Smart Grid as an Infrastructure Platform

CARIMET Regional Workshop on Metrology and Technology Challenges of Climate Science and Renewable Energy

April 15, 2015

Dr. David Wollman david.wollman@nist.gov

Deputy Director, Smart Grid and Cyber-Physical Systems Program Office, Engineering Laboratory, National Institute of Standards and Technology

U.S. Department of Commerce

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

engineering laboratory

NIST role in smart grid

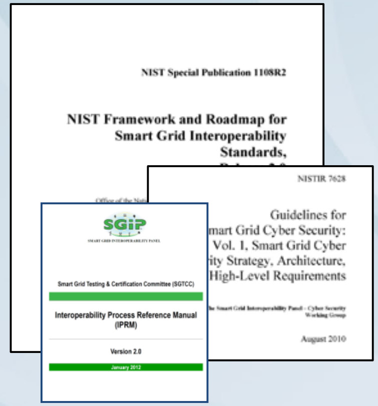
- NIST: non-regulatory agency in U.S. Dept. of Commerce
- NIST standards coordination

  EISA 2007: coordination with government agencies, fed/state regulators, utilities, vendors, standards developing orgs., …

The Energy Independence and Security Act of 2007 gave NIST *“primary responsibility to coordinate development of a framework that includes … **standards** … to achieve interoperability of smart grid devices and systems…”*

http://www.nist.gov/smartgrid/

- NIST Framework and Roadmap for SG Interoperability, Release 3.0

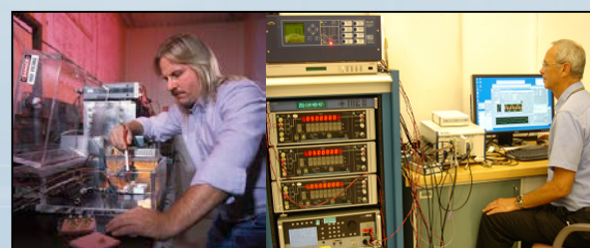


NIST Smart Grid Domains

- Smart Grid Interoperability Panel

  www.sgip.org
  Catalog of Standards
  Priority Action Plans

- NIST research program

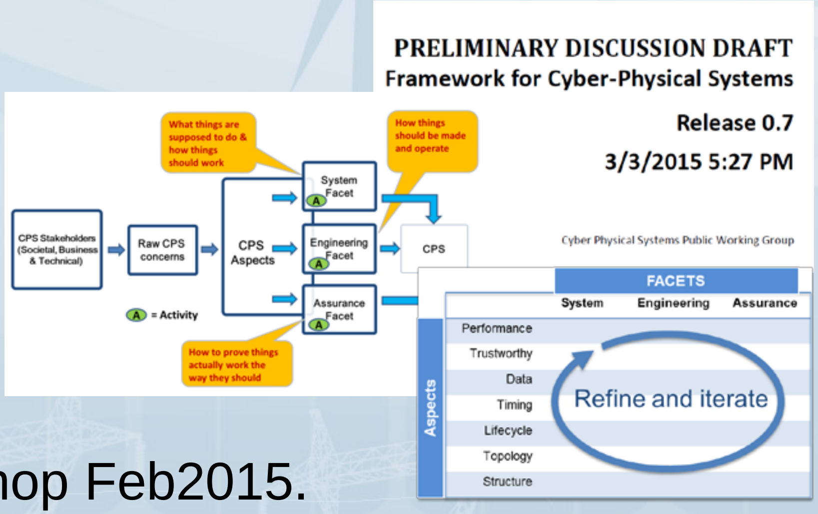


NIST measurement testbeds

NIST role in cyber-physical systems

- Global Cities Team Challenge
  - Smart Cities are key platforms to show replicable, scalable and reproducible CPS/Internet of Things deployments
  - Festival: 40+ teams and 180+ participating companies, cities and universities. www.nist.gov/cps/sagc.cfm

- CPS Public Working Group
  - NIST leadership w/industry, academia; CPS experts in 5 working groups creating draft CPS Framework. www.cpspwg.org



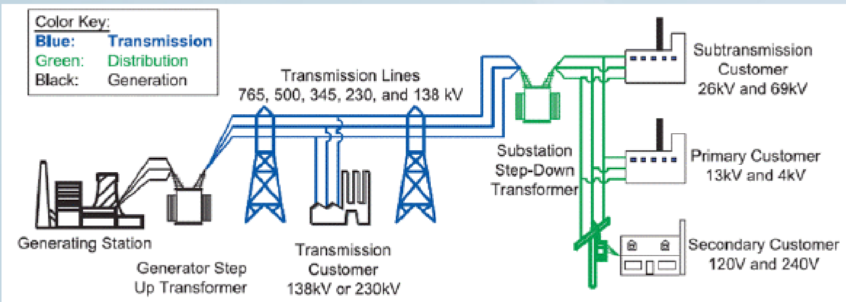
- CPS Test Bed
  - Conceptual design in progress; workshop Feb2015.
- CPS Standards and Research
  - Cybersecurity, industrial control systems, manufacturing, healthcare, ….

Outline

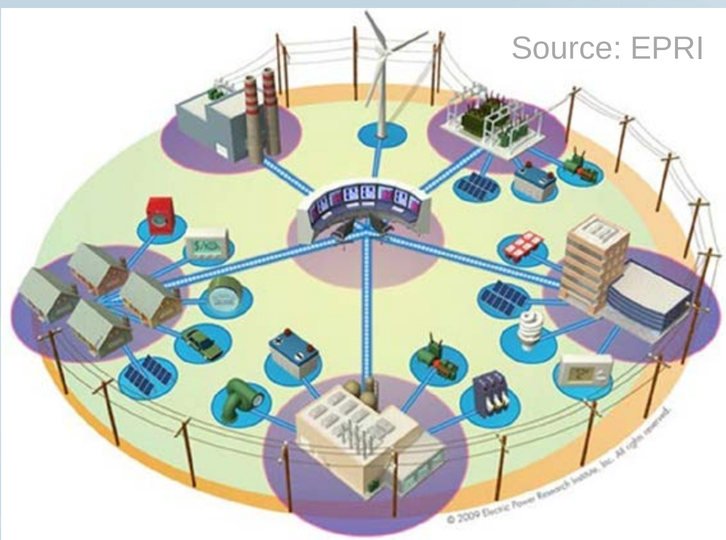
- Grid Modernization and Drivers
  – Caribbean context
- Smart Grid as Platform
- What to look for?
- Microgrids

Electric Grid Modernization

Grid 1.0 Legacy Grid



Grid 2.0 Smart Grid



Grid 3.0 Future Grid

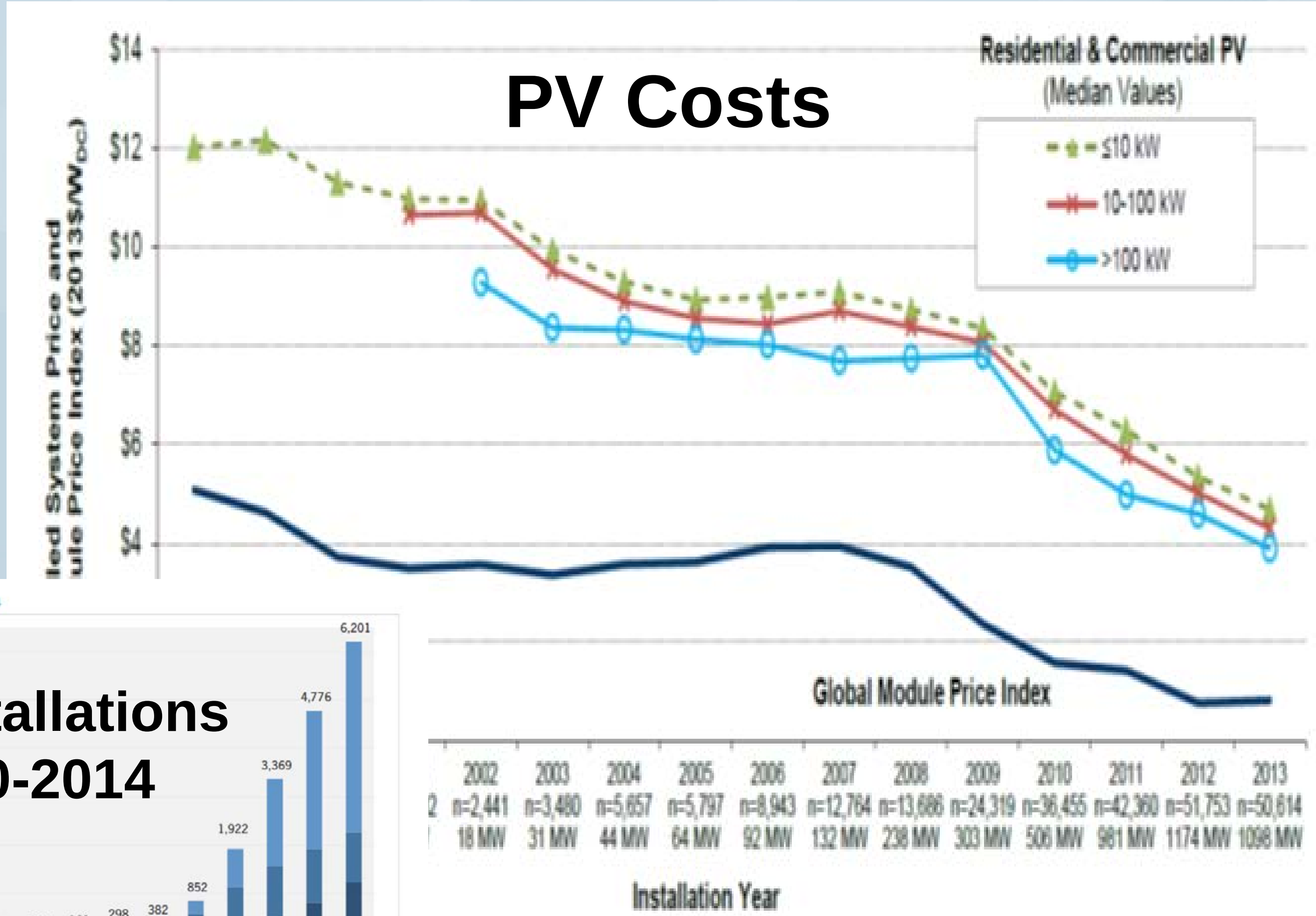
"Grid 3.0 Workshop" at NIST - http://www.nist.gov/cps/grid-3-workshop.cfm

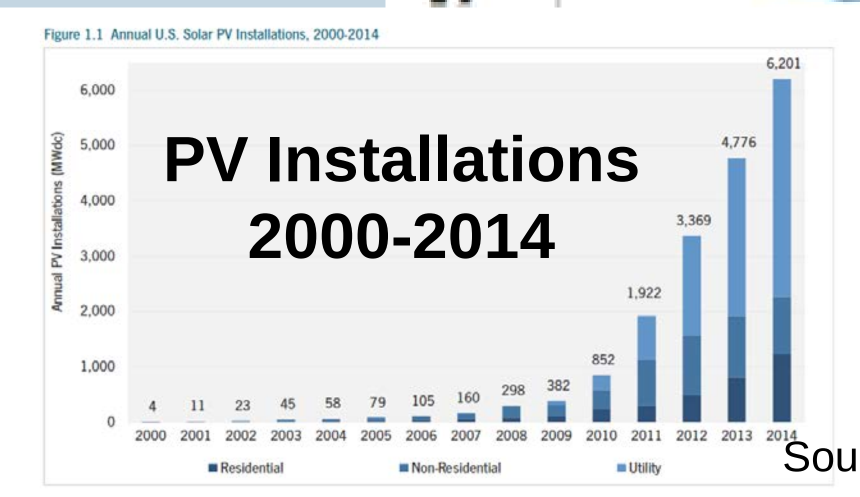
Drivers for Change

- Renewable energy
- Policy and economics
- Energy efficiency
- Energy storage
- Internet of everything
- Greenhouse gas emission targets
- Electric vehicles
- Microgrid technologies … and more

Drivers for Change: Renewables

Source: Feldman, et al. Photovoltaic System Pricing Trends: Historical, Recent, and Near-Term Projections - 2014 Edition

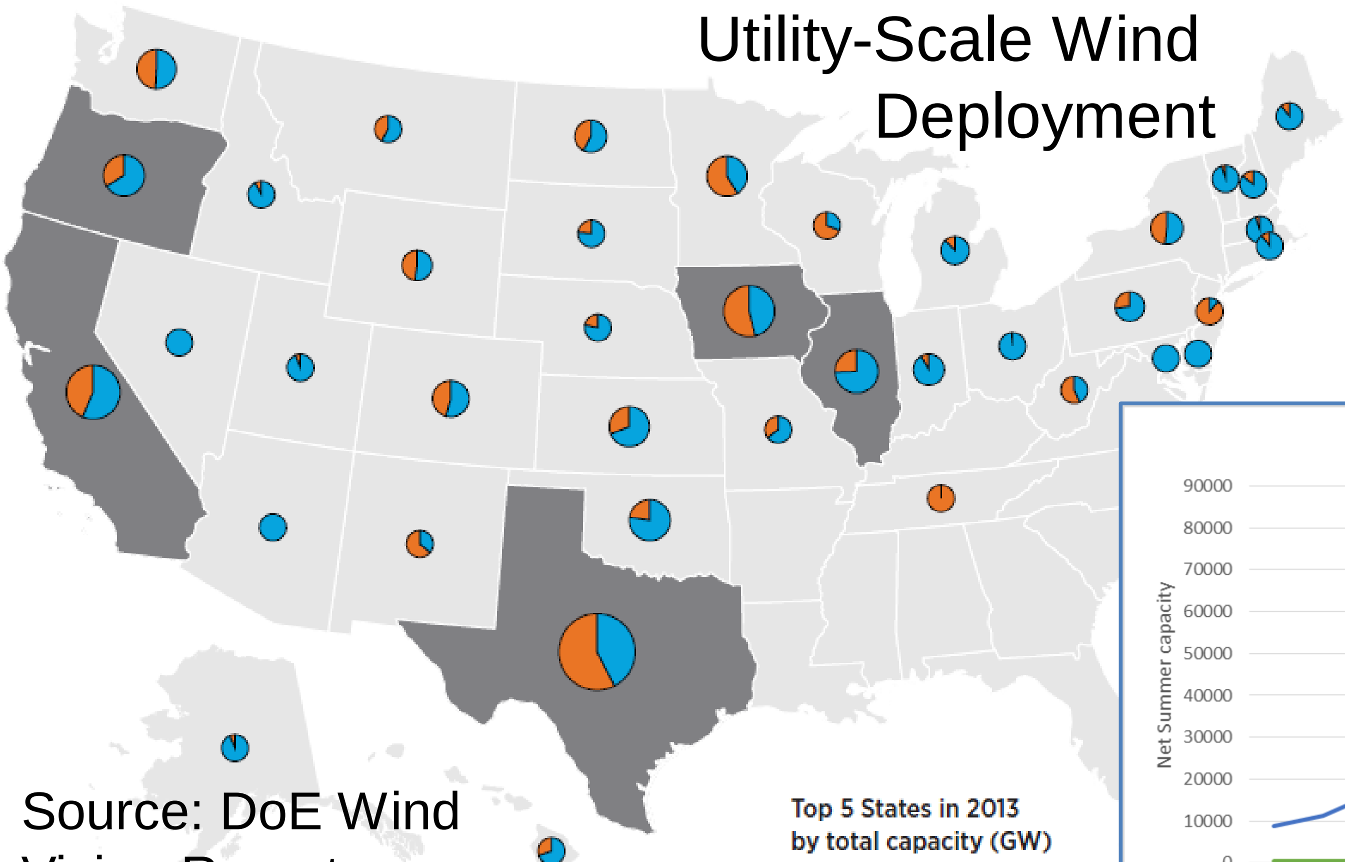




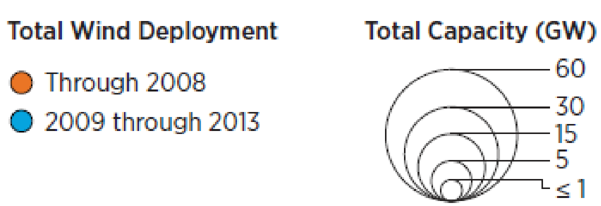
Source:US Solar Market Insight; GTM Rsrch & SEIA

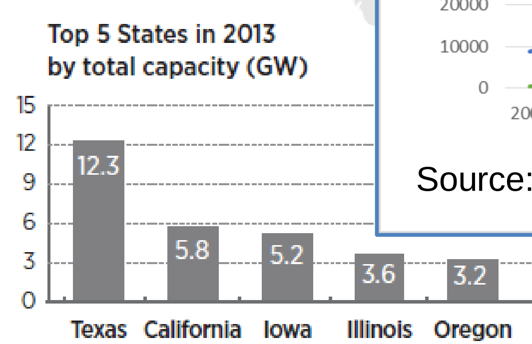
Drivers for Change: Renewables

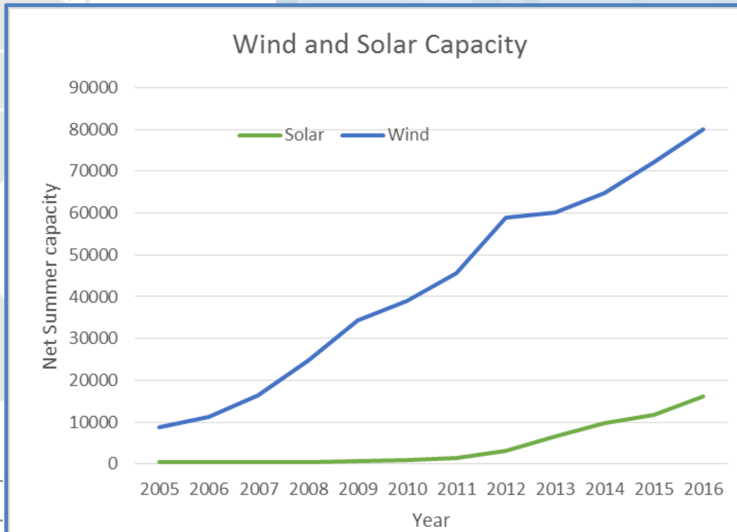
Utility-Scale Wind Deployment



Source: DoE Wind Vision Report



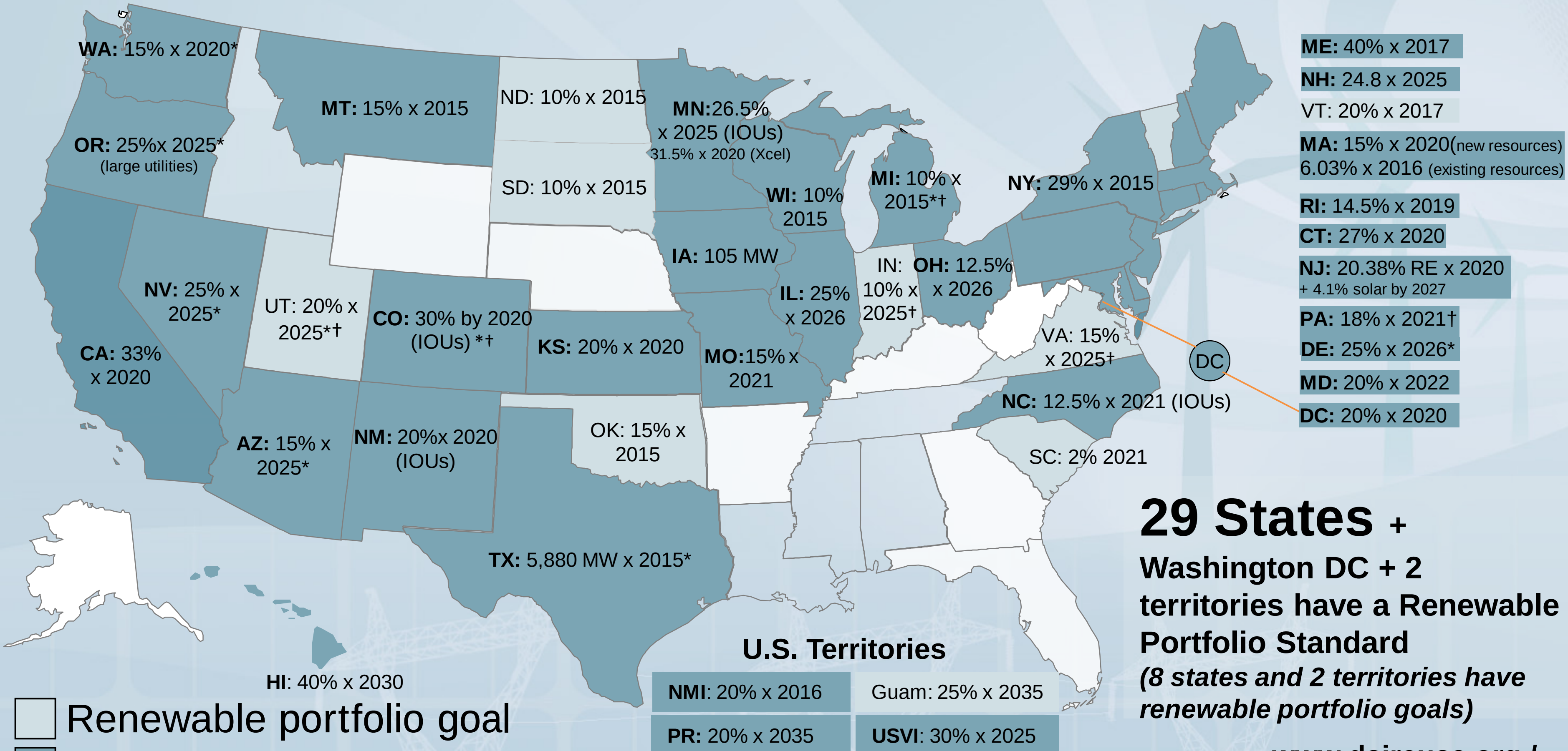




Source: US EIA, Short-term Energy Outlook

Renewable Portfolio Standard (RPS) Policies

Example: California utilities required to generate 33% of electricity from renewables by 2020



29 States +

Washington DC + 2 territories have a Renewable Portfolio Standard

(8 states and 2 territories have renewable portfolio goals)

Renewable portfolio goal

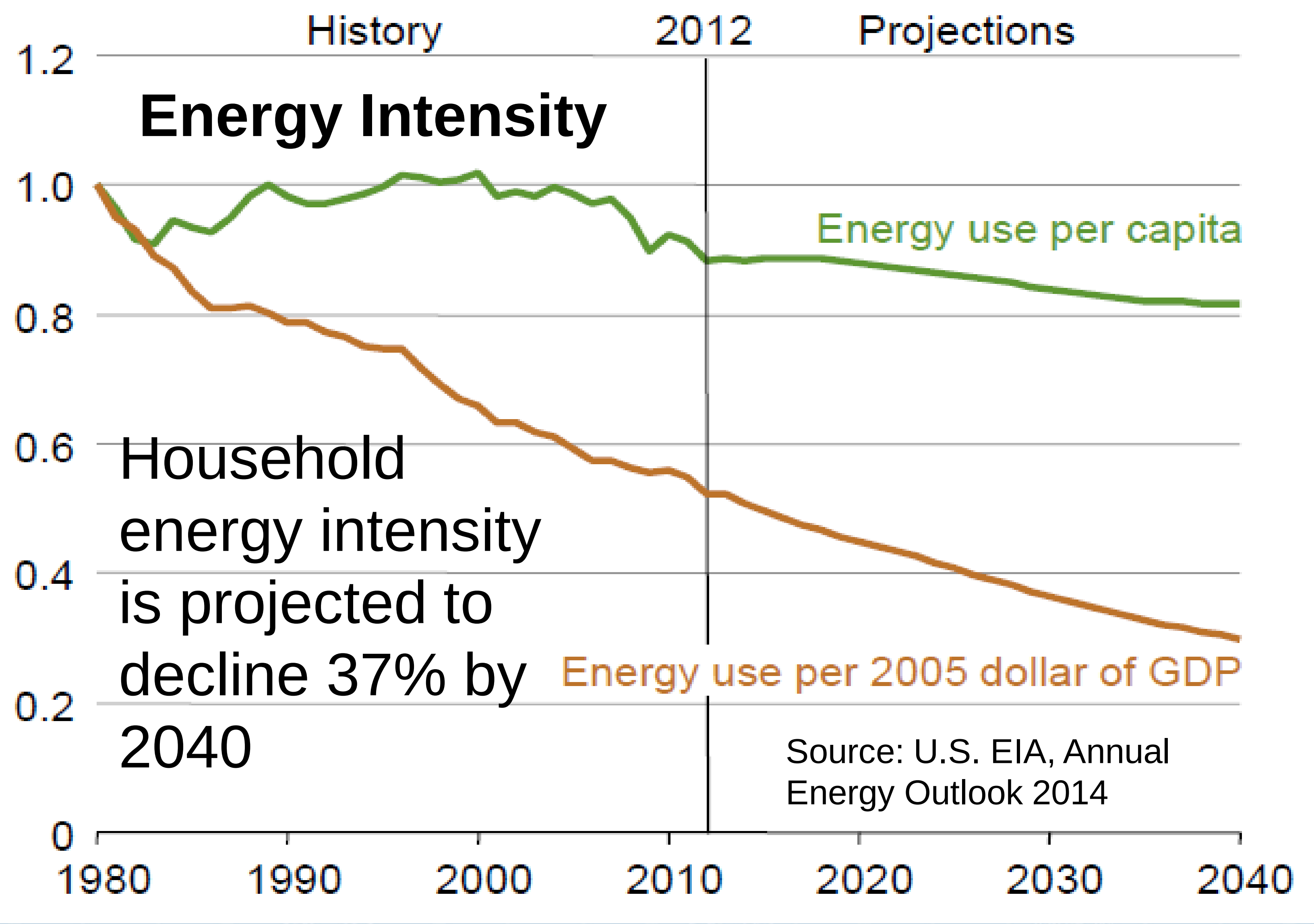
Renewable portfolio standard

† Includes non-renewable alternative resources

* Extra credit for solar or customer-sited renewables

www.dsireusa.org / March 2015

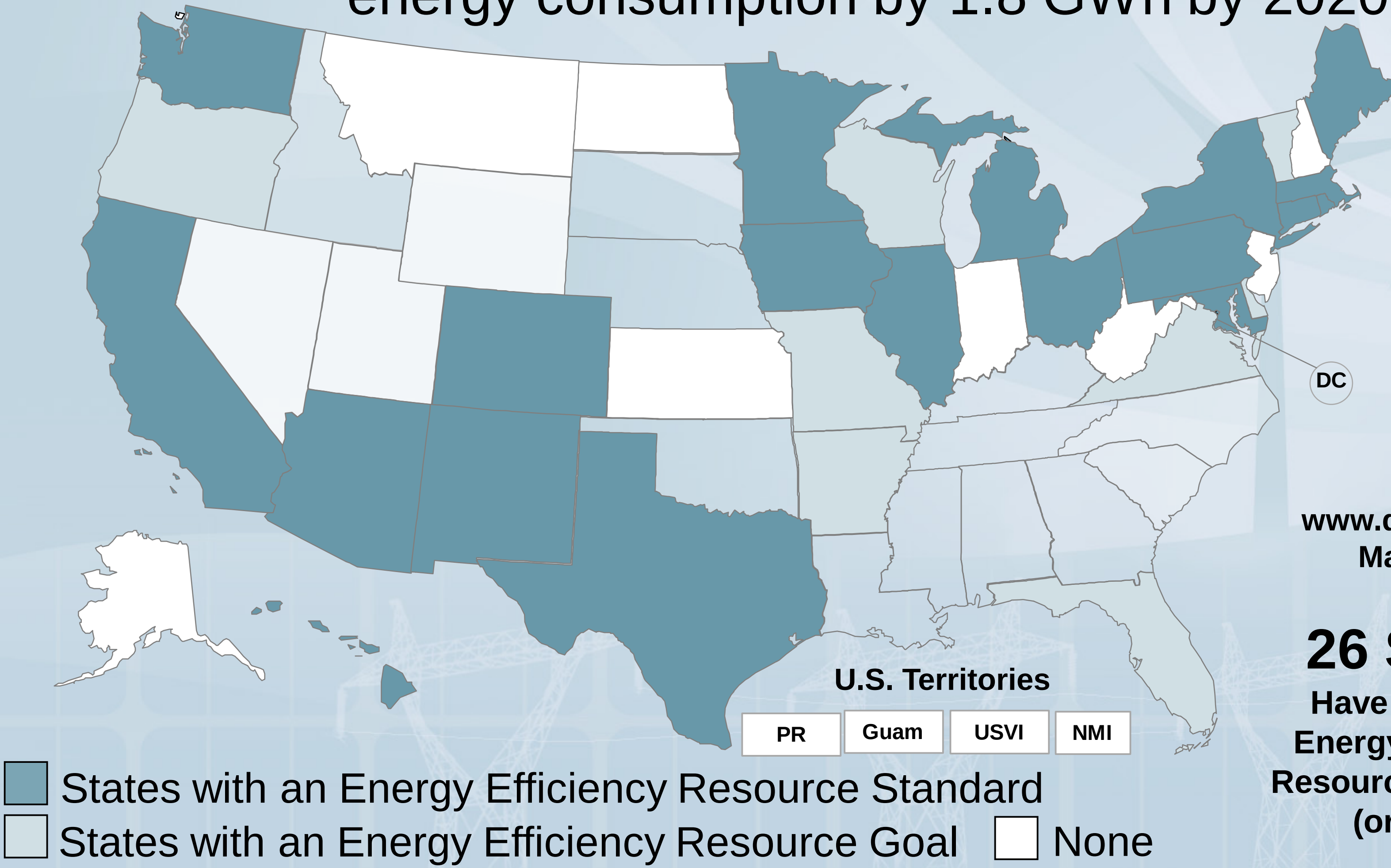
Drivers for Change: Energy Efficiency



Drivers for Change: Policies

Energy Efficiency Resource Standards (and Goals)

Example: California utilities to reduce electric energy consumption by 1.8 GWh by 2020



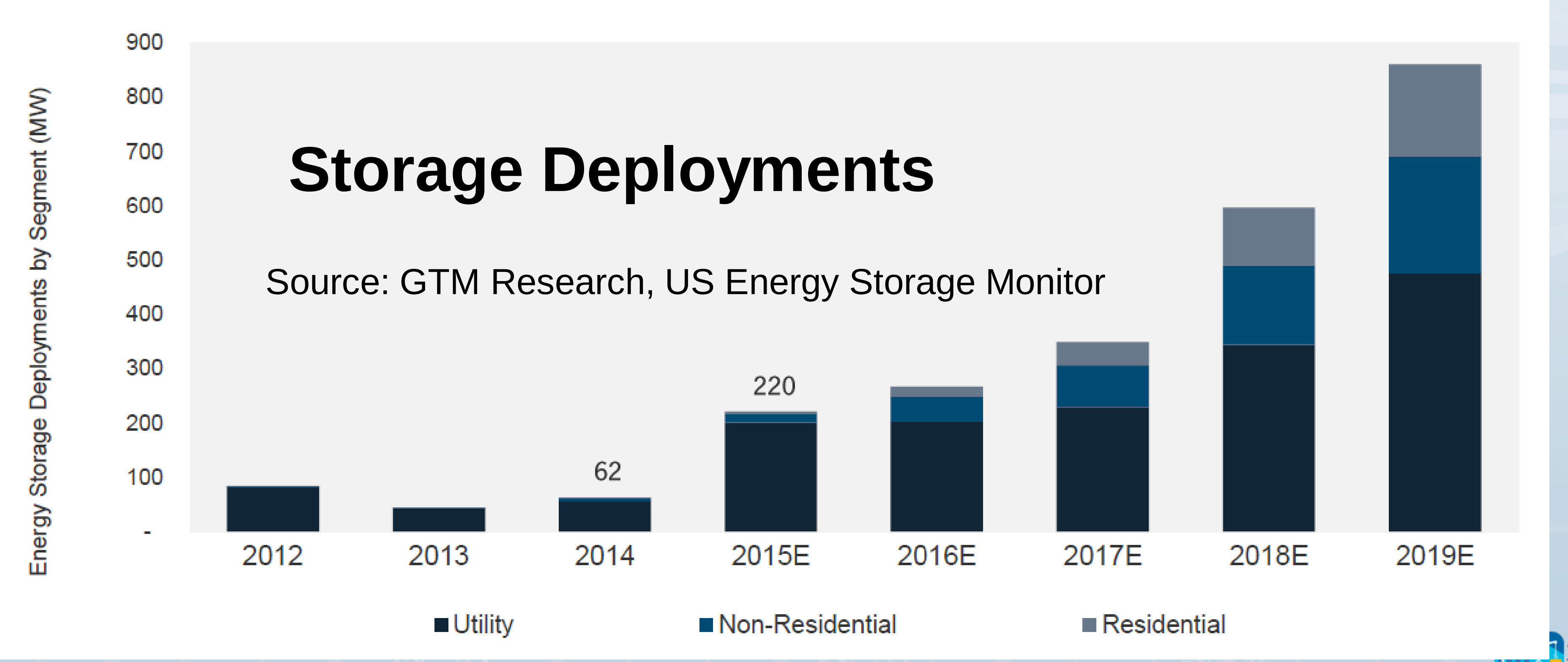
www.dsireusa.org / March 2015

26 States

Have Statewide Energy Efficiency Resource Standards (or Goals)

Drivers for Change: Storage

- Federal Energy Regulatory Commission (FERC) Order 792 revised Small Generator Procedures&Agreements to include energy storage
- California energy storage targets for IOUs totaling 1,325 MW by 2020
- Arizona to procure ~20 MW storage, Hawaii considering 60-200 MW



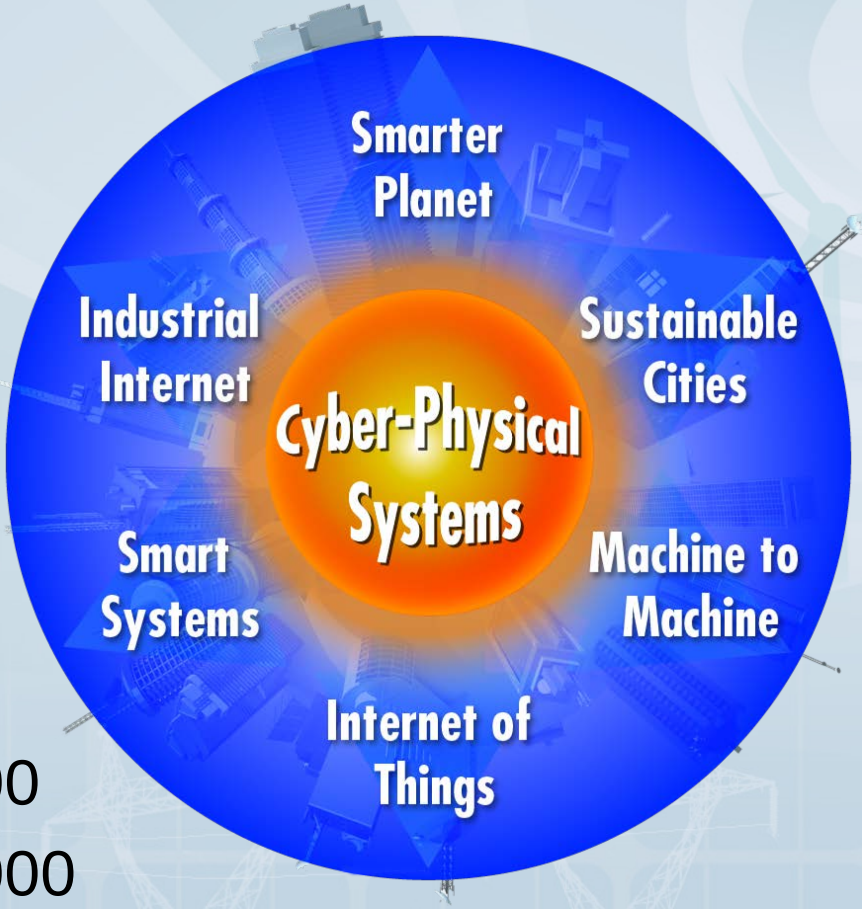
Drivers for Change: Internet of Things

Internet of Things

Devices connected to the Web:

- 1970 = 13
- 1980 = 188
- 1990 = 313,000
- 2000 = 93,000,000
- 2010 = 5,000,000,000
- 2020 = 31,000,000,000

Source: Intel



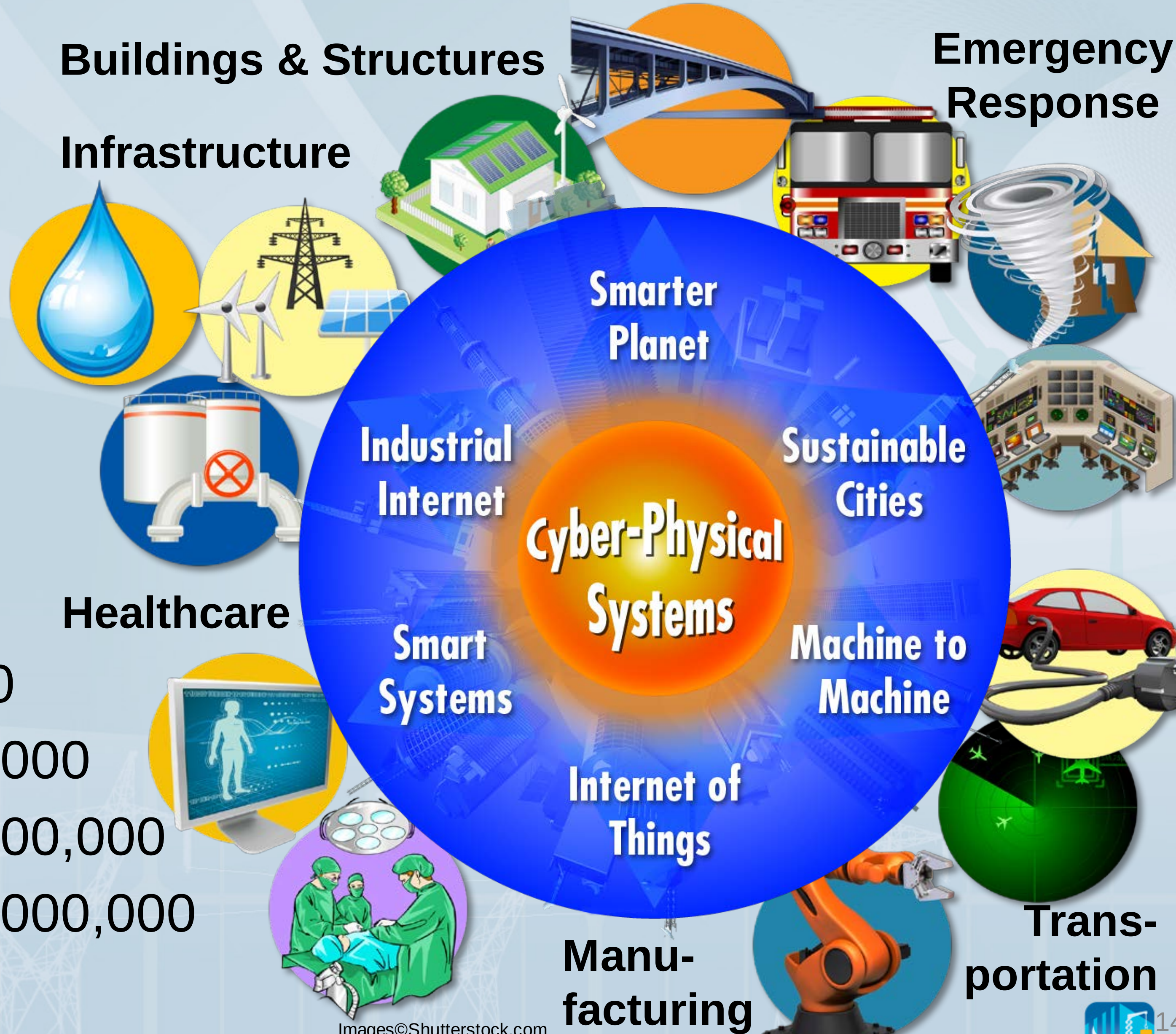
Drivers for Change: Internet of Everything

Internet of Things

Devices connected to the Web:

- 1970 = 13
- 1980 = 188
- 1990 = 313,000
- 2000 = 93,000,000
- 2010 = 5,000,000,000
- 2020 = 31,000,000,000

Source: Intel



Drivers for Change: Internet of Everything

Smart Grid is the key Infrastructure platform connecting all sectors

Drivers for Change: Caribbean context

- High electricity costs (avg 33¢/kWh) – diesel
- Renewables (solar, wind, geothermal, hydro, biomass) replacing some imported diesel
- Climate change concerns
- Resilience (microgrids)
- RPS example: Virgin Islands - 30% by 2025
- New initiatives: Bonaire, Branson/Necker Island…

Recent relevant events:

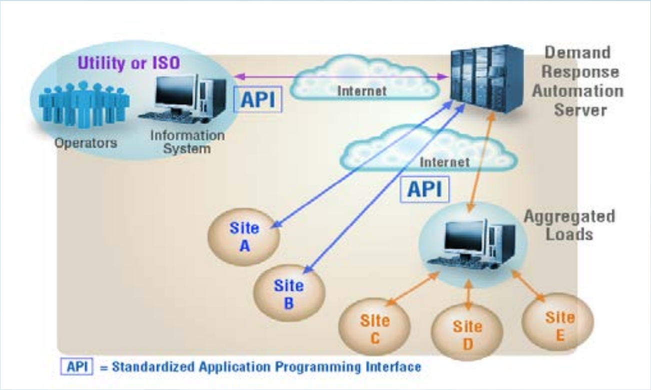
- Caribbean Clean Energy Tech Symposium
- President Obama visit to Jamaica
- Vice President Biden hosts Caribbean Energy Security Summit

Smart Grid – Trends

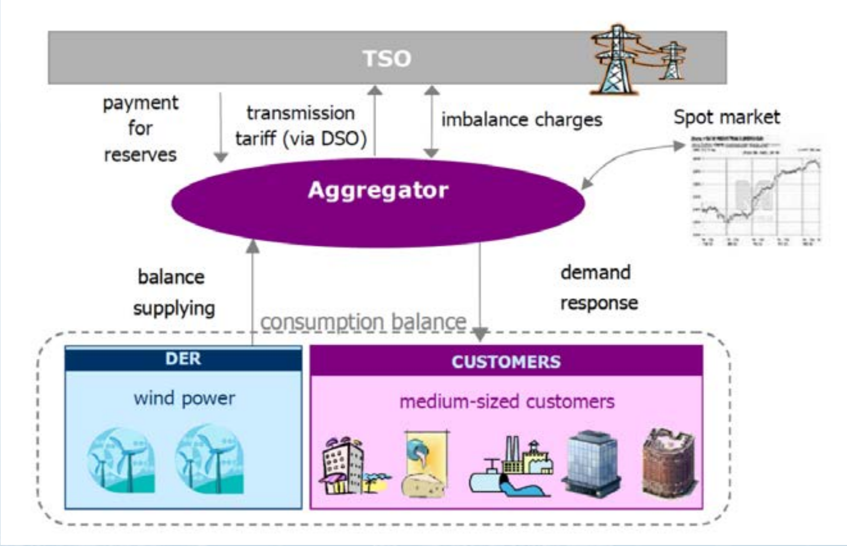
- Grid as platform
- Grid as integrated infrastructure

Grid as platform

- New Services
  - Green Button, Demand Response, …



- New Business Models
  - Transactive energy, …

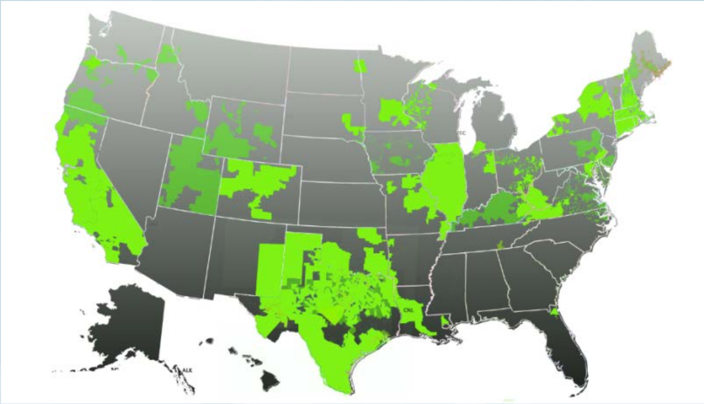


- New Actors
  - Aggregators, …
- New Regulatory Environments
- New Skills for Utility Workers
- Increased Consumer Expectations

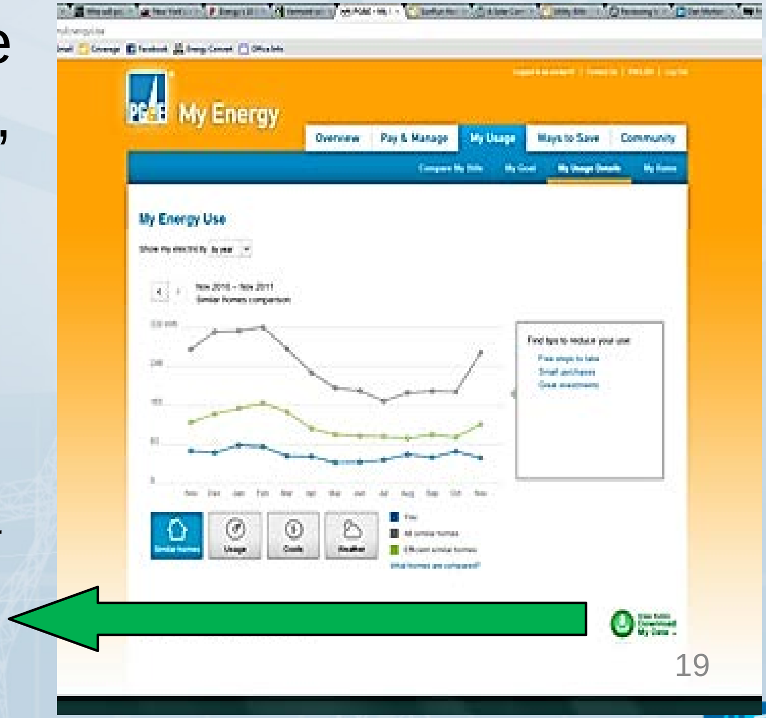
Green Button Initiative

www.greenbuttondata.org

- Enables electronic consumer access to energy data and supports development of ecosystem (apps)
- Available to 100+ million consumers in the US and and additional CANADA: 8 million+ consumers
- Result of collaboration among White House, NIST, DOE, state regulators, utilities, vendors, SGIP, and North American Energy Standards Board
- New: Green Button Alliance
- Green Button Download My Data and Green Button Connect My Data



Map of US Green Button Commitments

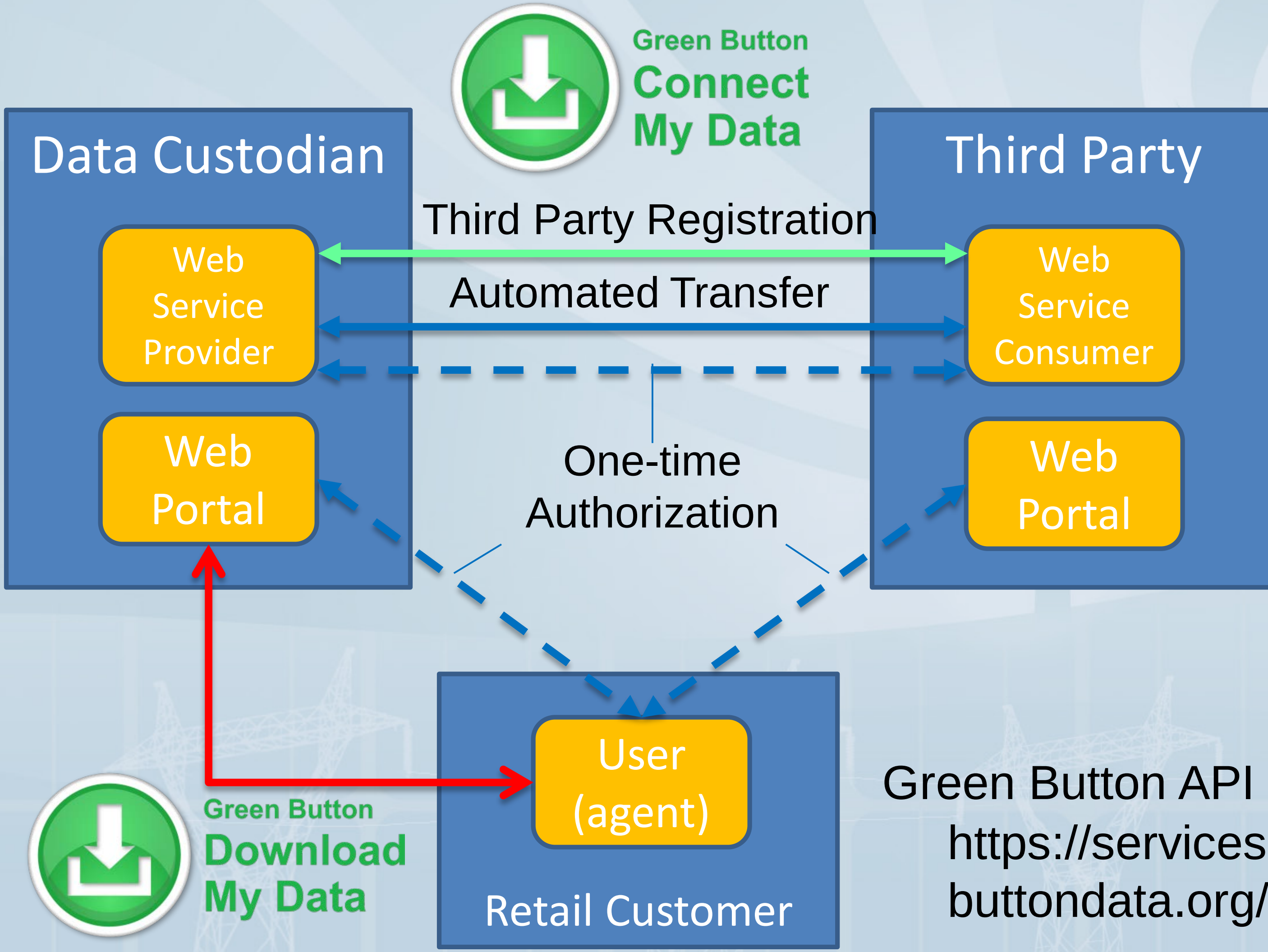


Green Button Connect My Data

Green Button Download My Data

Green Button Data Exchange - APIs

Application programming interfaces (APIs) are how modern Internet software and apps talk to each other, allowing data to be shared across boundaries



Green Button API Sandbox
https://services.greenbuttondata.org/

Policy: Data Disclosure

- New York City: Building benchmarking (tool: EPA's Portfolio Manager – APIs for data)

29 Broadway
New York, NY

2012: 7/100

Lowest 7%

2013: 80/100

Top 20%

39 Broadway
New York, NY

2012: 79/100

Top 21%

2013: 78/100

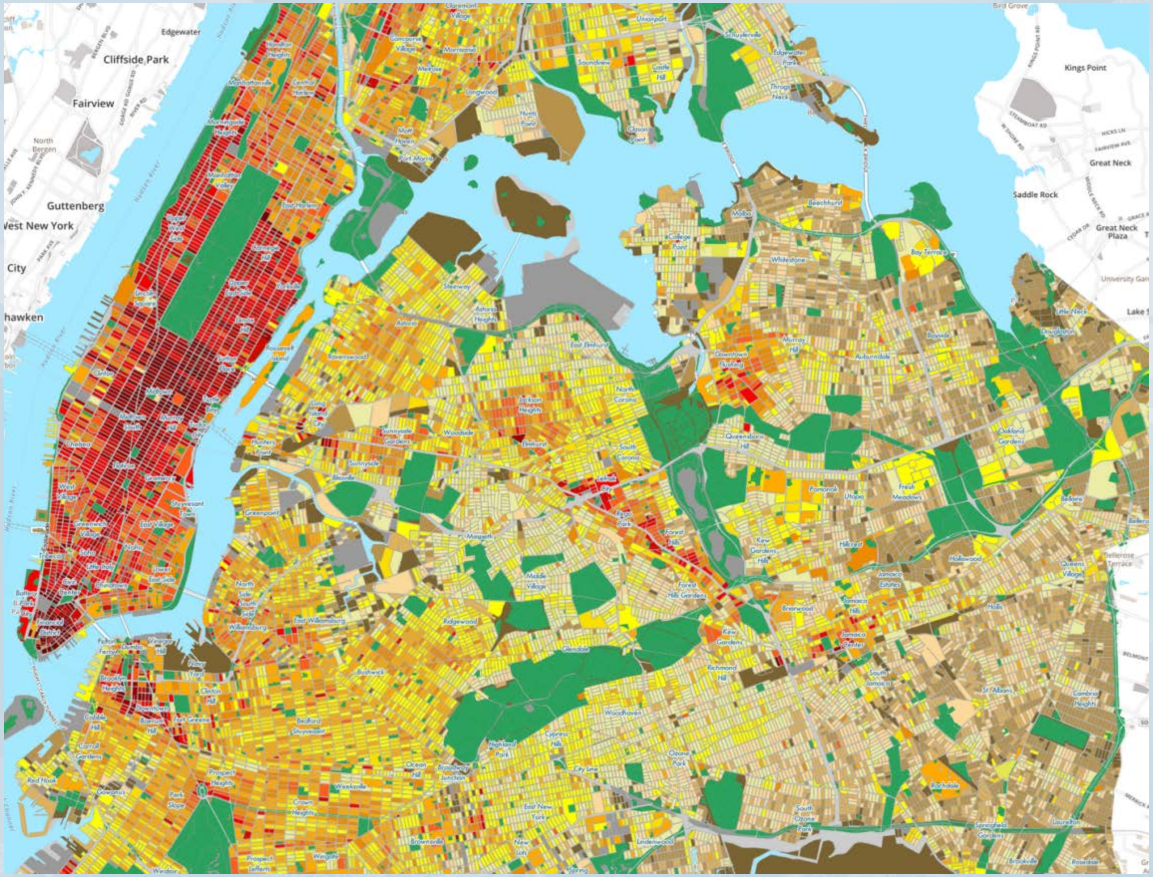
Top 22%

Courtesy: Patrick Hughes (NEMA)

Innovative uses of data

Data enables:

- Targeted demand-side management
- Meter analysis to remotely identify energy inefficiencies



Energy Use by Building in New York City (kWh/m^2)

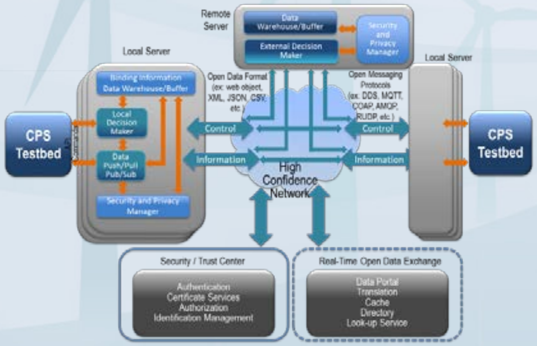
Source: Sustainable Engineering Lab, Columbia University

http://sel-columbia.github.io/nycenergy/

Courtesy: Patrick Hughes (NEMA)

Grid as integrated infrastructure

- Smart Cities
  - Intrinsic integration requirements
- Interoperability at Scale
  - Integrated infrastructure
- Instrumentation
  - Big data, phasor measurement units
  - New control strategies, virtualization
- Reliability and resilience
  - Distributed energy resources
  - Renewables, Storage, Microgrids



What are a few things to look for?

- Effective planning
  - System architecture foundation
- Interoperability
  - Standards-based interfaces, testing and certification
  - NIST Smart Grid Framework Release 3.0
  - Interoperability decision maker's check list (DOE: GWAC)
- Data
  - Data strategy, IT enterprise/data expertise, APIs, …
- Security (cyber and physical)
  - Cybersecurity: active risk management (not checkboxes)
  - Multiple resources: NISTIR 7628 Release 1 Guidelines for Smart Grid Cybersecurity (3 volumes), Dept. of Energy (C2M2) Cybersecurity Capability Maturity Model , …

Phasor Measurement Units – NIST Calibration and Testing technical support

- NIST support for IEEE Conformance Assessment Program (ICAP) for PMUs
- NIST has developed a portable system to calibrate PMU calibrators
- NIST is conducting a PMU testing inter-laboratory comparison.
- NIST has been assessing the performance of PMUs from multiple vendors (both in production and pre-production models).

NIST Grant and technical expertise supported the development of Fluke Calibration's commercially available, fully automated PMU calibration system.

- NIST expert completed 3 week on-site tech support and calibration for test lab PMU calibration system (Consumers Energy, Michigan)

What are a few things to look for?

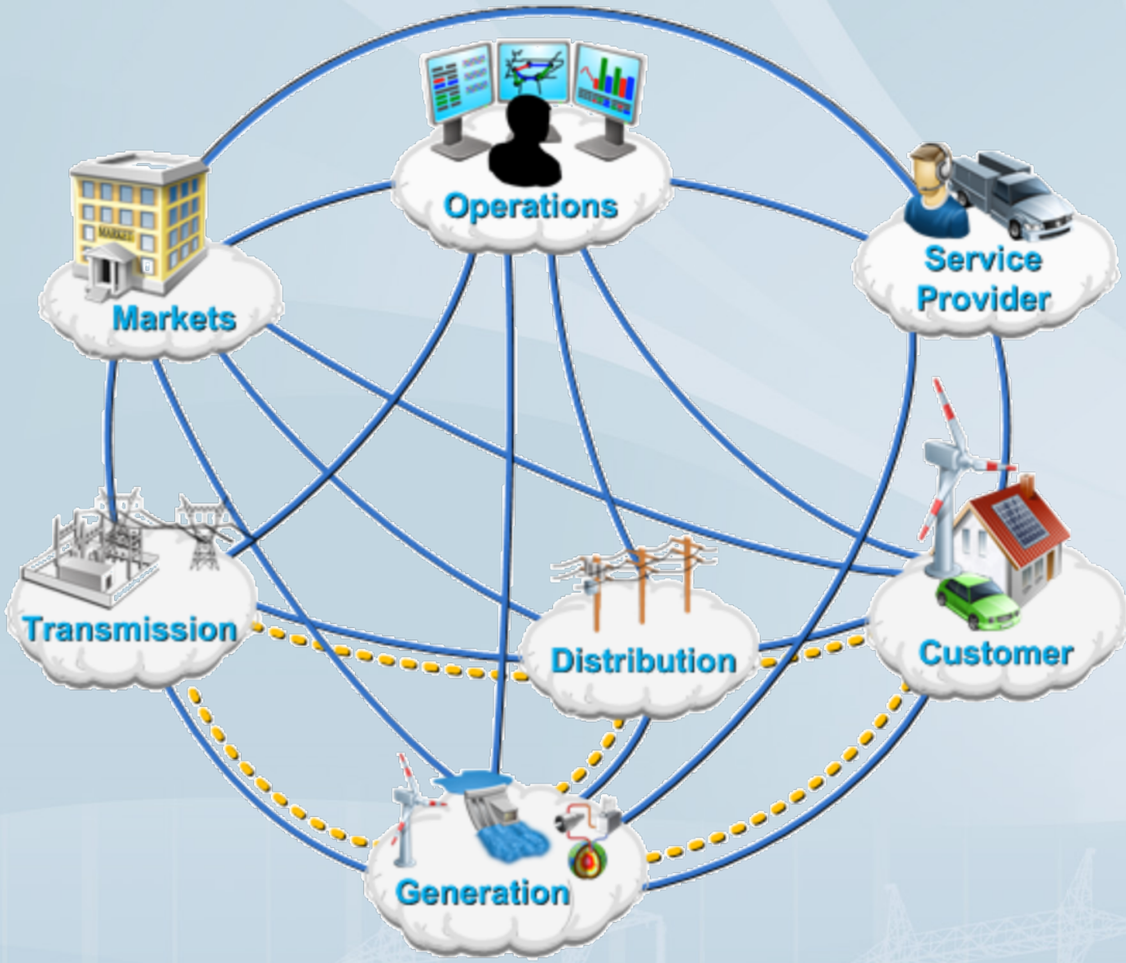
- Effective planning
  - System architecture foundation
- Interoperability
  - Standards-based interfaces, testing and certification
  - NIST Smart Grid Framework Release 3.0
  - Interoperability decision maker's check list (DOE- GWAC)
- Data
  - Data strategy, IT enterprise/data expertise, APIs, …
- Security (cyber and physical)
  - Cybersecurity: active risk management (not checkboxes)
  - Multiple resources: NISTIR 7628 Release 1 Guidelines for Smart Grid Cybersecurity (3 volumes), Dept. of Energy (C2M2) Cybersecurity Capability Maturity Model , …

System architecture

- A discipline for describing, analyzing, and communicating structural representations of complex systems. Architecture should precede system design, to help manage complexity.
- Example smart grid architectural zones to consider:
  - Back Office Systems
  - Field Area Network and Edge Devices
  - Customer Side Systems
  - Physical Power System Infrastructure

Courtesy: Erich Gunther (EnerNex)

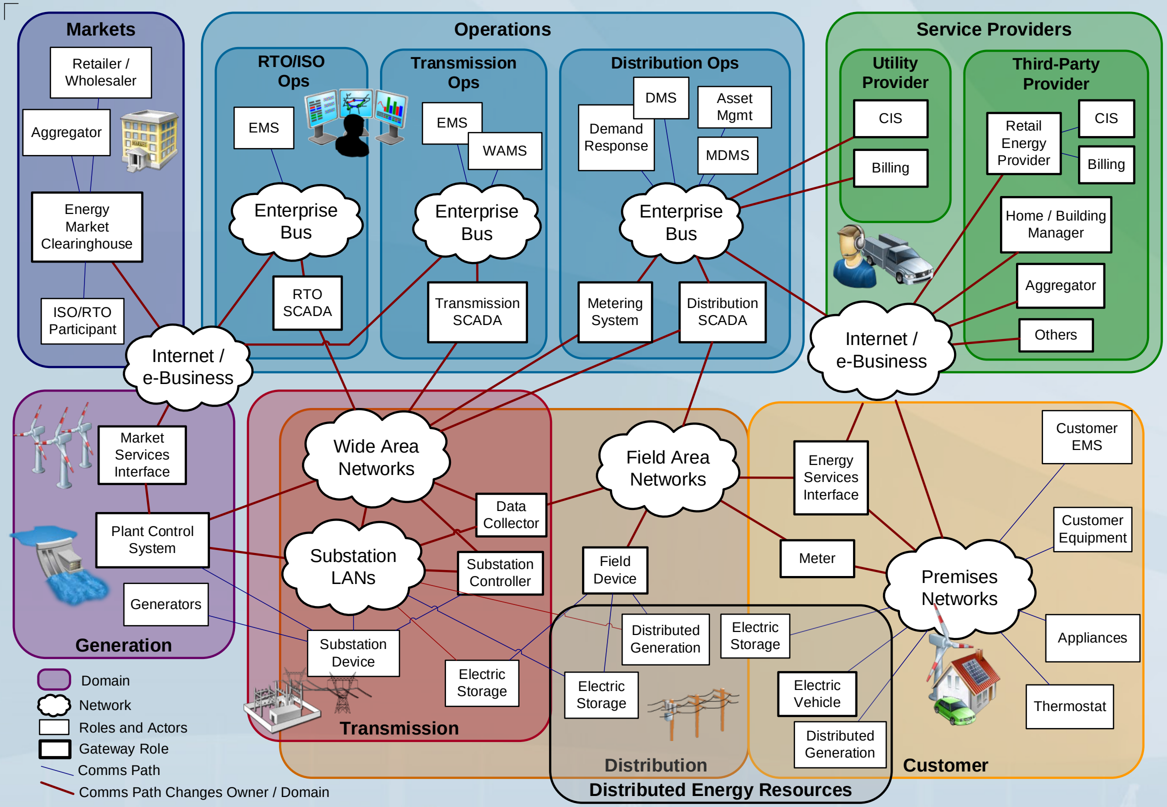
Smart Grid: layers and iteration levels



Smart Grid Conceptual Model
(NIST Framework and Roadmap for Interoperability Standards, Release 3.0 – published Sept. 30, 2014)

- Context/Vision
  - Goals? Current State?
- Conceptual
  - What to accomplish? What services needed?
- Logical
  - How accomplished? How structured?
- Physical
  - What resources required?
- Implementation
  - What are specific choices?

Smart Grid: layers and iteration levels



Logical Model of Legacy Systems Mapped onto Conceptual Domains

(NIST Framework and Roadmap for Interoperability Standards, R1, R2, & R3 –Sept 2014)

Context/Vision

Goals? Current State?

Conceptual

What to accomplish?
What services needed?

Logical

How accomplished?
How structured?

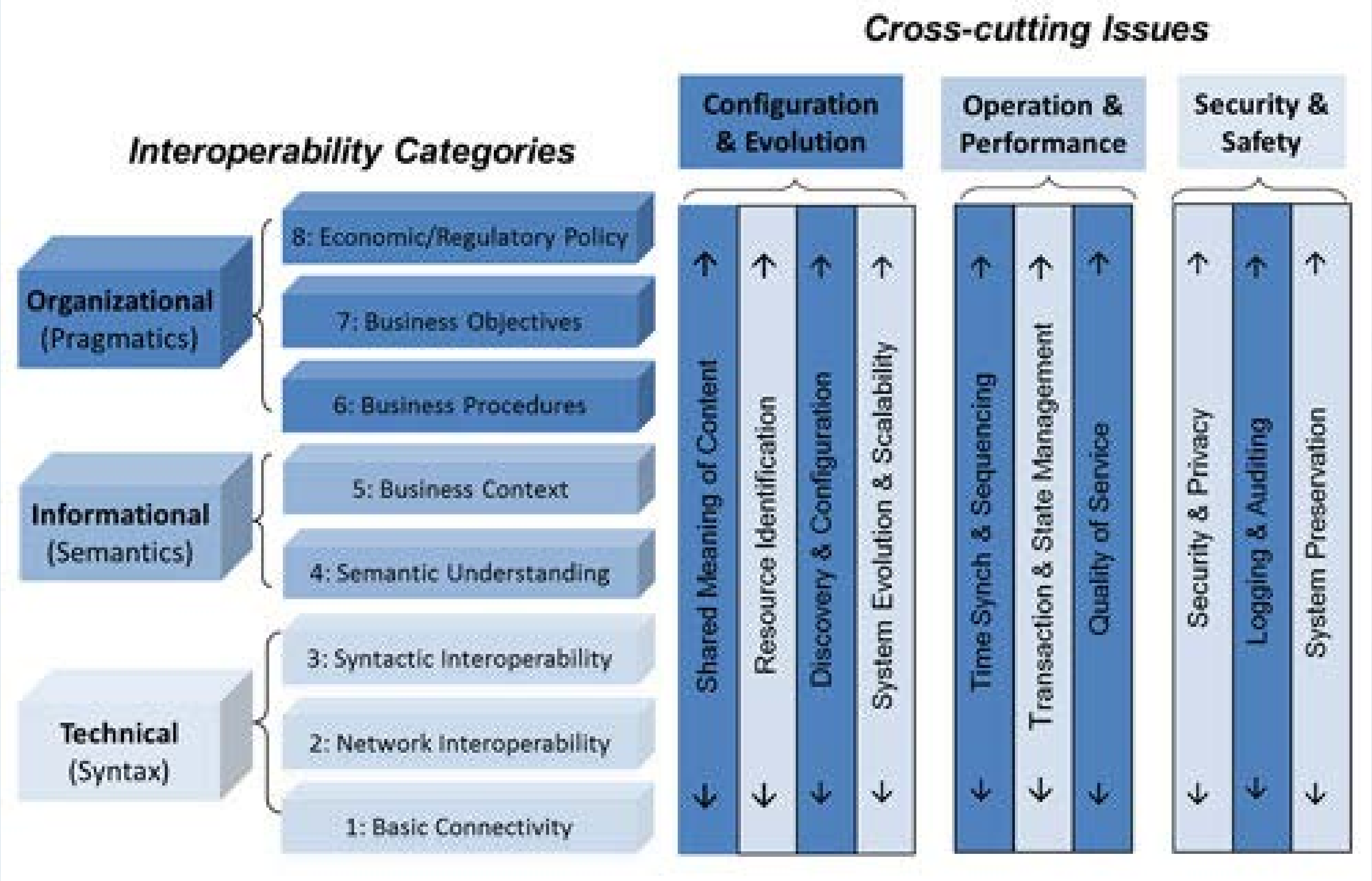
Physical

What resources required?

Implementation

What are specific choices?

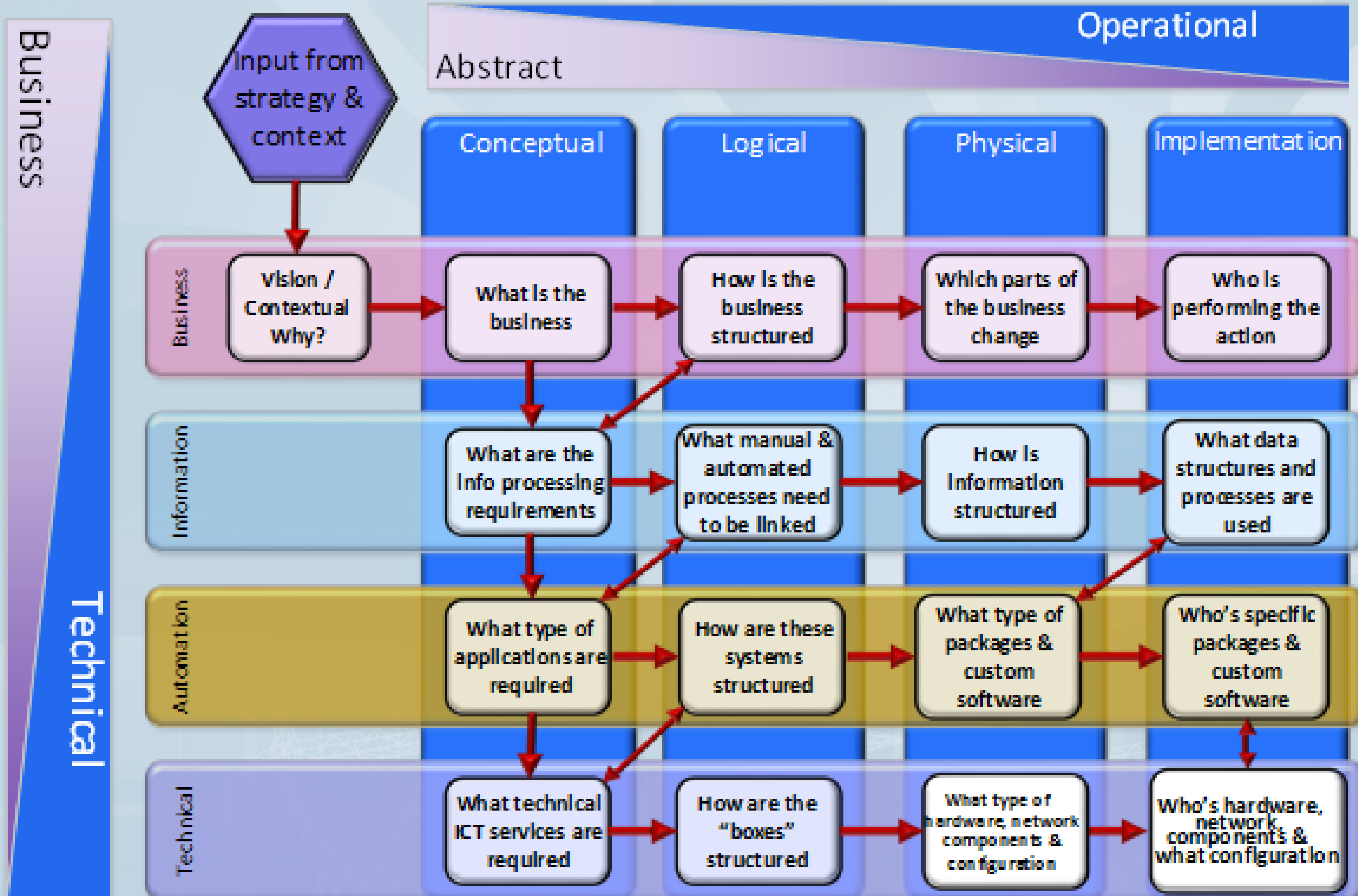
Smart Grid: layers and iteration levels



GridWise Architecture Committee ("GWAC Stack")

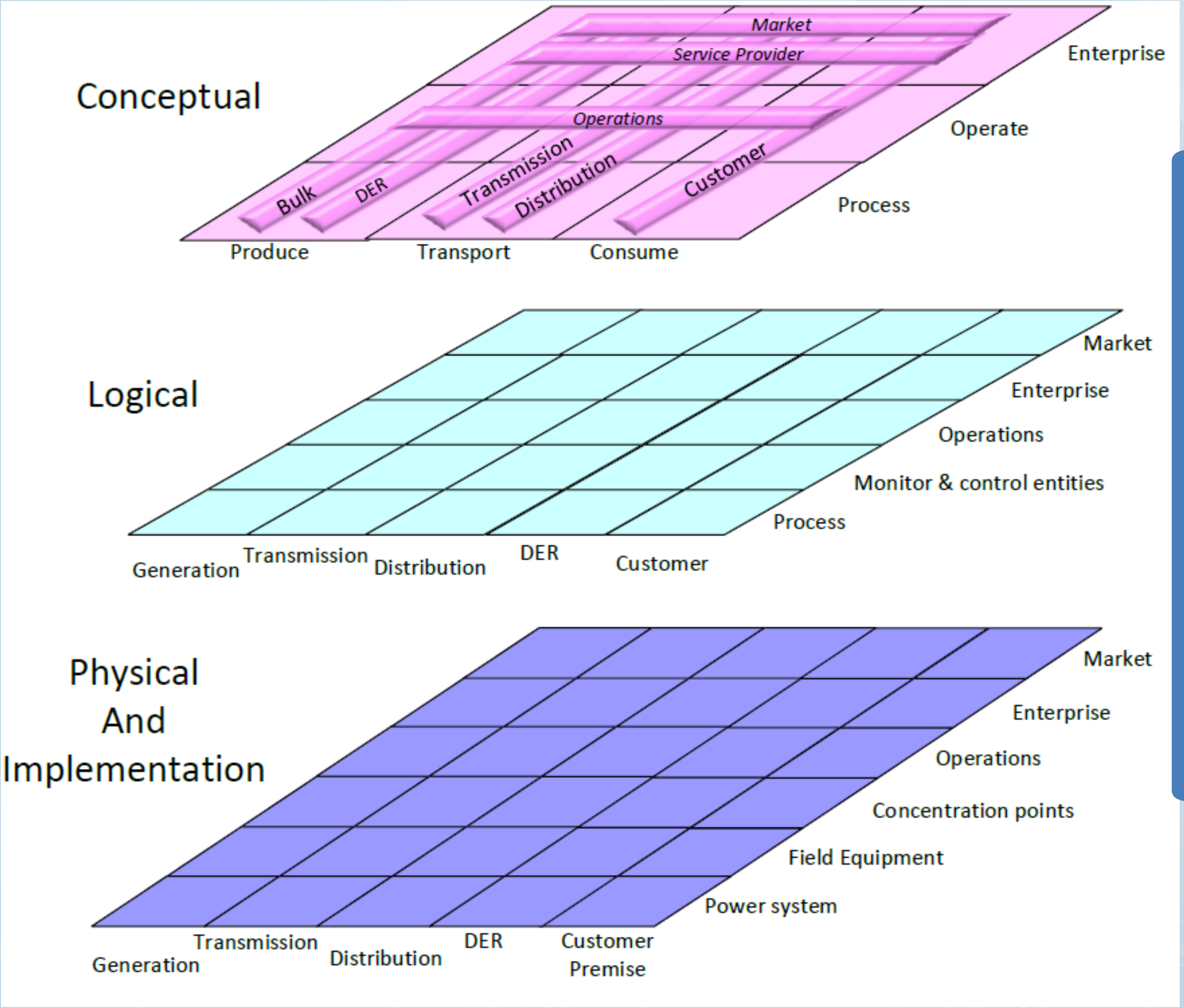
(from GWAC KnowledgeBase & Interop Context-Setting Framework, and used in NIST Framework and Roadmap for Interoperability Standards, Releases 1.0, 2.0 and 3.0)

Smart Grid: layers and iteration levels



(NIST Framework and Roadmap for Interoperability Standards, Release 3.0 –Sept 2014)

Smart Grid: layers and iteration levels



Context/Vision

Goals? Current State?

Conceptual

What to accomplish? What services needed?

Logical

How accomplished? How structured?

Physical

What resources required?

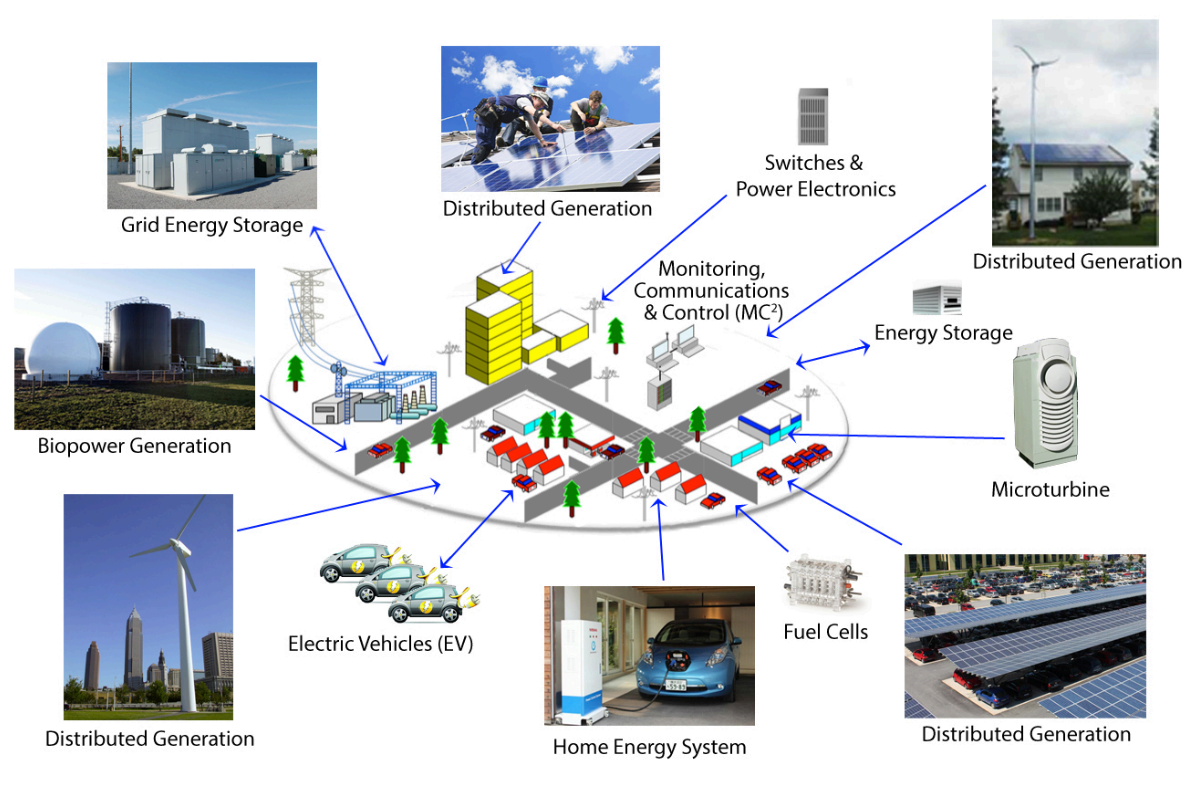
Implementation

What are specific choices?

(NIST Framework and Roadmap for Interoperability Standards, Release 3.0 –Sept 2014)

Microgrids – definition

- A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid.
- A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode.
- A smart microgrid is built on smart grid.



Courtesy: Terry Mohn (General Microgrids)

Microgrid classifications by energy generation

- **Single Facility** (<2MW) - Smaller individual facilities with multiple loads, e.g., hospitals, schools, hotels complex
- **Multi-Facility** (2-5MW) - Small to larger traditional Combined Heat and Power (CHP) facilities plus a few neighboring loads exclusively commercial & industrial (C&I)
- **Feeder** (5-20MW) - Small to larger traditional CHP facilities plus many or large neighboring loads, typically C&I
- **Substation** (>20MW) - Traditional CHP plus many neighboring loads, will include C&I plus residential
- **Rural Electrification** (various size MW) - Rural villages of many emerging markets of developing countries, as well as rural settlements found in Europe and North America, Indian reservations, remote geographical locations.

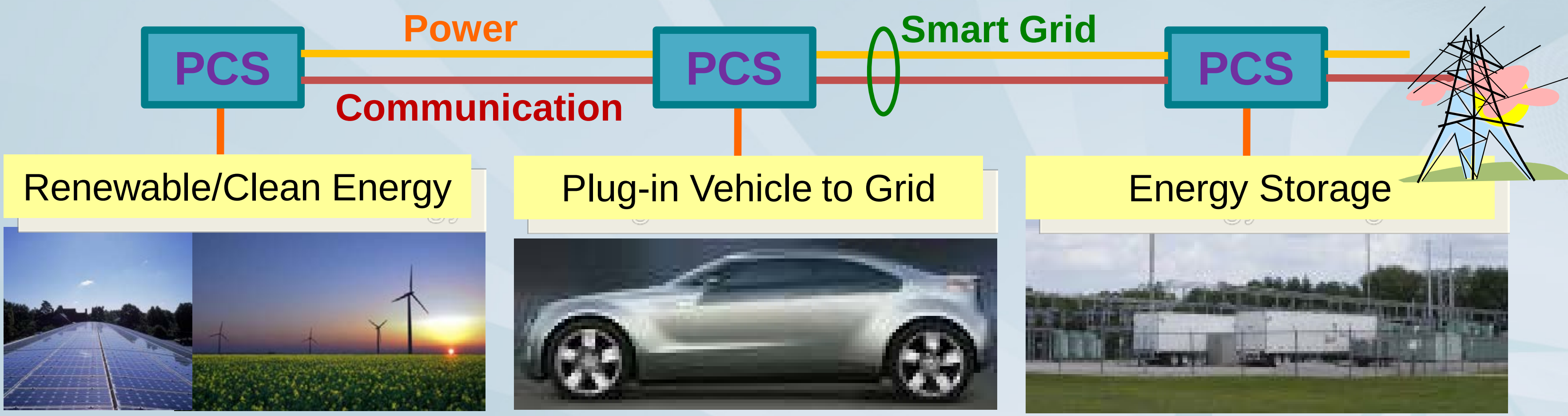
Courtesy: Terry Mohn (General Microgrids)

Some microgrid benefits

- Reliability and resiliency
  - Available and operational during utility grid shutdowns
  - Provides price stability, protects from market fluctuations
  - Security of electricity supply is enhanced, reduced losses
  - Supports mixed utility integration (water, phone, gas, …)
- Scalability
  - Supports population growth, increased electrical use
  - Meets dispersed rural demand (lack of power/unreliable power)
- Environmental support
  - Transition from (diesel) fossil-fuel on-site generation to use multiple sources including renewable/green energy
  - Reduced fuel usage, supports regional/national emission standards
- Smart Grid integration
  - Use smart grid standards (physical interface and data)
  - Two-way power flows, active distribution system management
  - Defer transmission/distribution investments

Adapted from Terry Mohn (General Microgrids)

High Penetration of Distributed Energy Resources

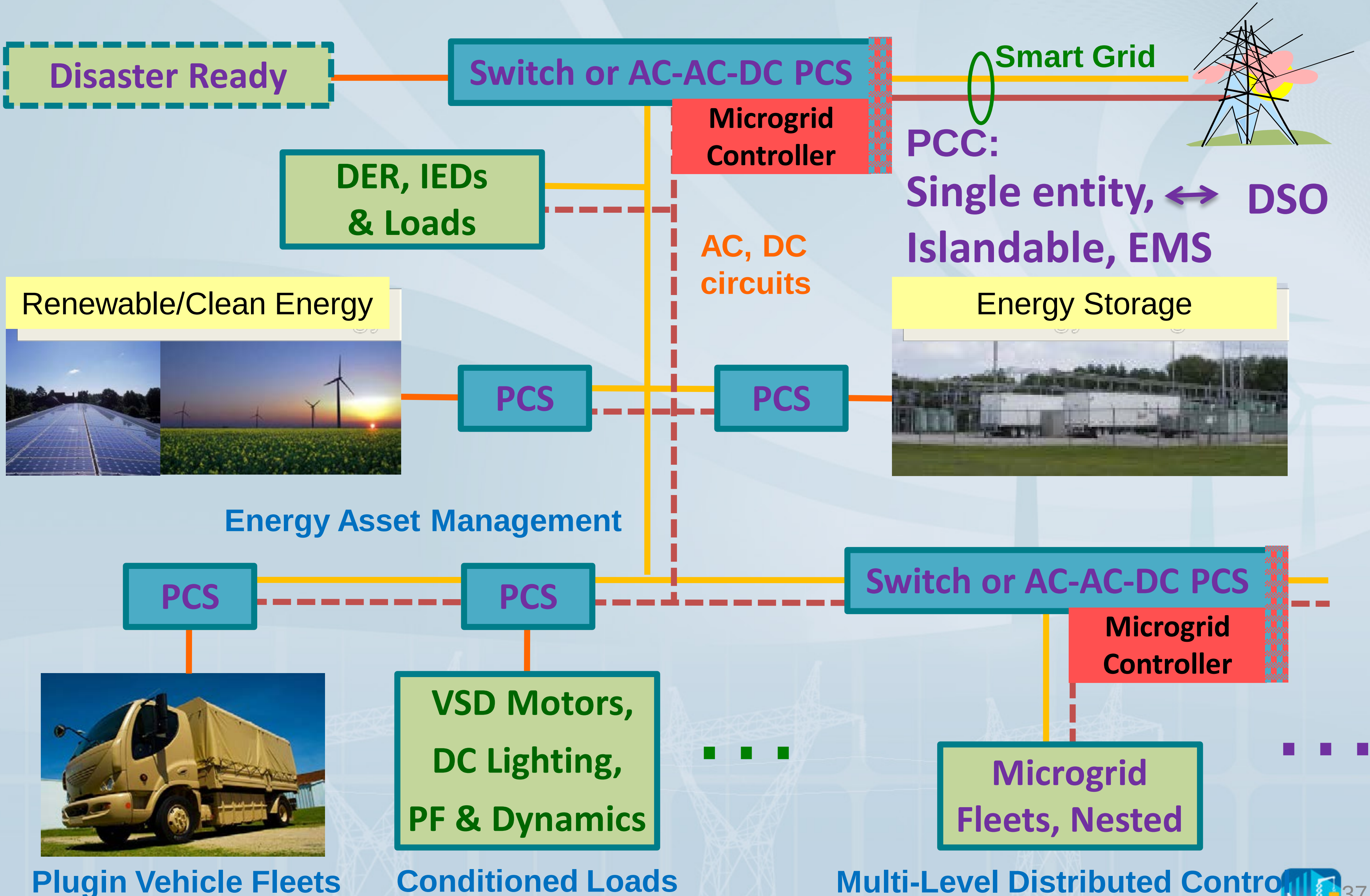


- Power Conditioning Systems (PCS) convert to/from 60 Hz AC for interconnection of renewable energy, electric storage, and PEVs

- "Smart Grid Interconnection Standards" required for devices to be utility-controlled operational asset and enable high penetration:
  - **Dispatchable real and reactive power**
  - **Acceptable ramp-rates to mitigate renewable intermittency**
  - **Accommodate faults without cascading/common-mode events**
  - **Voltage regulation and utility-coordinated islanding**

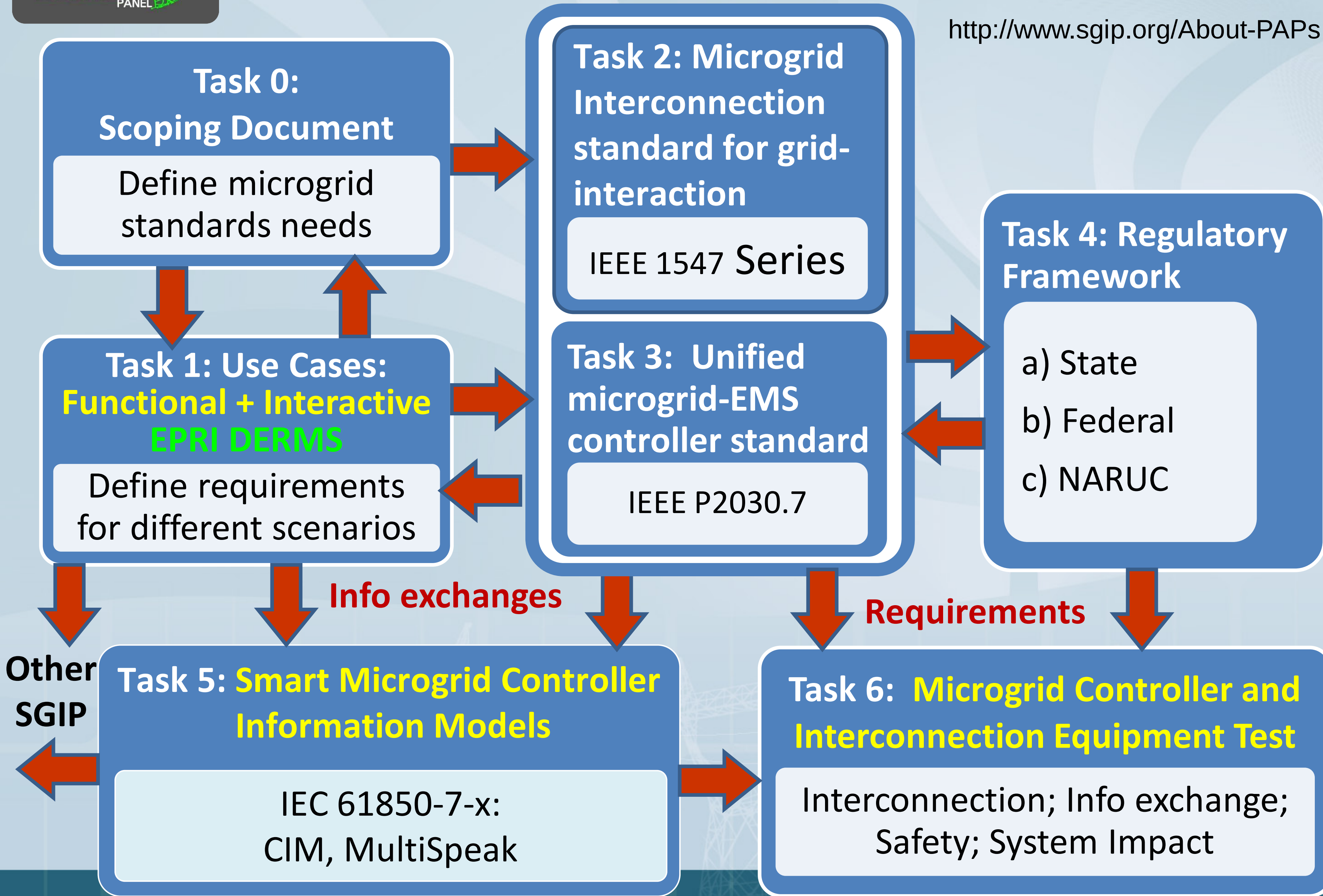
http://www.nist.gov/pml/high_megawatt/2008_workshop.cfm

Microgrids Enable Pervasive DER and Resiliency



PAP 24 – Microgrid Operational Interfaces

http://www.sgip.org/About-PAPs

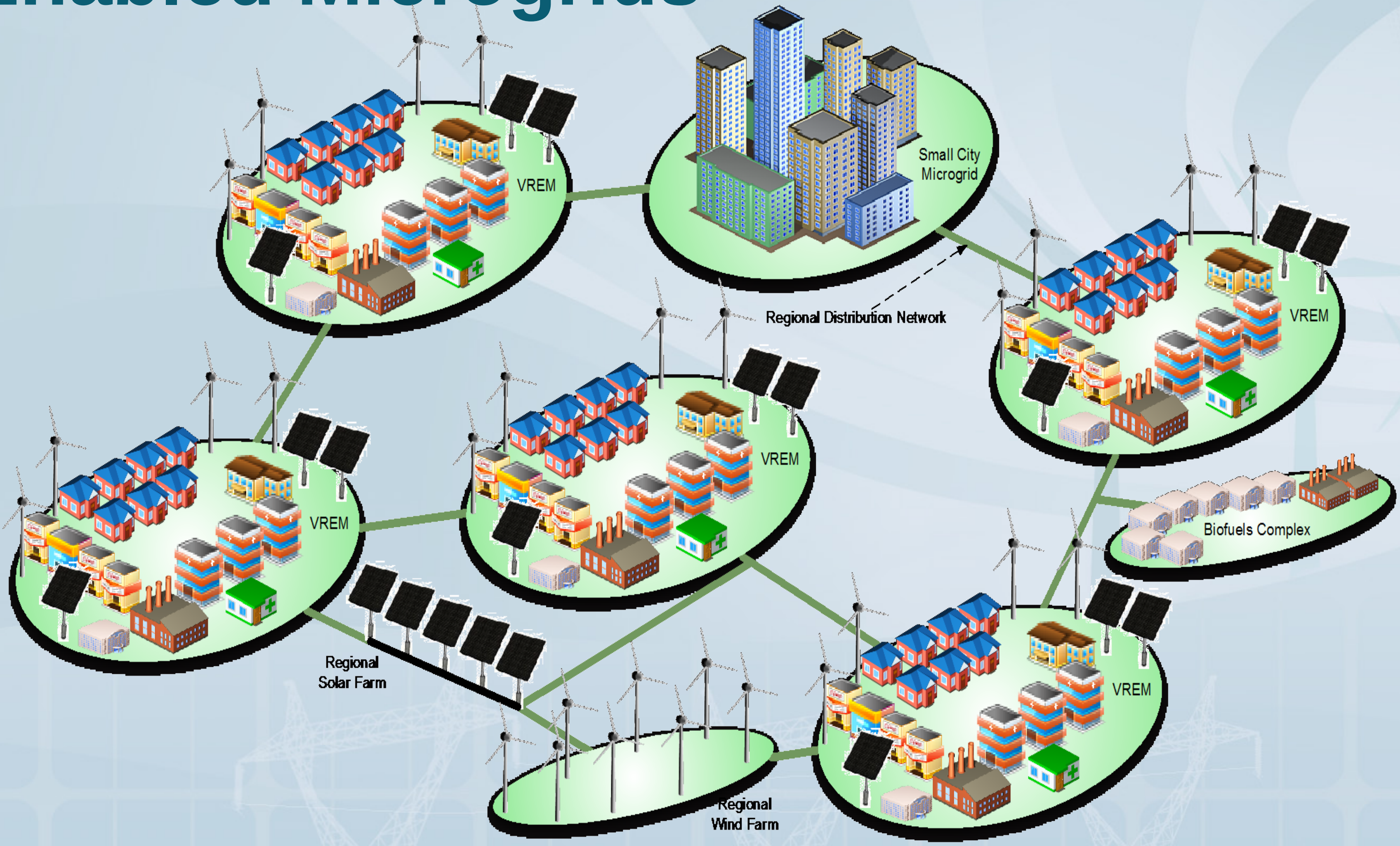


Opportunities for Developing Countries

- Strategically deploy microgrid technologies (Distributed Energy Resources - generation, storage, controls, distribution, building automation)
- Establish standard approach for physical and cyber interconnections
- Create capacity for maintenance of the system
- Integrate resources and future requirements for sustainability – design to scale

Courtesy: Terry Mohn (General Microgrids)

Interconnected Village Renewables-Enabled Microgrids



Courtesy: Terry Mohn (General Microgrids)

Contact info

- David Wollman
  Deputy Director, Smart Grid and CPS Program Office
  Engineering Laboratory
  NIST
  david.wollman@nist.gov