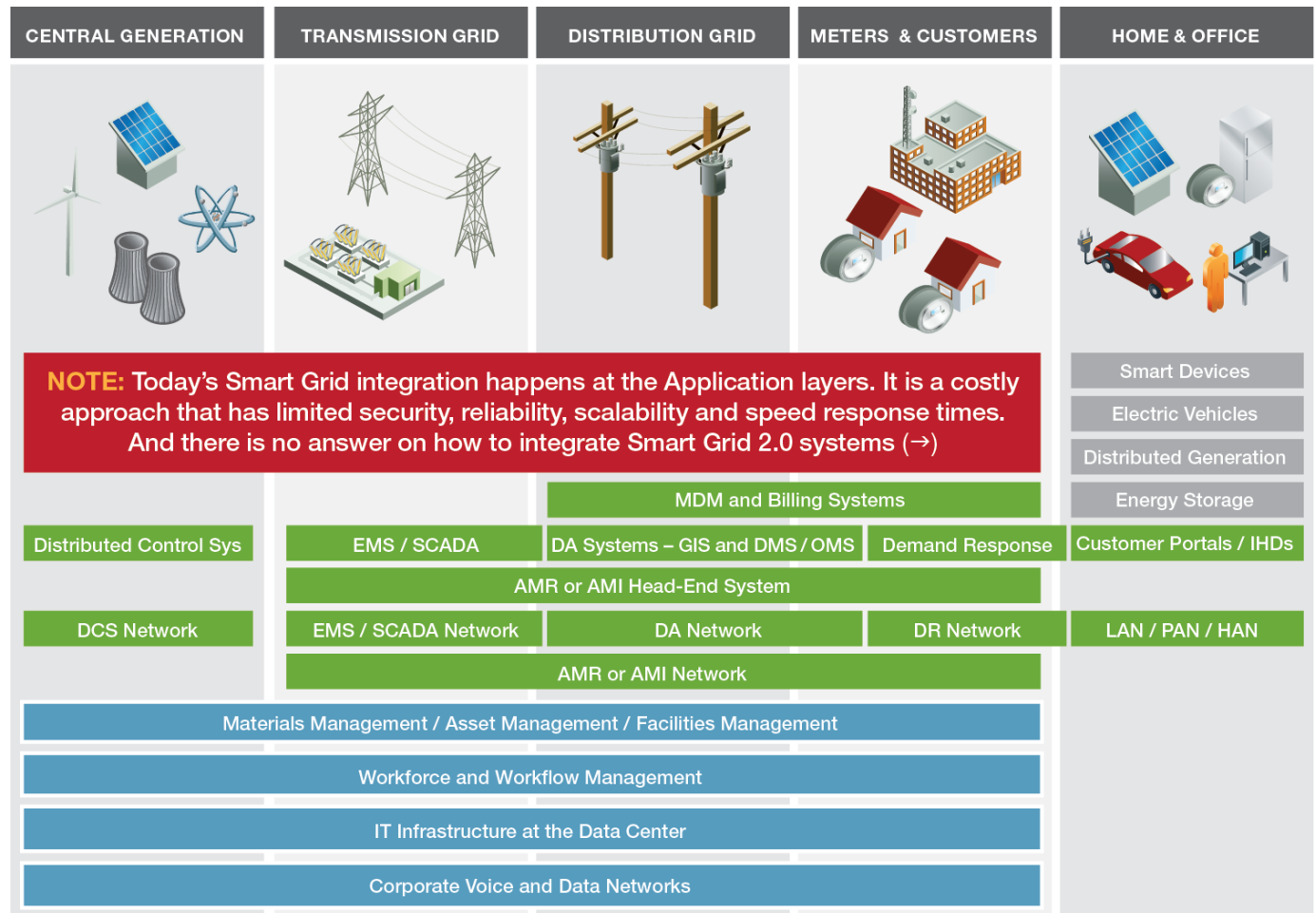
Smart Grid 1.0 (SG1)

Most Smart Grids start with an Application and then face numerous System Integration projects.

Utilities are controlled by silos and lack of interoperability

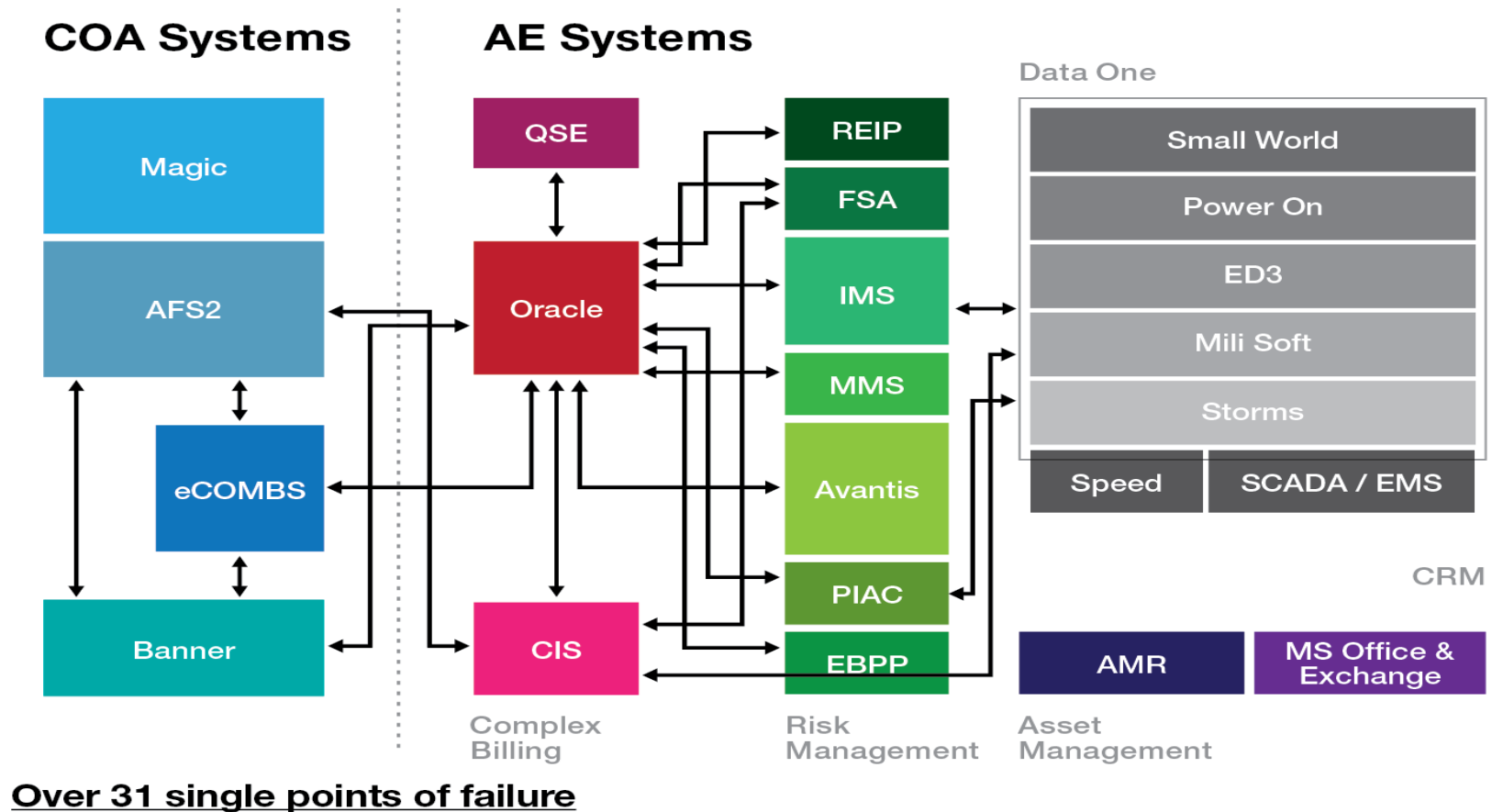
Lack of competition and monopoly behaviors prevent innovation

Regulatory model does not help either





Multiple Versions of The Truth





What is the Smart Grid 2.0 (SG2)?

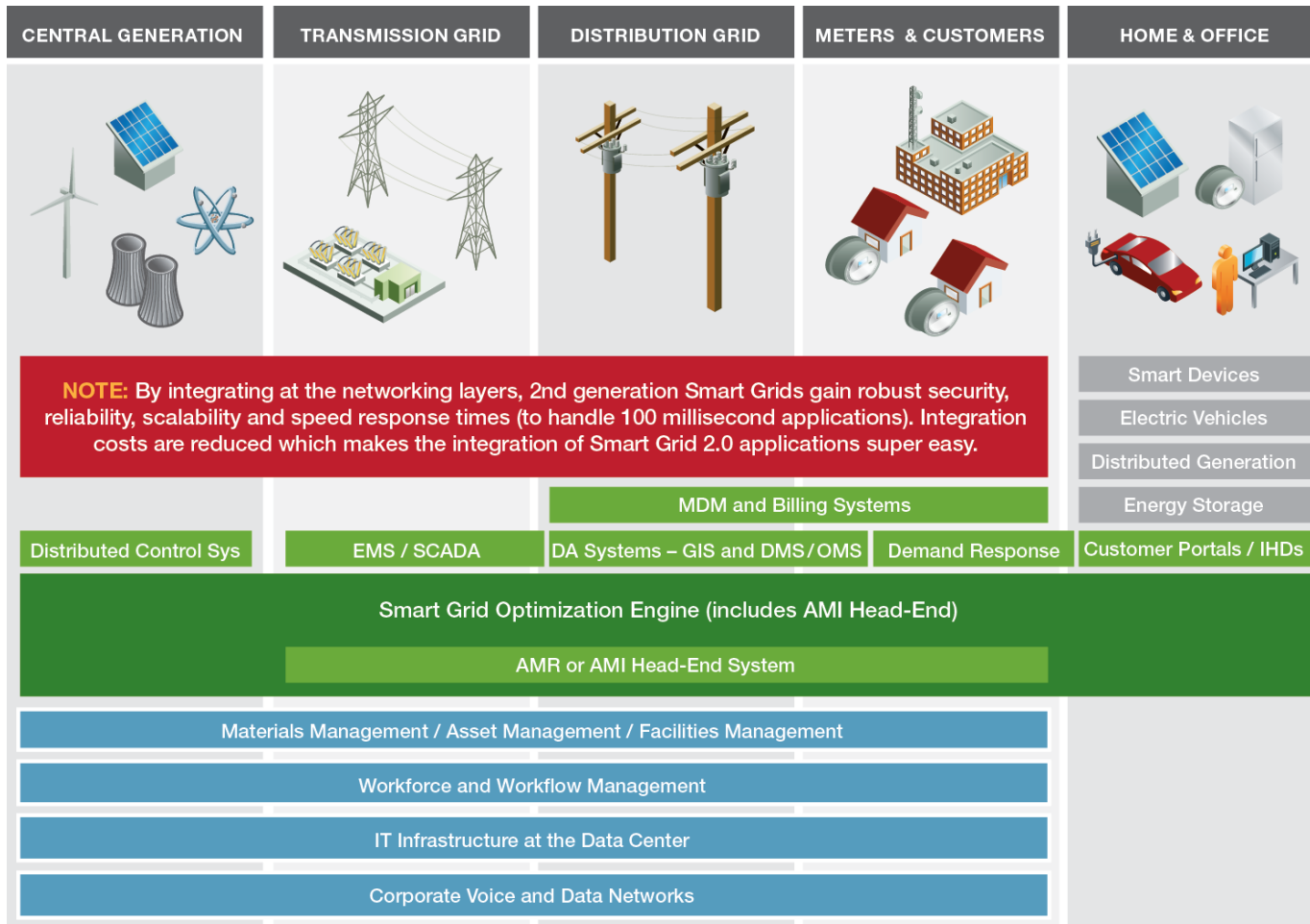
Utility Grids + Buildings + Homes + Vehicles

- ivy Smart Grid definition since March 5, 2004 united the Utility Grid, Buildings, Homes, and Vehicles into one grid
- **Smart Grid = GA + TA + SA + DA + DR + AMI + DER (i.e. DG + ES + EV)**
- The Smart Grid monitors, controls and manages the creation, distribution and consumption of energy
- The Smart Grid of the future is distributed, interactive, self-healing and reaches every device connected to it.



Smart Grid 2.0 (SG2)

(a.k.a. The Advanced Smart Grid)



The Advanced Smart Grid starts with a Network Design and Integrated Network Plan, and becomes able to integrate Applications as needed, more efficiently and securely.

Interoperability and standards are key. Protection of distribution network is also key.

Customer assets like Solar PV, EVs, smart appliances, micro CHP, energy storage and their control systems require integration.



Smart Grid 1.0 and Smart Grid 2.0

	Smart Grid 1.0 (SG1)	Smart Grid 2.0 (SG2)
Initial Step	Application (e.g., AMI, DR, DA, V2G, etc.)	Smart Grid Architecture Framework Design & IP Network Plan
Networks	Networks driven by Application Choices	Networks driven by Use Case Requirements and Design
System Integration Project Requirement	Multiple Projects: $(N*(N-1))/2$, where N = number of systems	Minimal Projects; the framework anticipates new applications
Security	Challenge; Each new application requires a security project	Optimized; Integrated Security is part of the Smart Grid Architectural Framework
Data Capacity	Determined by the weakest link in the chain	Optimized; Integrated Energy Ecosystem is designed for optimal data capacity / performance
Total Cost of Ownership (TCO)	Higher	Lower



When How You Start Really Matters

OSI MODEL

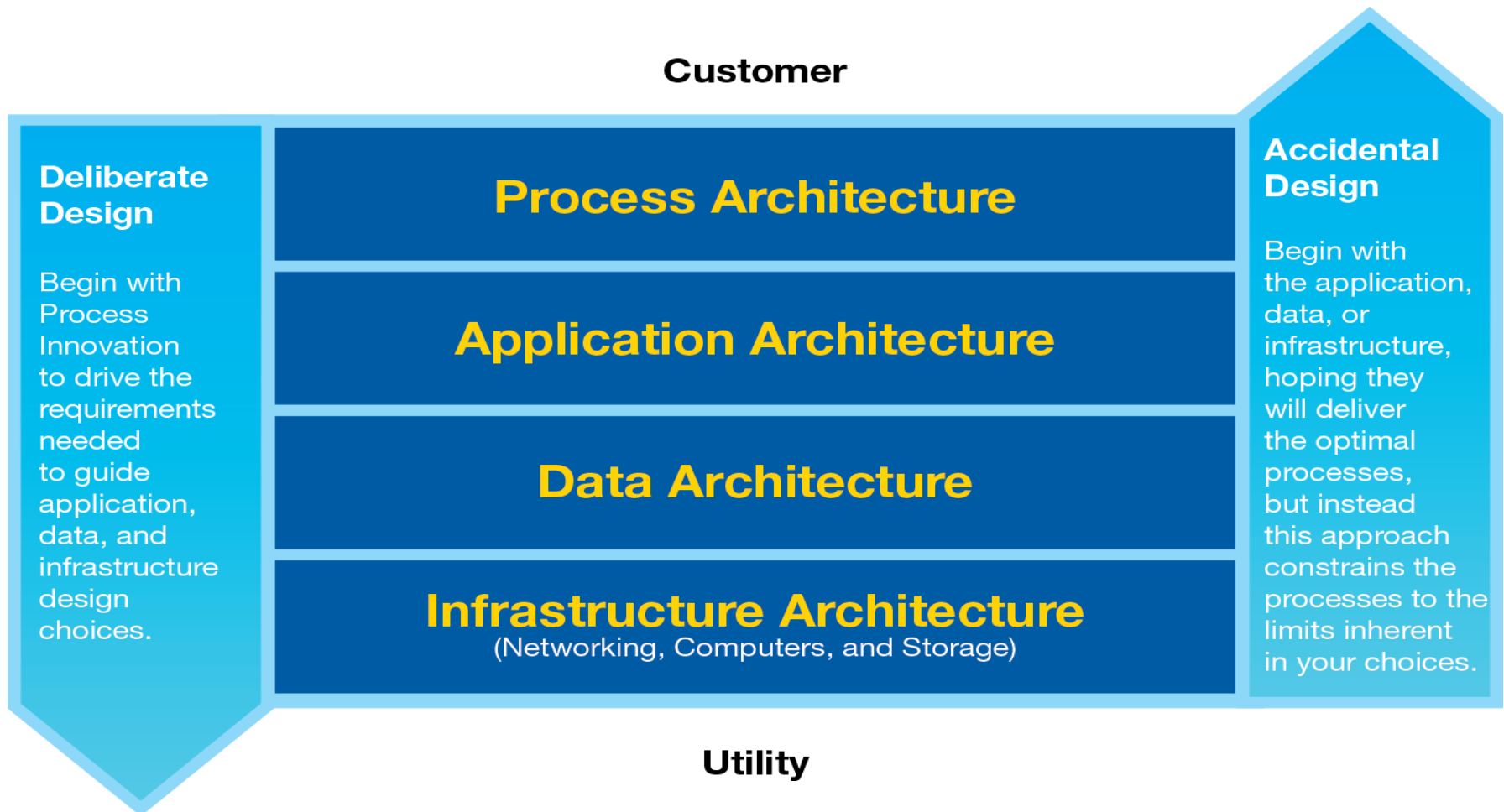
7	Data	Application Network Process to Application
6	Data	Presentation Data Representation to Encryption
5	Data	Session Interhost Communication
4	Segments	Transport End-to-End Connections and Reliability
3	Packets	Network Path Determination and IP (Logical Addressing)
2	Frames	Data Link MAC and LLC (Physical Addressing)
1	Bits	Physical Media, Signal and Binary Transmission

Most Smart Grids start with an Application and then face numerous System Integration projects.

The Advanced Smart Grid starts with a Network Design and Integrated Network Plan, and becomes able to integrate Applications as needed, more efficiently and securely.

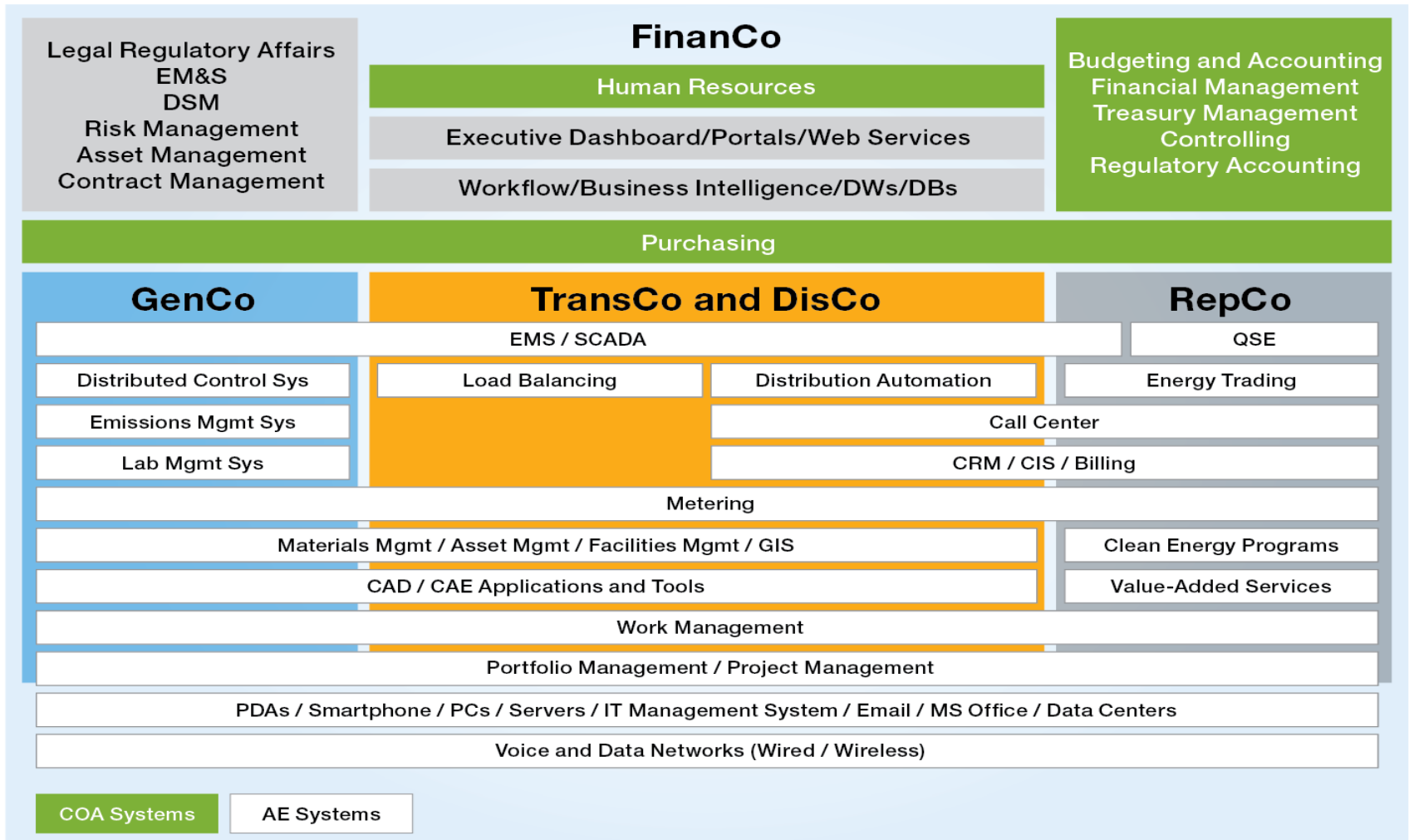


Deliberate vs. Accidental Design



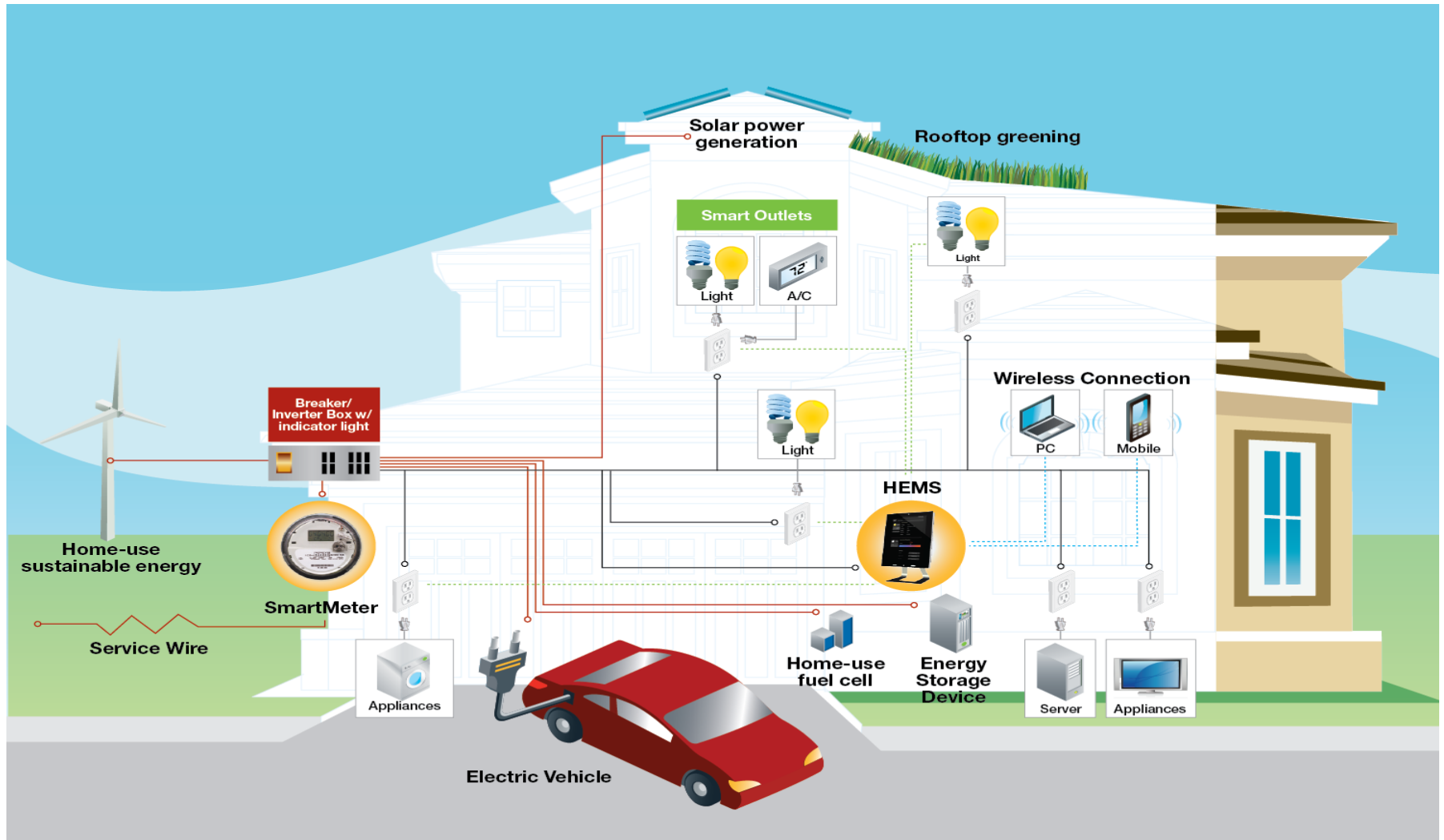


The Advanced Smart Grid Architecture Design



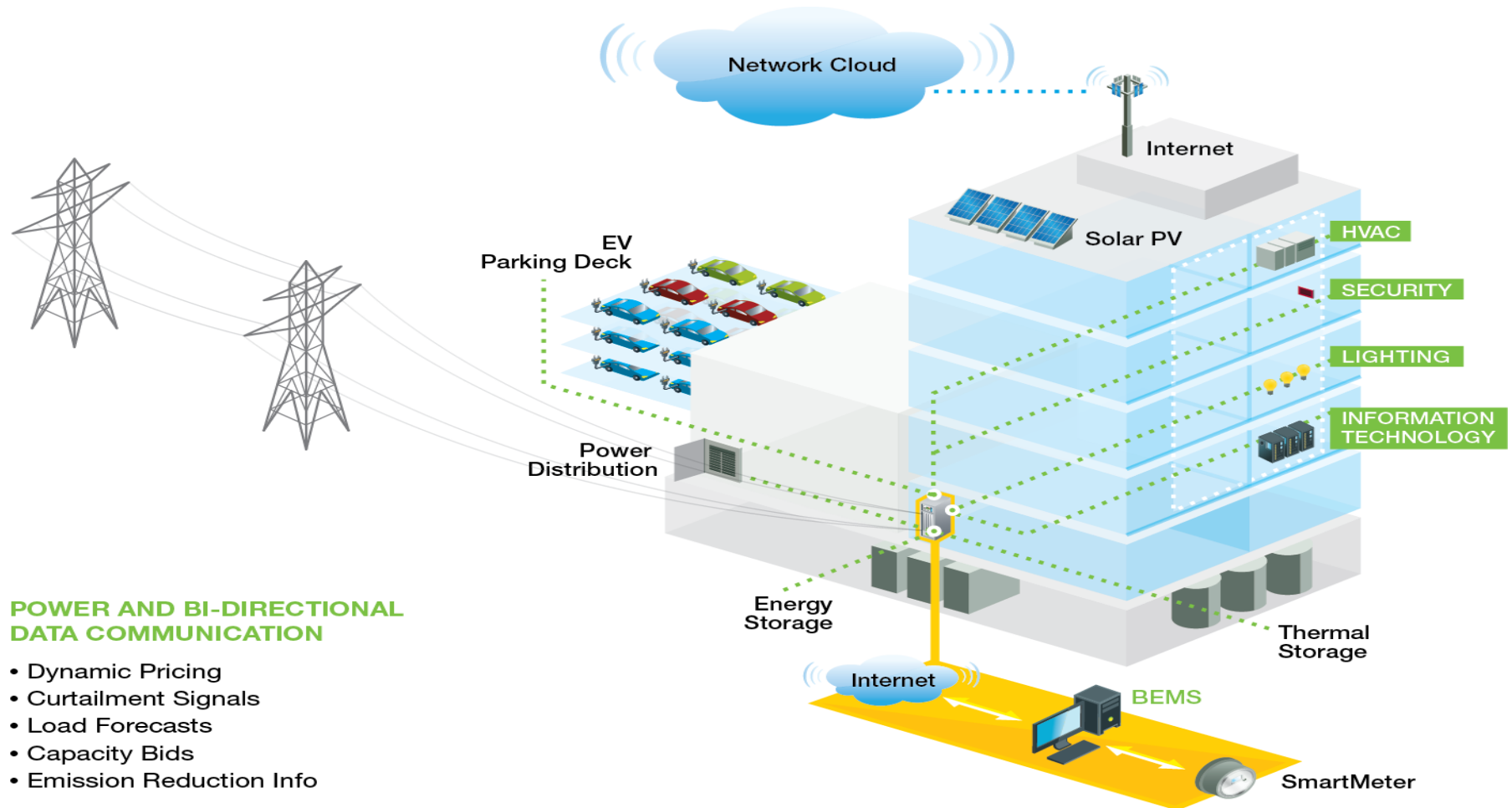


Smart Home Design





Smart Building Design

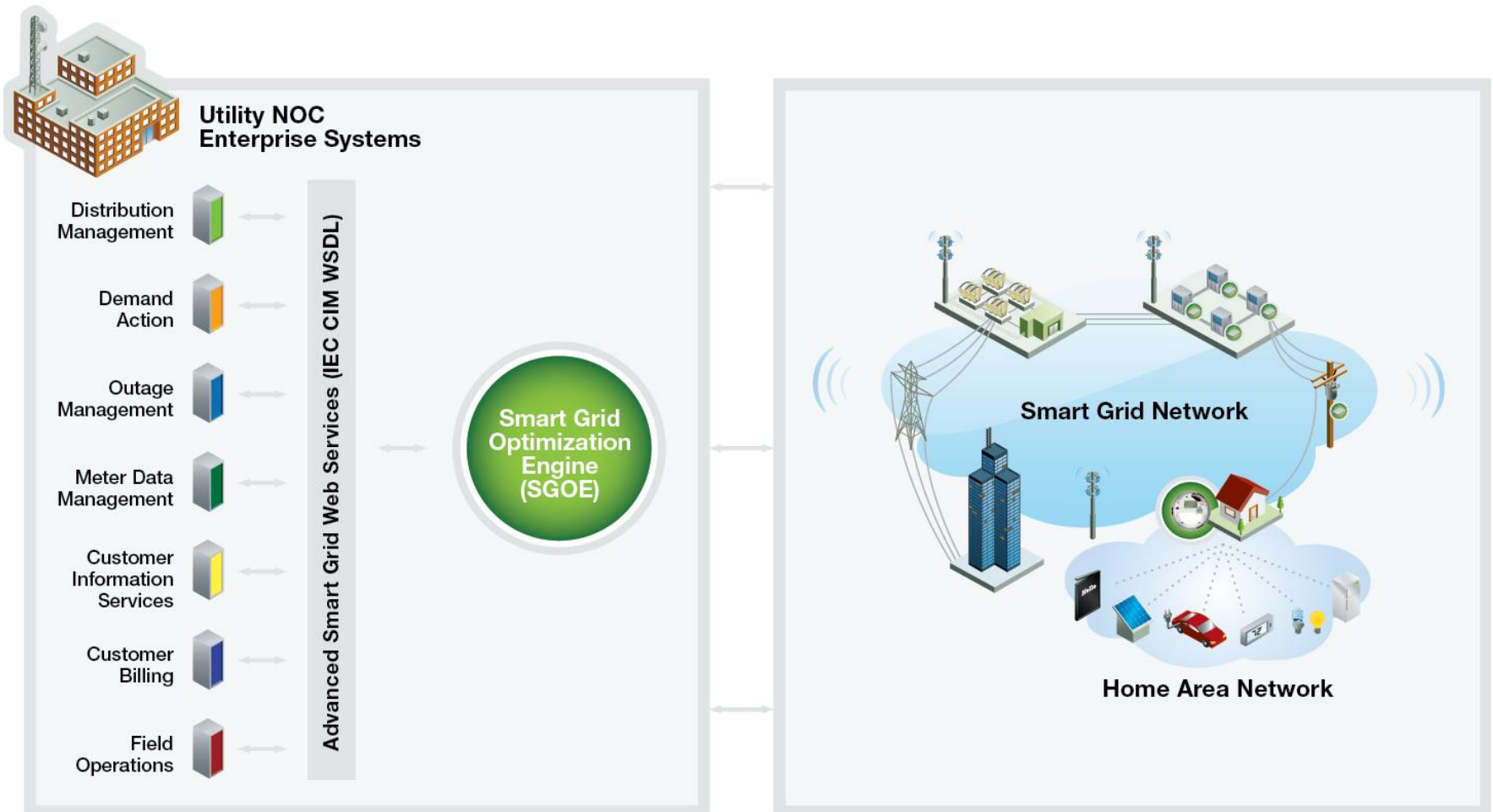


POWER AND BI-DIRECTIONAL DATA COMMUNICATION

- Dynamic Pricing
- Curtailment Signals
- Load Forecasts
- Capacity Bids
- Emission Reduction Info

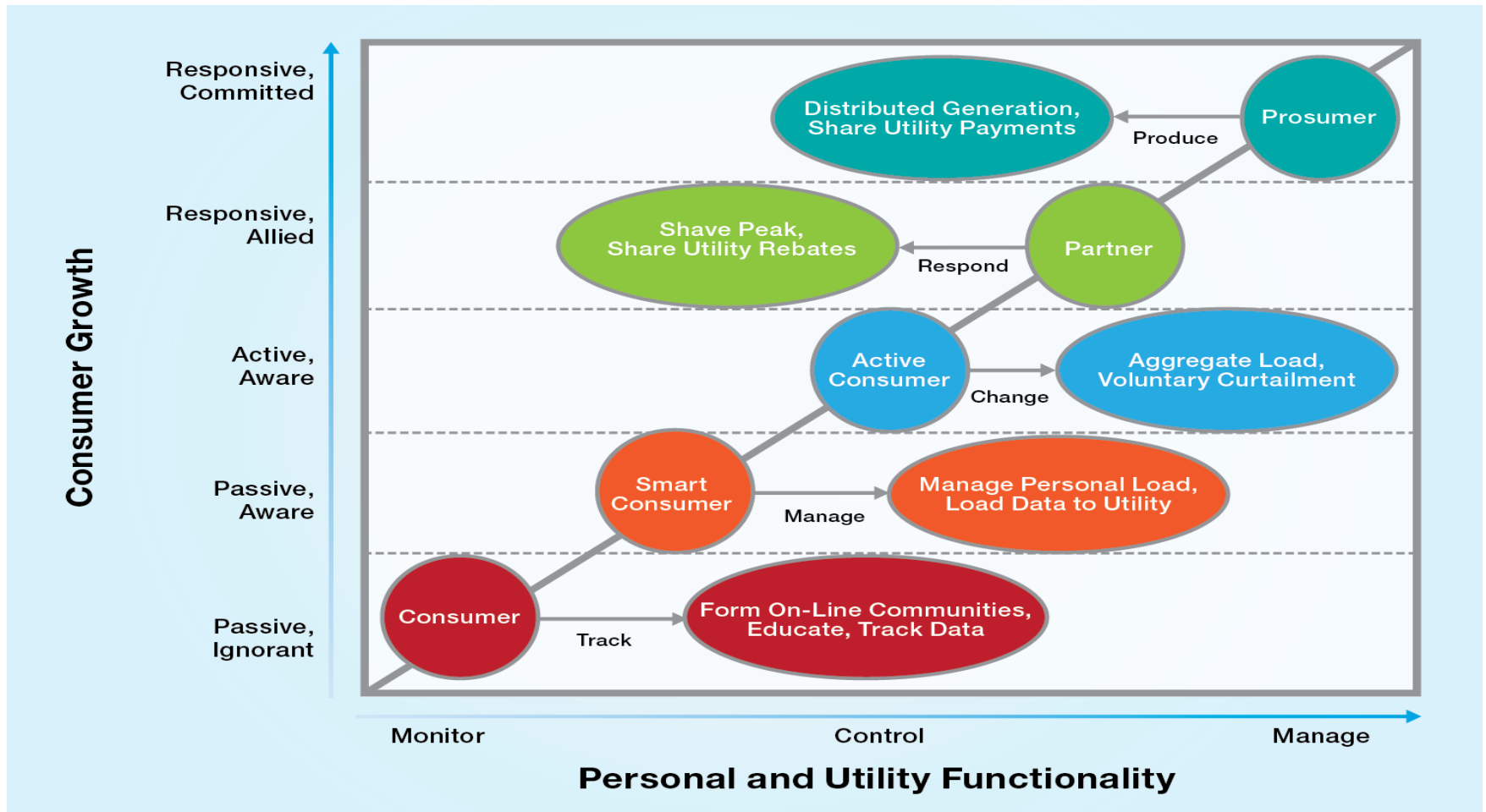


Smart Utility Design



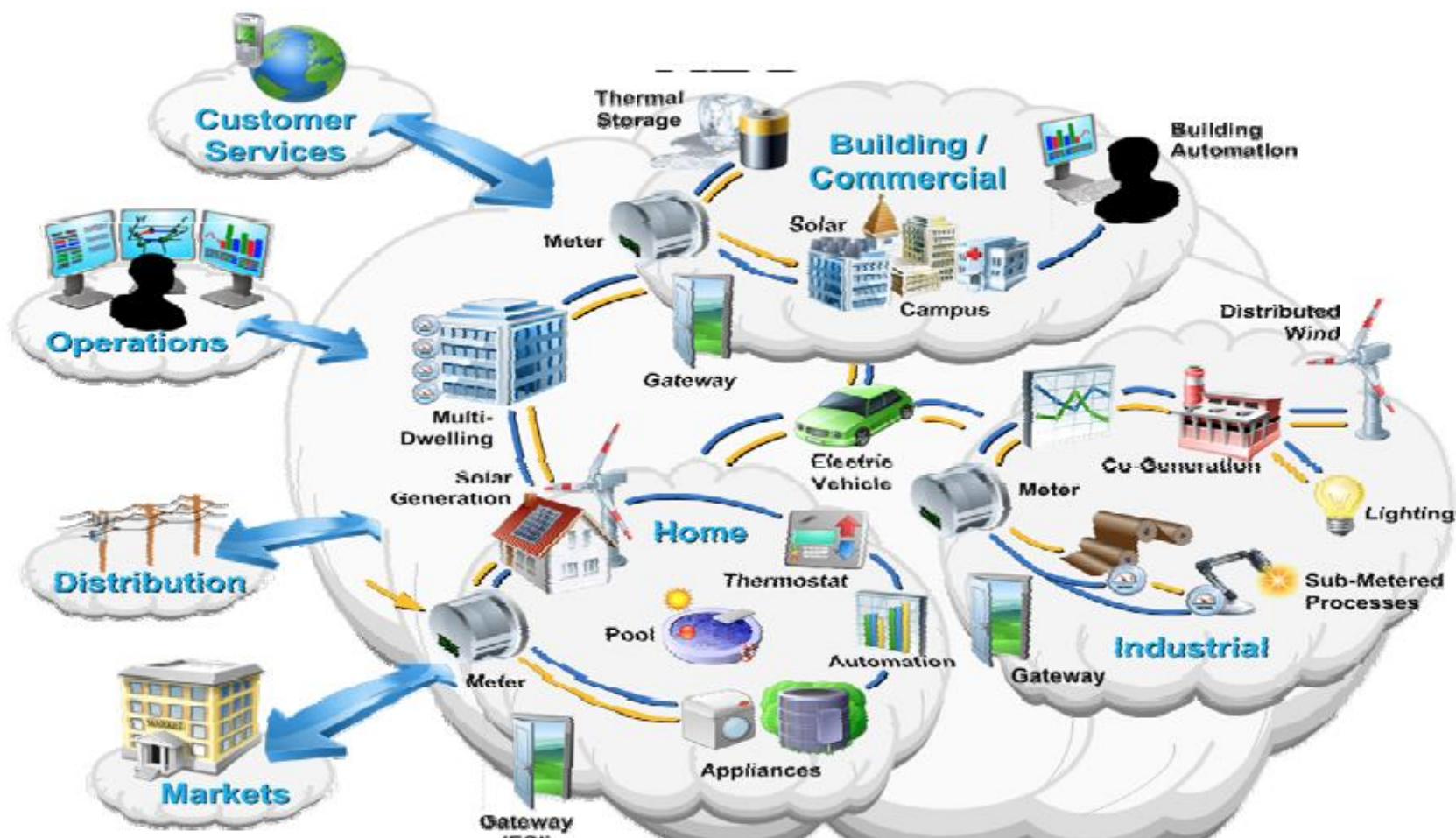


From Consumers to Prosumers





SG2 Enables Smart City





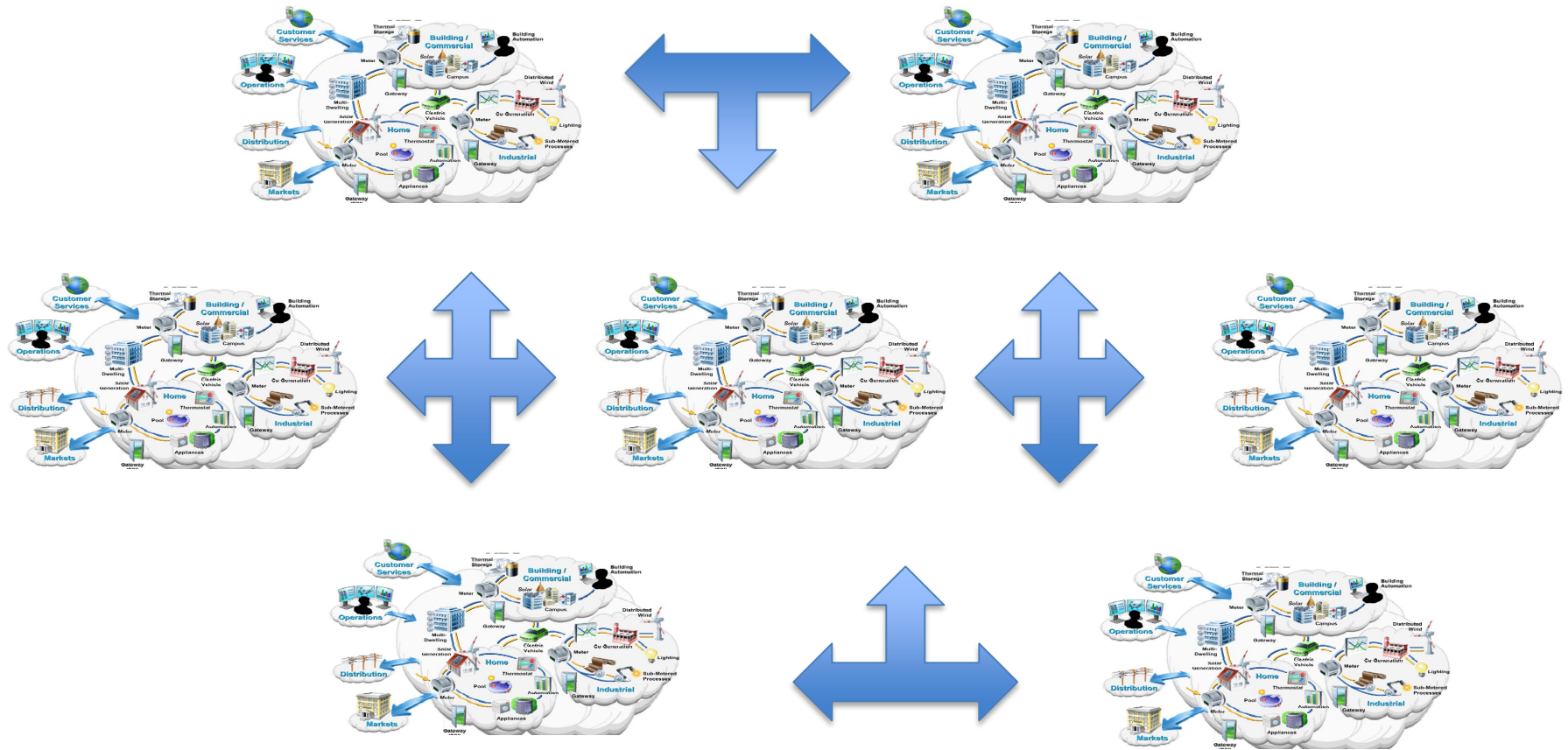
What is the Smart Grid 3.0?

Smart Grid 2.0's interconnected enabling energy roaming

- Every Smart Grid definition since March 5, 2004 unites the Utility Grid, Buildings, Homes, and Vehicles into one grid and predicts the eventual roaming of energy among service territories.
- Either ISO/RTOs, Utilities or New Energy Service Providers will perform such roaming exchange and settlements.
- This new reality will decouple the transaction for the commodity from the physical delivery of it regionally, national, internationally, globally.



SG3 enables Smart Nation





Smart Grid Journey from 1.0 to 2.0 to 3.0

Smart Grid Maturity Model¹

LEVELS	DESCRIPTIONS	RESULTS
Level 5: Innovating – Next wave of improvements	New business, operational, environmental and societal opportunities present themselves, and the capability exists to take advantage of them.	Perpetual Innovation Self-healing operations Autonomic Business INNOVATORS
Level 4: Optimizing – Enterprise- Wide	Smart Grid functionality and benefits realized. Management and operational systems rely on and take full advantage of observability and integrated control across and between enterprise functions.	Transformation Real-time corrections Broad reuse VICTORS
Level 3: Integrating – Cross Functional	Smart Grid spreads. Operational linkages established between two or more functional areas. Management ensures decisions span functional interests, resulting in cross functional benefits.	Systemization Repeatable practices Shared information CROSS LOB CHAMPIONS
Level 2: Functional Investing	Making decisions, at least at functional level. Business cases in place, investments being made. One or more functional deployments under way with value being realized. Strategy in place.	Strategy Proof of Concepts MISSIONARIES
Level 1: Exploring and Initiating	Contemplating Smart Grid transformation. May have vision, but no strategy yet. Exploring options. Evaluating business cases, technologies. Might have elements already deployed.	Vision Experiments PROPHETS AND HEROES

¹ Smart Grid Maturity Model (SGMM) Overview, Software Engineering Institute, Carnegie Mellon University (Pittsburgh, PA, 2009)



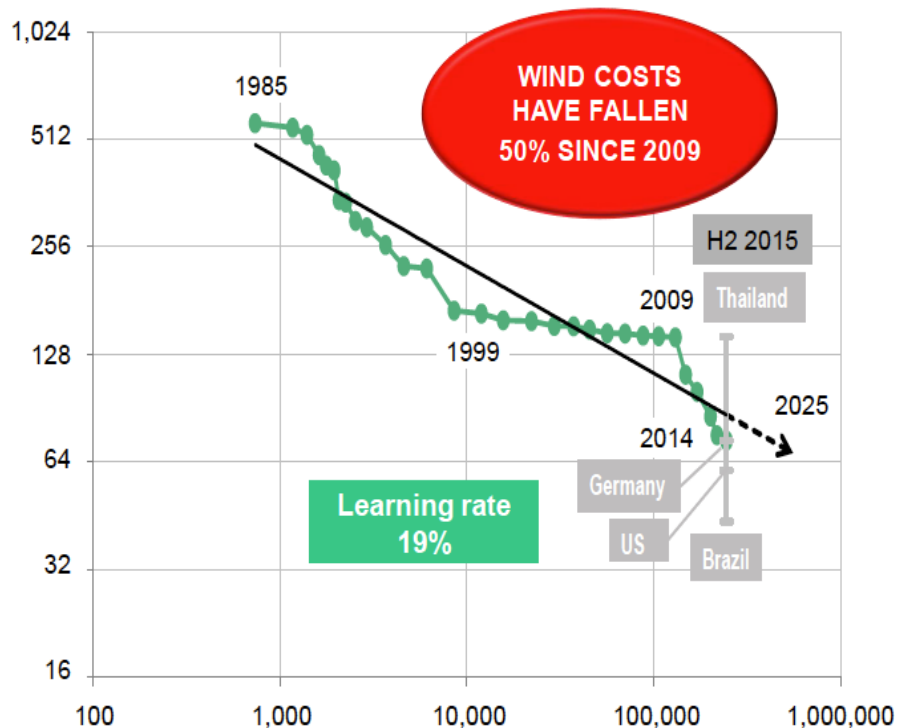
9 Energy Disruptions

- Renewable Energy
- Demand Response
- DER and Microgrids
- Energy Storage
- Electric Vehicles
- Retail Choice
- Product Bundling
- Prosumerism
- New Business Models

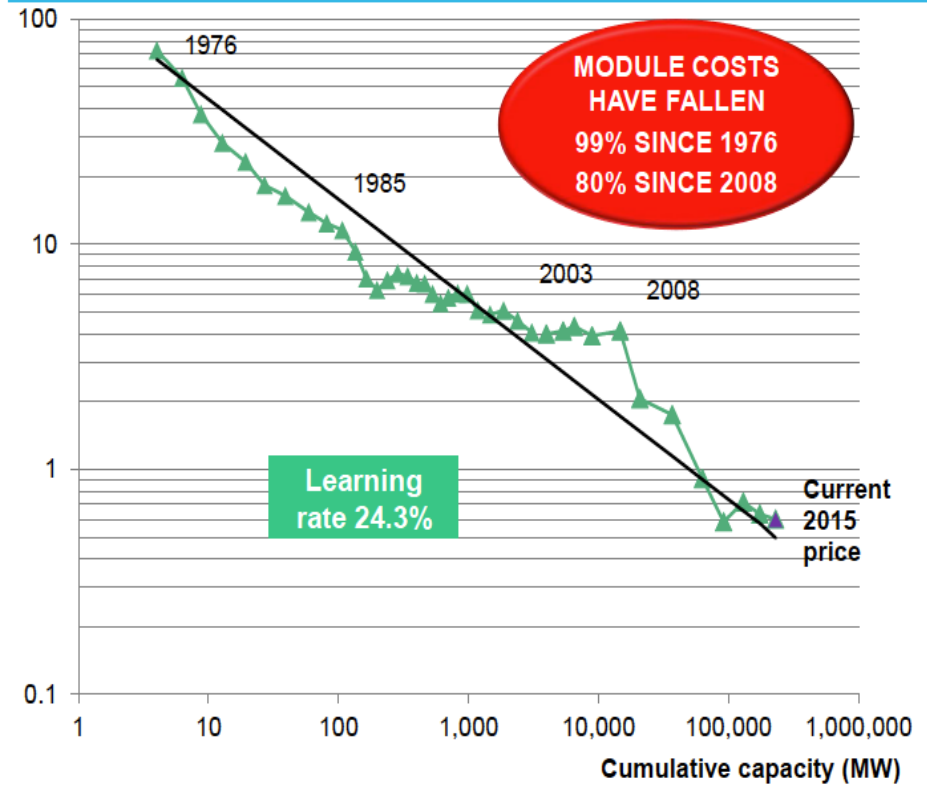


Renewable Energy

ONSHORE WIND LEVELISED COST (\$/MWh)

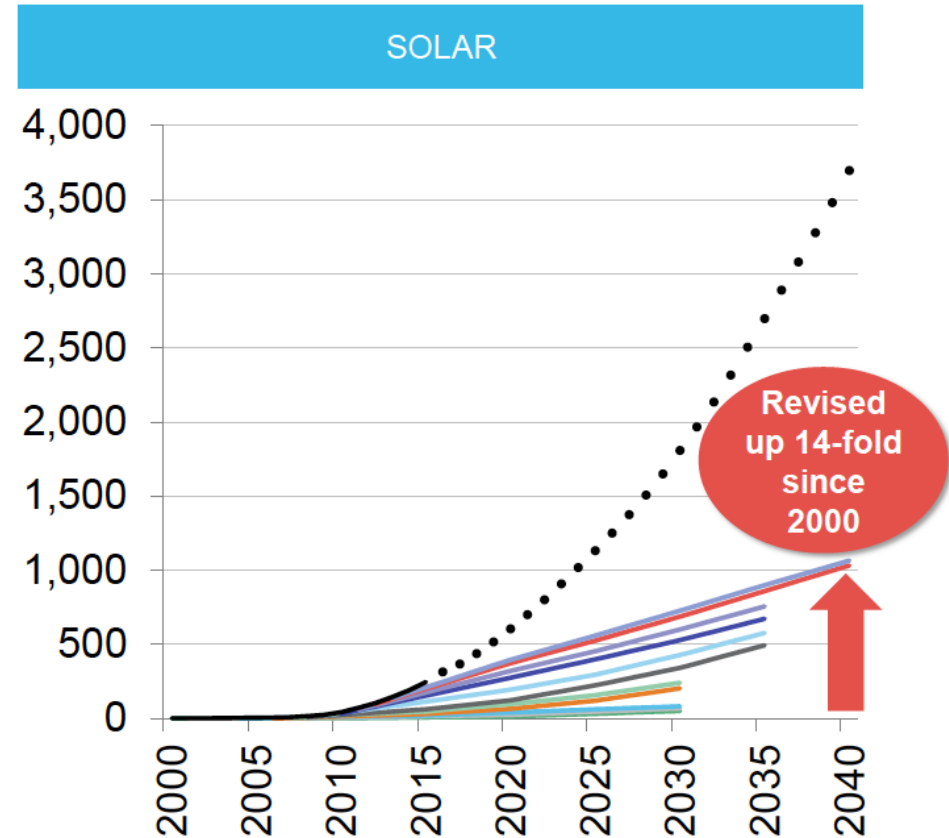
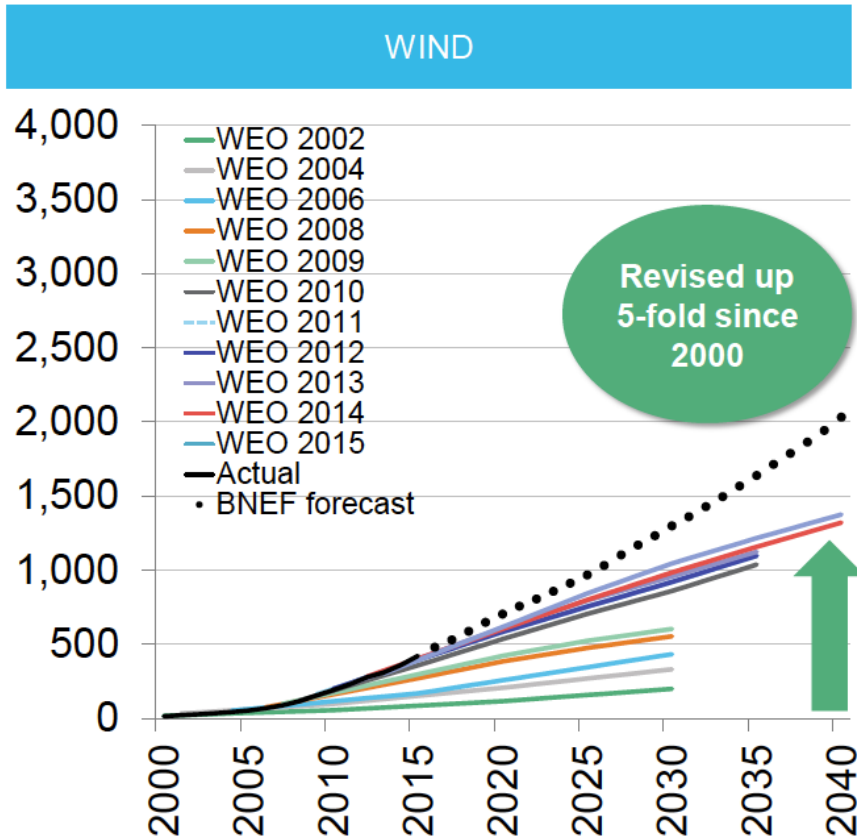


SOLAR PV MODULE COST (\$/W)





Renewable Energy





Demand Response (Capacity)

- Wholesale market operators are getting impacted through the input of grid-scale and transmission-connected renewables.
- This complexity is augmented because adding intermittent renewables both centralized and/or distributed make the dispatch equation much more complicated.
- As frequency and duration of intermittency grows, adding and managing generation reserves are not good enough.
- Demand Response as we know it and Dynamic Demand Response both emerge as great tools to solve this problem. Virtual Power Plants emerge.



DER & Microgrids

- **Microgrid Proliferation**
 - Trend is being helped by low interest rates, low cost of solar PV, and low cost of natural gas.
 - Moore's Law starting to impact equipment vendors.
 - Government, Industrial and Commercial customers adopt microgrids (e.g. Hudson Yards)
 - Key reasons include right to choose, right power source, total power security, and better reliability.
- **Distributed Energy proliferation**
 - Reduces dependence on utilities and lowers carbon footprint
 - Creates potential for P2P energy trading
 - Enables owner to earn revenue stream from ancillary services back to utilities, while increasing resiliency

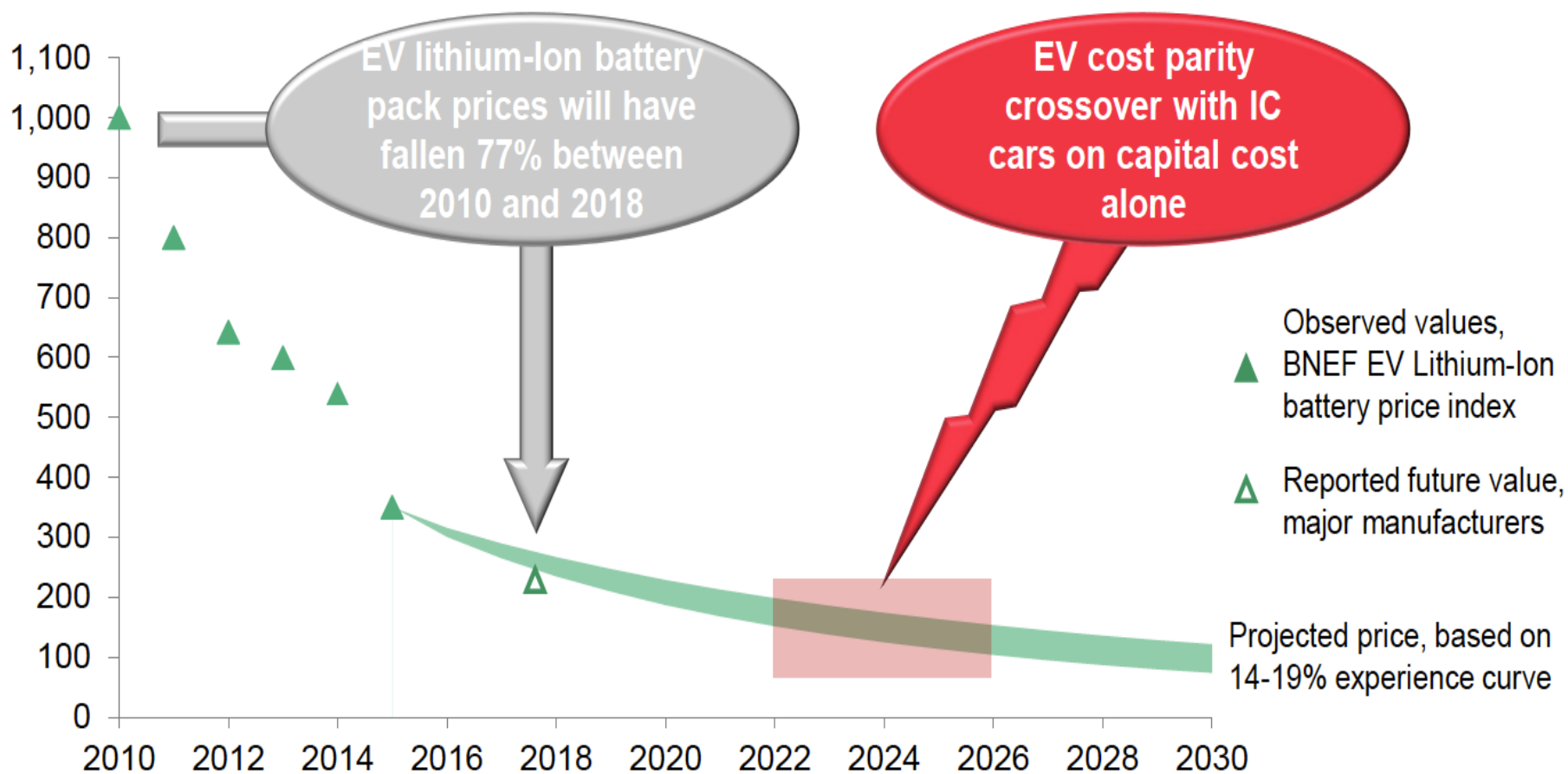


Energy Storage

- Voltage support, reactive power support, power factor correction and power quality enhancement.
- Frequency regulation and ancillary services.
- Flattening or shifting of the load profile – by storing when the generation cost is low and delivering when the generation cost (or need) is high.
- Support for intermittent generation resources like wind and solar (curtailment avoidance, smoothing, shifting, flexible discharge for peakers)
- Transmission and distribution capital deferral through congestion relief.



Energy Storage Cost



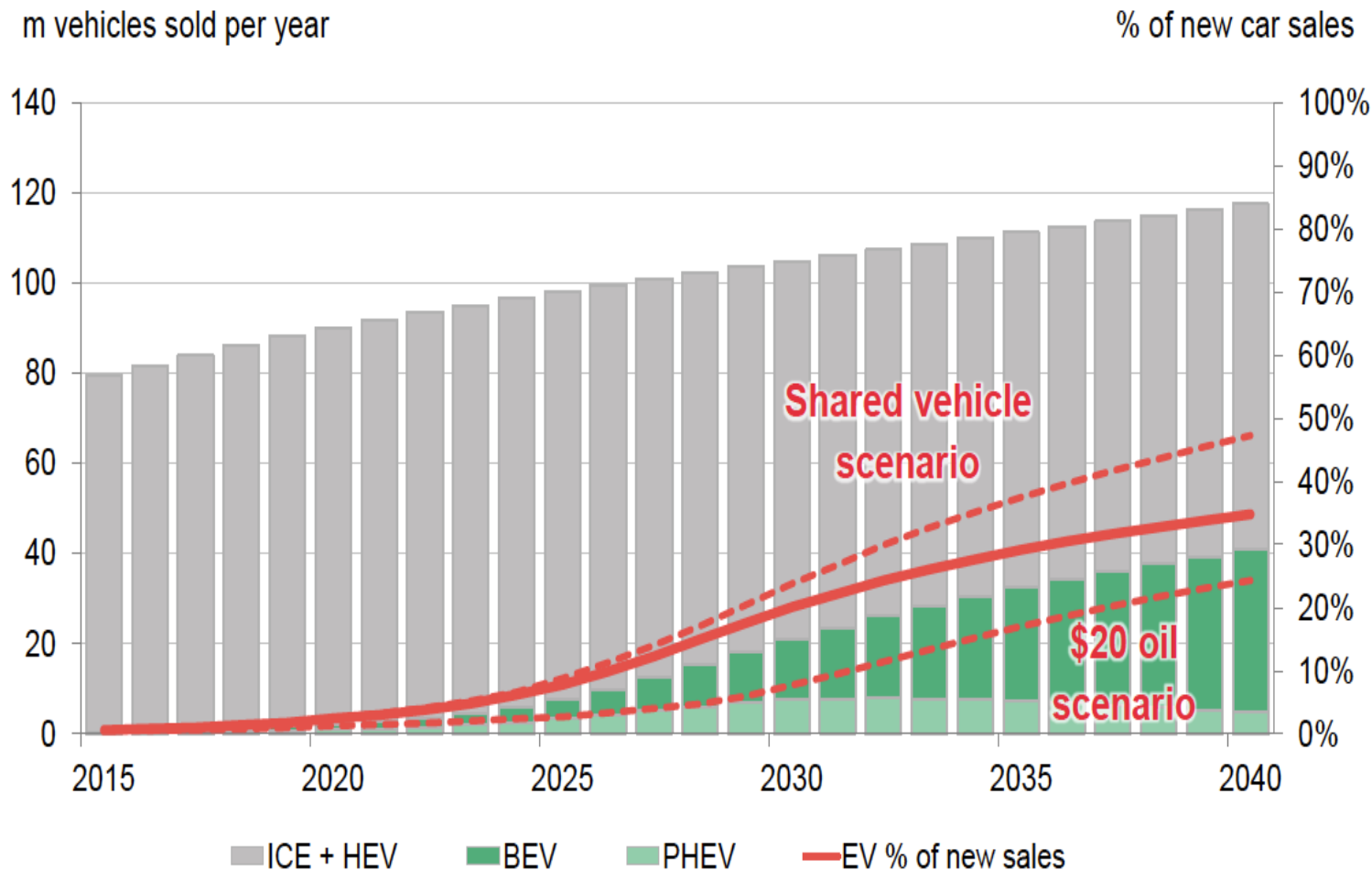


Electric Vehicles

- US growth of Electric Vehicles (EVs) reached over 522,519 cumulative units up to Sep 2016 since 2007.
 - US (17%), Japan (18%), Europe (29%), China (33%).
- EV charging not managed or coordinated in any way (e.g. load control or price signals) would introduce serious infrastructure and safety risks that could impact severely the power grid and its power quality.
- EV s are a special case of Energy Storage and can offer the same benefits with the ability to be moved to further relief traffic congestion and peak loads.



Global EV Forecast



By 2040
Up to 50%
of new cars
will be EVs



Retail Choice

- Retail Choice was approved in Connecticut, Delaware, Washington DC, Illinois, Maine, Maryland, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, and Texas between 2000 and 2002.
- Australia, New Zealand, and Western Europe adopted retail choice from 1998 to 2003.
- UK adopted retail choice in 2004 and is now all over the EU.
- Competitive Markets show significant technology and business model innovation along with cheaper prices and better customer satisfaction.

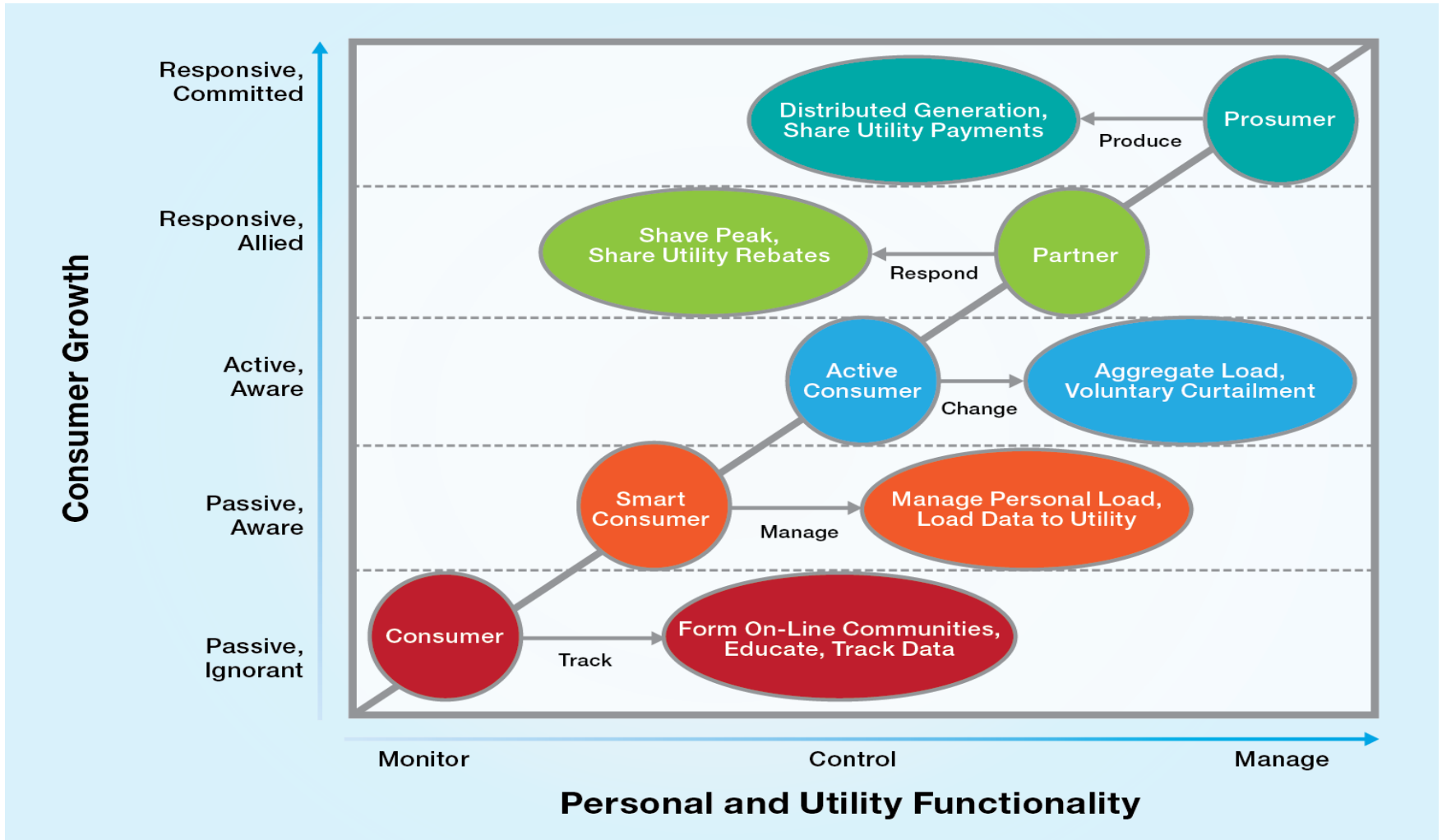


Product Bundling

- Players from the telecom, Internet, cable, natural gas, water, and home security industries are consolidating into a single group of companies (e.g., Comcast, Time Warner, AT&T, Verizon, Sprint) that deliver services bundled to customers.
- Comcast and NRG, via its subsidiary EnergyPlus, are offering such a bundle in several locations in Pennsylvania.
- Many utilities in Australia, New Zealand, and Western Europe offer bundled products and one-bill to all their customers.



Prosumerism





New Business Models

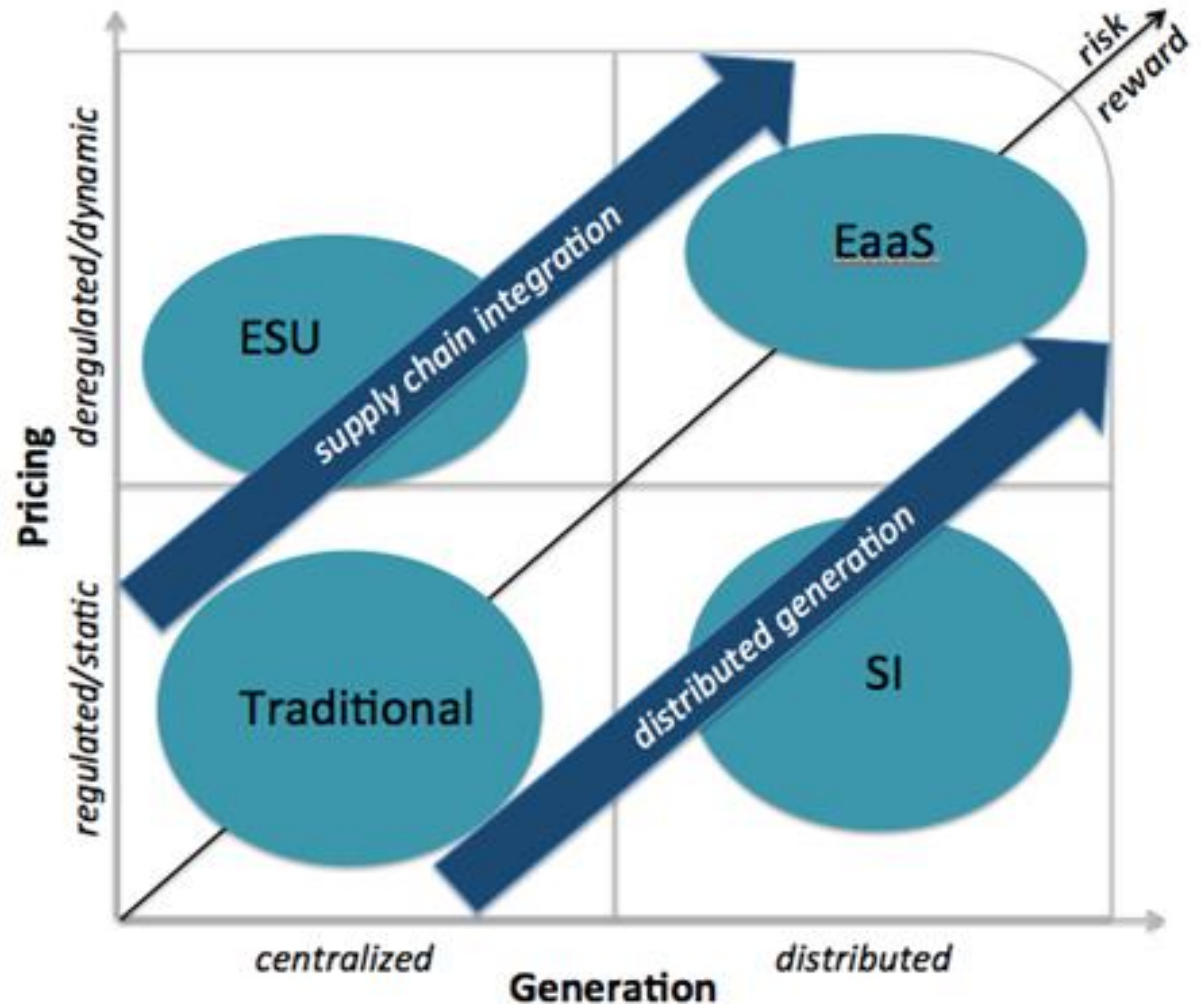
CMG believes that there is a significant improvement to be made to the business model suggestions made by the Brattle Group in 2012.

An EaaS is completely deregulated, dynamic, and distributed (i.e. leveraging and owning solar PV, CHP, energy storage and VPP as resources).

SI = Smart Integrator

ESU = Energy Services Utility






EaaS = Energy as a Service



IT Trends

- LTE vs. LPWA vs. RF Mesh vs. Others
- Cloud Computing
- Big Data

LAN vs. LPWA vs. Cellular

	Local Area Network Short Range Communication	Low Power Wide Area (LPWAN) Internet of Things	Cellular Network Traditional M2M
	40%	45%	15%
	Well established standards In building	Low power consumption Low cost Positioning	Existing coverage High data rate
	Battery Live Provisioning Network cost & dependencies	High data rate Emerging standards	Autonomy Total cost of ownership
	Bluetooth 4.0  WiFi	RF Mesh LoRa WiSUN	 3G+ / H+ 4G

Evolution to 5G

Evolution to 5G

Network Requirements

Higher capacity
More devices
Faster throughput
Lower latency
Increased bits/Hz/km²
Deeper coverage
More flexibility
Greater energy efficiency

2015

2020

2025

4G Evolution

5G

Wireless Technology

*Evolution of LTE-Advanced
Closer integration of LTE and WiFi*

New technology for dense deployment of high-speed low-latency services

Spectrum

*Spectrum neutrality Spectrum sharing
700MHz/800MHz for rural/deep coverage
Unlicensed bands for traffic offload*

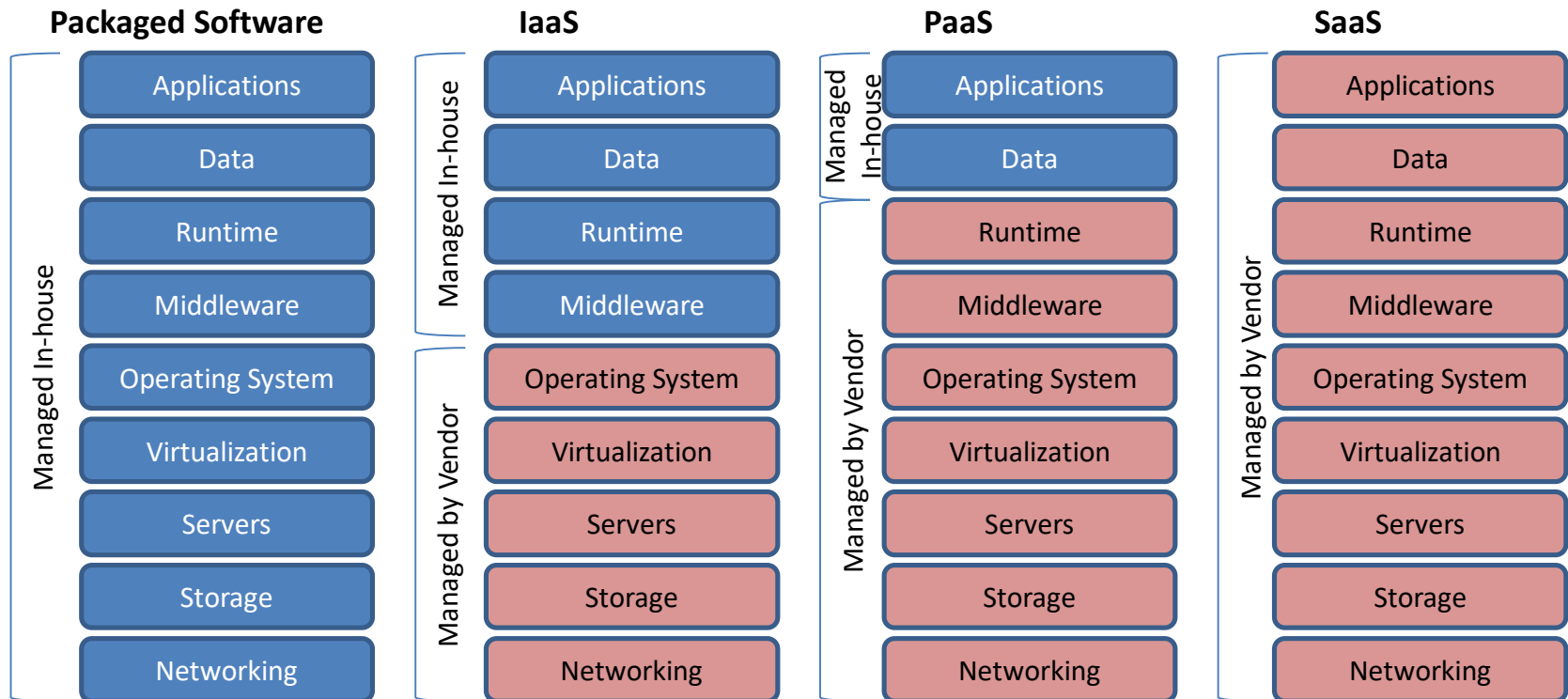
Centimetre/millimetre waves 6GHz->100GHz for dense cell deployment

New techniques

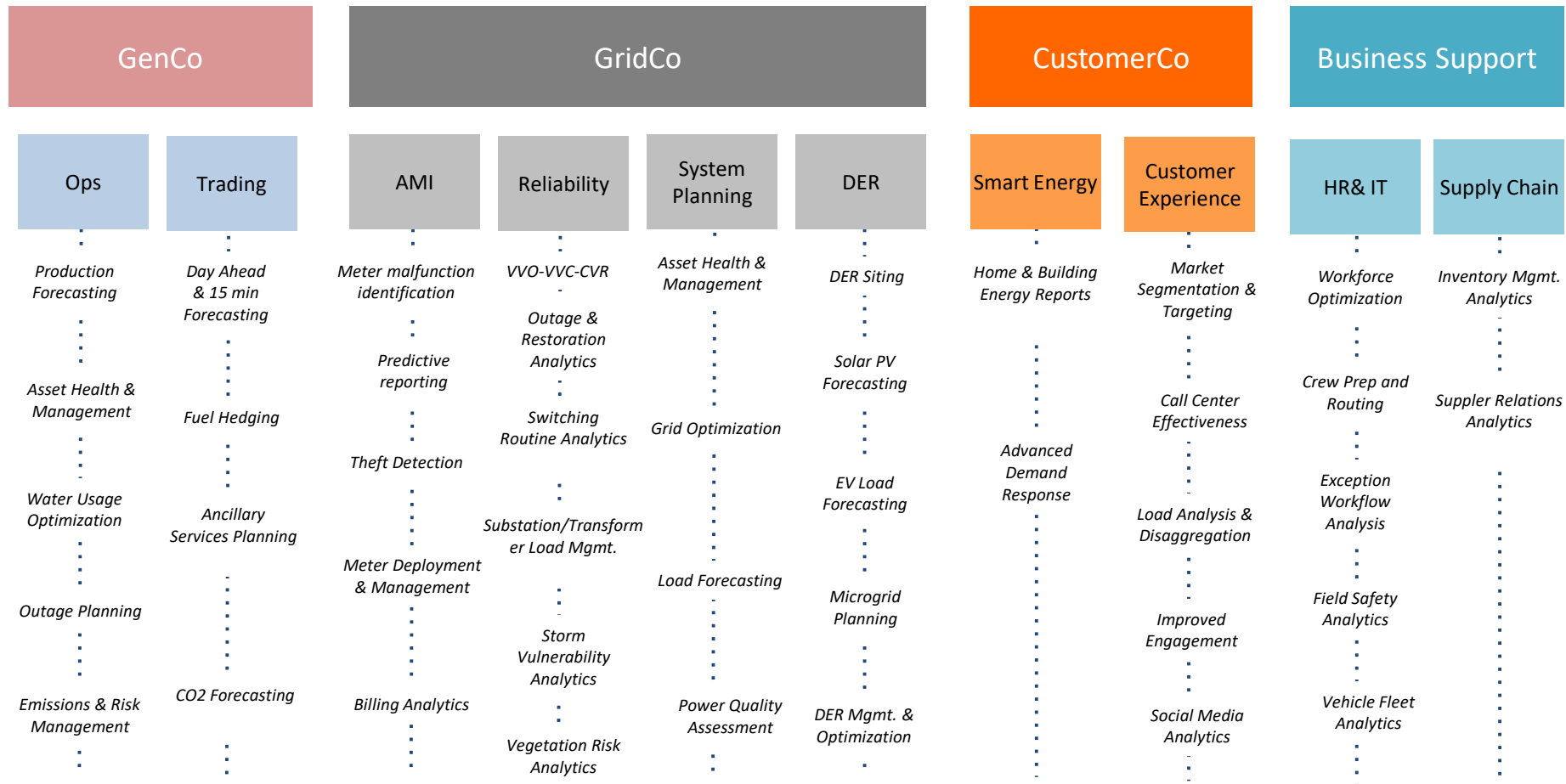
*Advanced Carrier Aggregation High-order MIMO Context-aware mapping of services to technologies
Radio resource coordination between cells
Lighter protocols Virtualisation*

Cloud Computing Types

IaaS, PaaS, and SaaS: The Three Main Layers of Cloud Computing



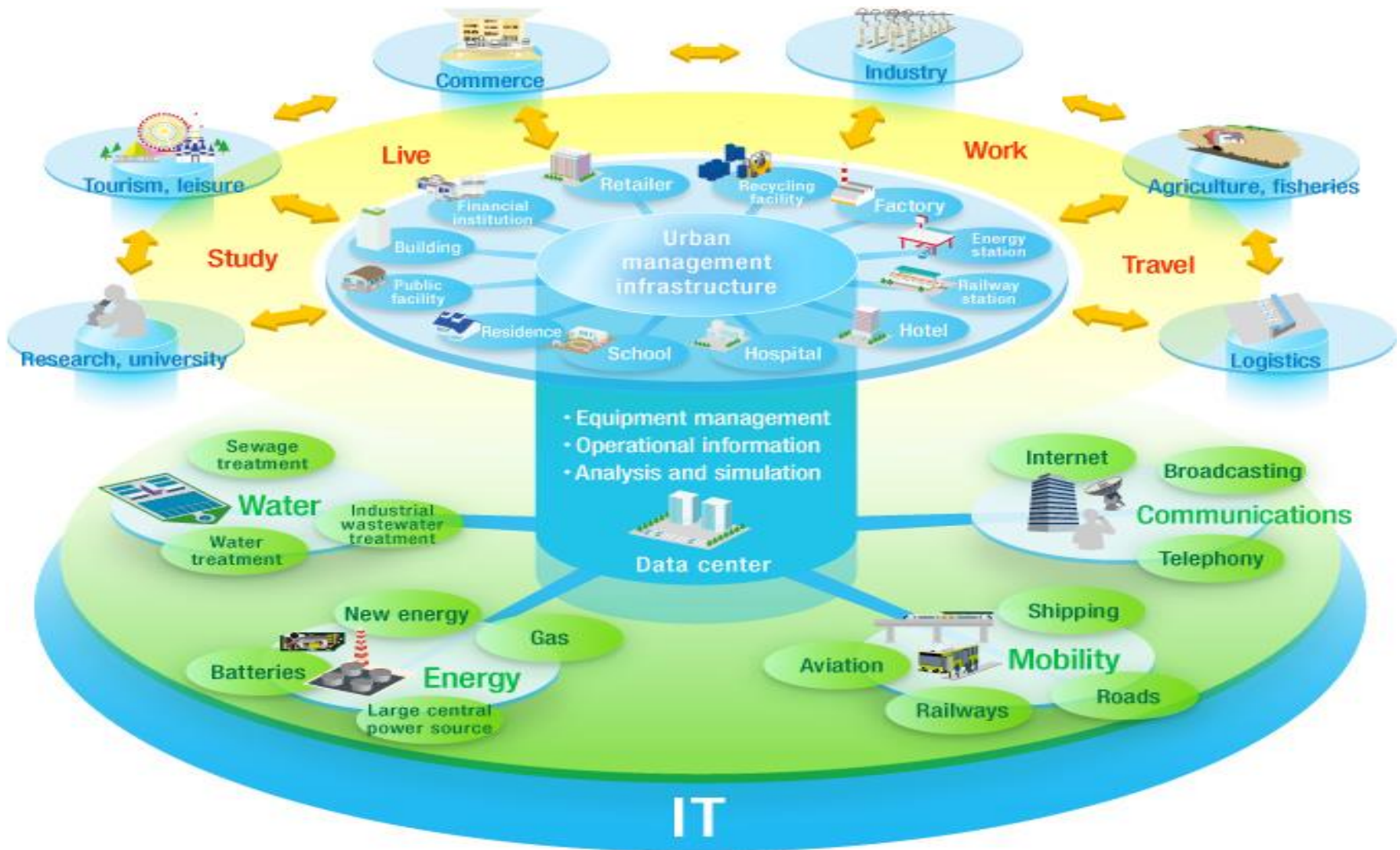
Big Data Use Cases





New Trend

Smart Cities





What were the Results?





Achievements



Austin Energy Key Achievements from 2003 to 2010

- Sales went from \$850 million in 2003 to \$1.3 billion in 2010
- Meters served went from 360,000 in 2003 to 420,000 in 2010
- Reduced SAIDI from 89 min in 2003 to 40 min in 2010
- FTE count went from 1,800 in 2003 to 2,000 in 2010
- Did Not Increase Customer Rates within 2003 and 2010



Questions???

- CMG is headquartered in **Austin, Texas** and has partner offices in **Atlanta, Boston, Chicago, Denver, Minneapolis, New York City, Seattle, Toronto, and Washington DC.**
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