U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Presentation to the National Academies

Committee on Modernizing the U.S. Electricity System

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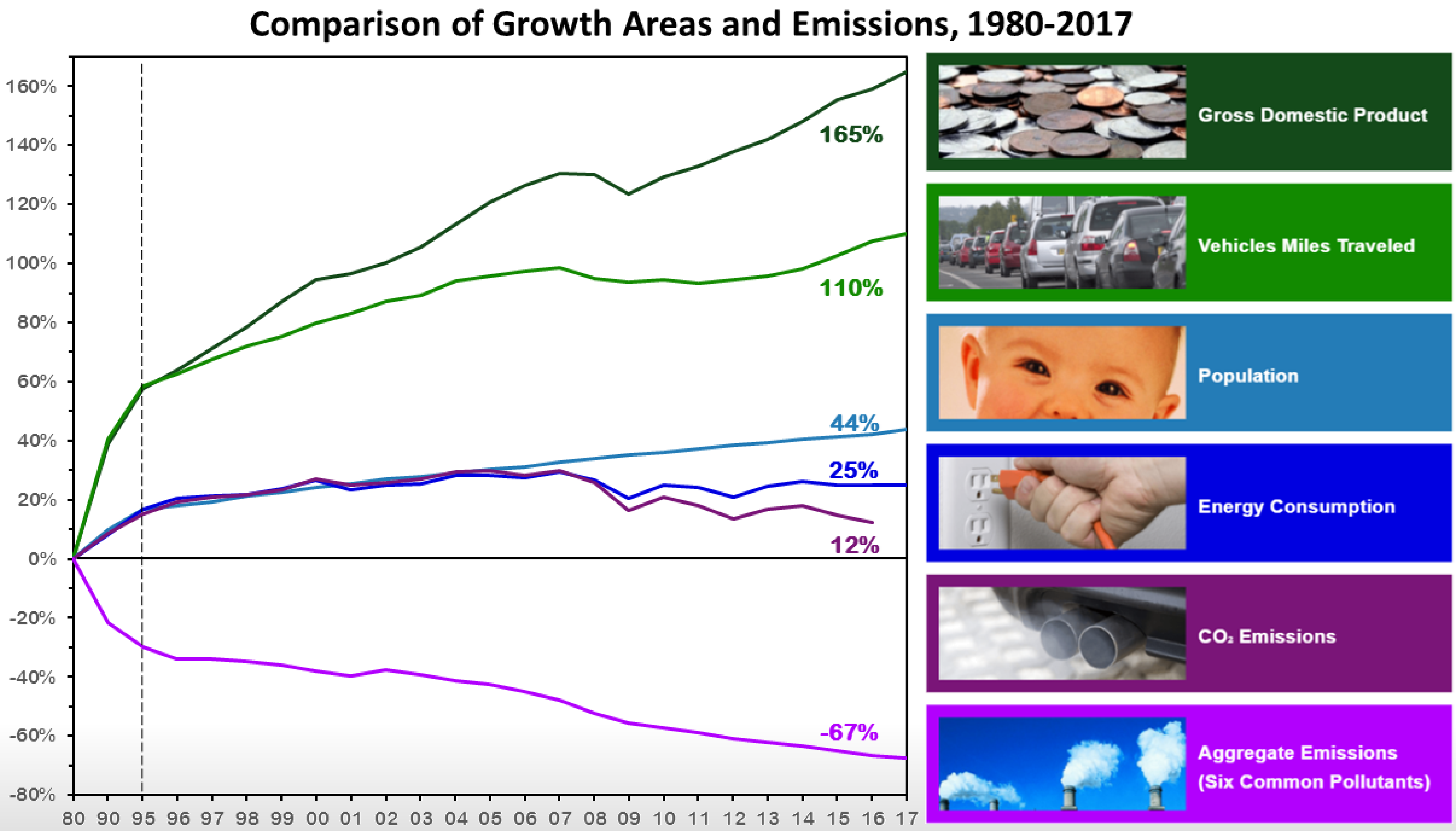
Steven G. Chalk, Acting Deputy Assistant Secretary for Renewable Power and Energy Efficiency

March 4, 2019

U.S. Productivity and the Environment



Source: EPA

EERE Organization with FY 2019 Funding

Assistant Secretary for Energy Efficiency and Renewable Energy
Daniel Simmons
*$2,379 million**

Chief of Staff
Alex Fitzsimmons

Deputy Assistant Secretary for Energy Efficiency
Steve Chalk (Acting)
$888 million

- Advanced Manufacturing Office
  Valri Lightner (Acting)
  $320 million
- Buildings Technologies Office
  David Nemtzow
  $226 million
- Federal Energy Management Program
  Rob Ivester
  $30 million
- Weatherization and Intergovernmental Programs
  Annamaria Garcia
  $312 million

Deputy Assistant Secretary for Renewable Power
Steve Chalk (Acting)
$528 million

- Geothermal Technologies Office
  Susan Hamm
  $84 million
- Solar Energy Technologies Office
  Charlie Gay
  $247 million
- Water Power Technologies Office
  Alejandro Moreno
  $105 million
- Wind Energy Technologies Office
  Valerie Reed (Acting)
  $92 million

Deputy Assistant Secretary for Sustainable Transportation
Michael Berube (Acting)
$690 million

- Bioenergy Technologies Office
  Jonathan Male
  $226 million
- Hydrogen and Fuel Cell Technologies Office
  Sunita Satyapal
  $120 million
- Vehicle Technologies Office
  Dave Howell (Acting)
  $344 million

Major Crosscutting Initiatives: DOE Grid Modernization Initiative – EERE: $180 million (includes $90 million for Beyond Batteries), Cyber Security: $50 million

** Funding for Federal Salaries, Strategic Programs, and NREL Stewardship not shown*

EERE Priorities

- EERE promotes affordable and reliable energy to enhance America's economic growth and energy security. Priority focus areas include:
  - **Energy Affordability** – continuing to drive down costs of the energy technologies in our portfolio
  - **Energy Integration** – facilitate the integration of new sources of generation and consider opportunities from greater flexibility in energy consumption
  - **Energy Storage** – technological advances to provide more flexible generation and more flexible load through a comprehensive approach to energy storage with smart buildings, pumped hydro, hydrogen storage, and batteries

Energy Affordability

- Dramatic reductions in the price of PV solar and onshore wind.
  - In 2017, the solar industry achieved the 2020 goal of $0.06/kWh for unsubsidized utility-scale systems.
  - Onshore wind saw a 60% reduction in LCOE from 2008–2017
- Cost of EV battery packs that have lower amounts of critical materials: Reduced battery cost by over 80% in the last 10 years from just over $1,000/kWh to $197/kWh (2018).
- Massive reductions in the cost of LED lightbulbs: 94% cost reduction from 2008–2016.

The costs of low-to-no-CO2-emitting sources of energy must out compete higher CO2-emitting resources for massive adoption.

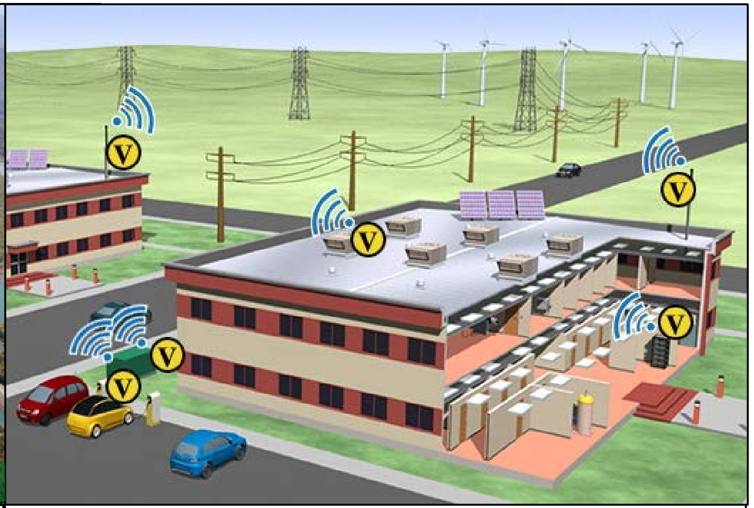
Energy Integration

With today's electric grid and the grid of the future, greater flexibility of both supply and load enables a wider array of technologies to contribute to the electric grid.

Pumped Storage Hydropower

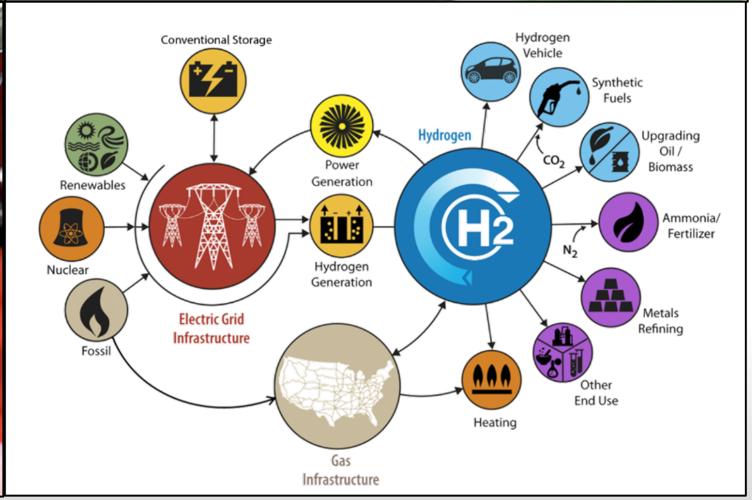

Credit: Southern Company and Georgia Power.

Buildings-to-Grid Integration



EV Charging Stations

Hydrogen @ Scale



Energy Storage

We need a portfolio approach to energy storage to create 1) more flexible generation and 2) more flexible load, thereby increasing the reliability and resilience of the U.S. electric grid.

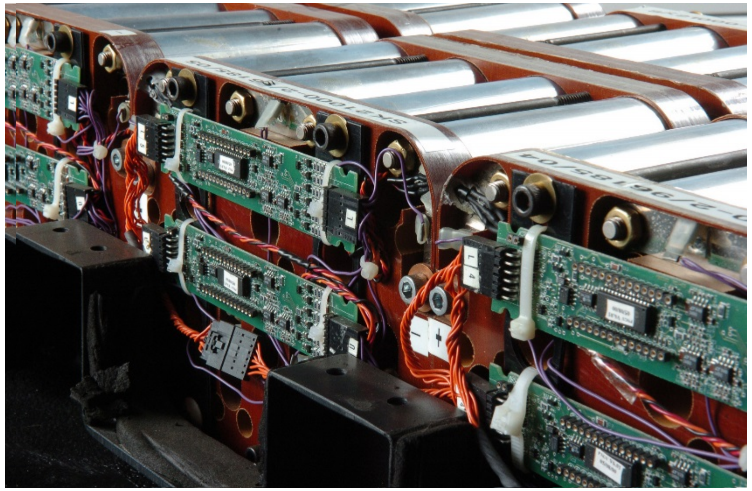
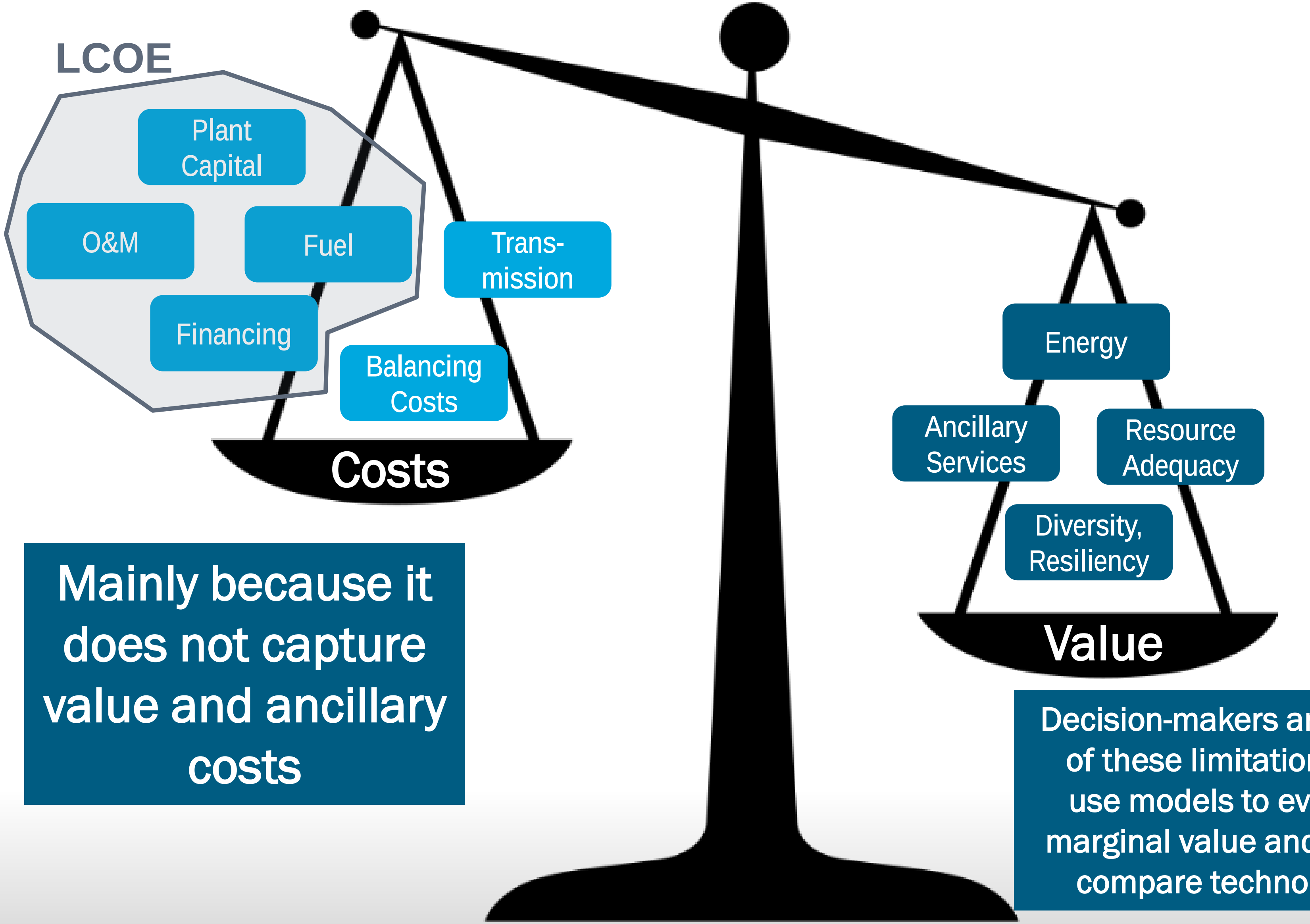


Photo courtesy of the Southern Company

Beyond the Levelized Cost of Energy (LCOE)

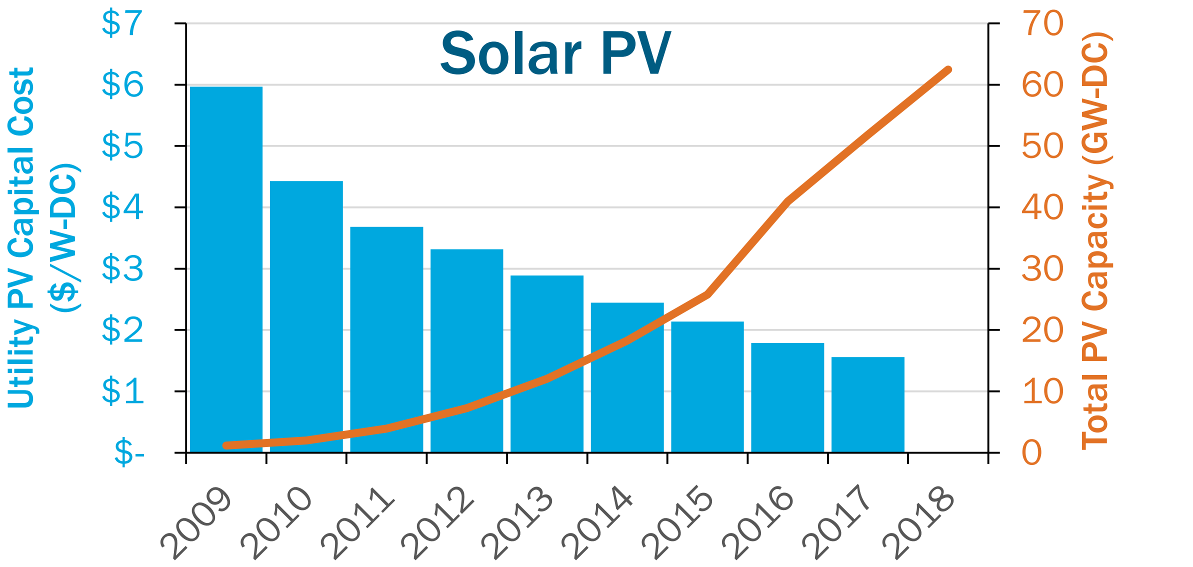
LCOE is not a bad metric…but an incomplete one

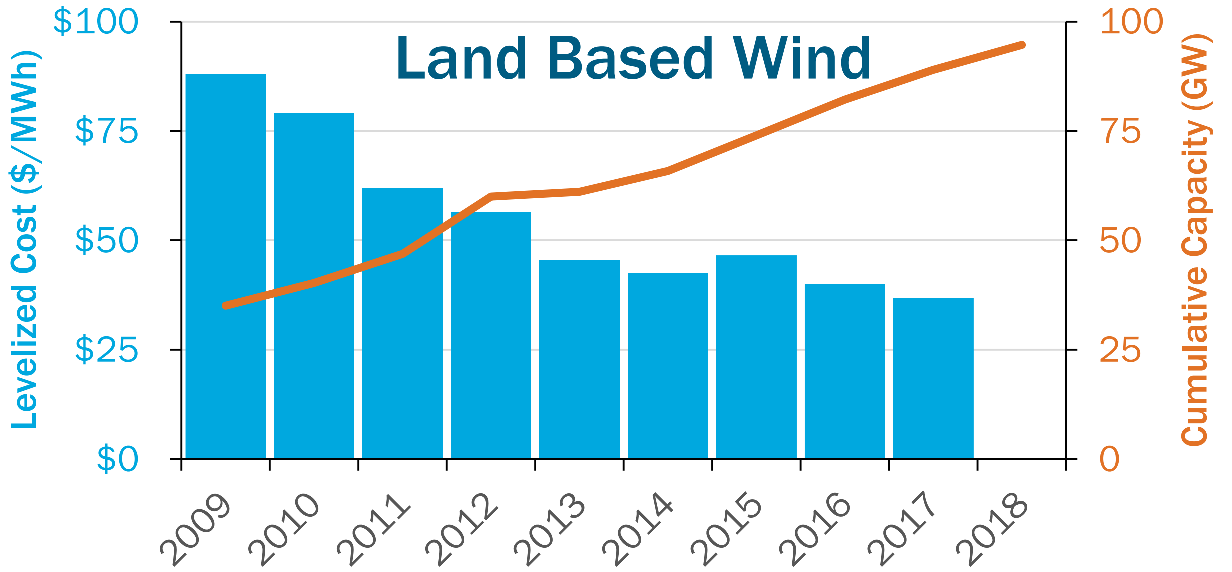


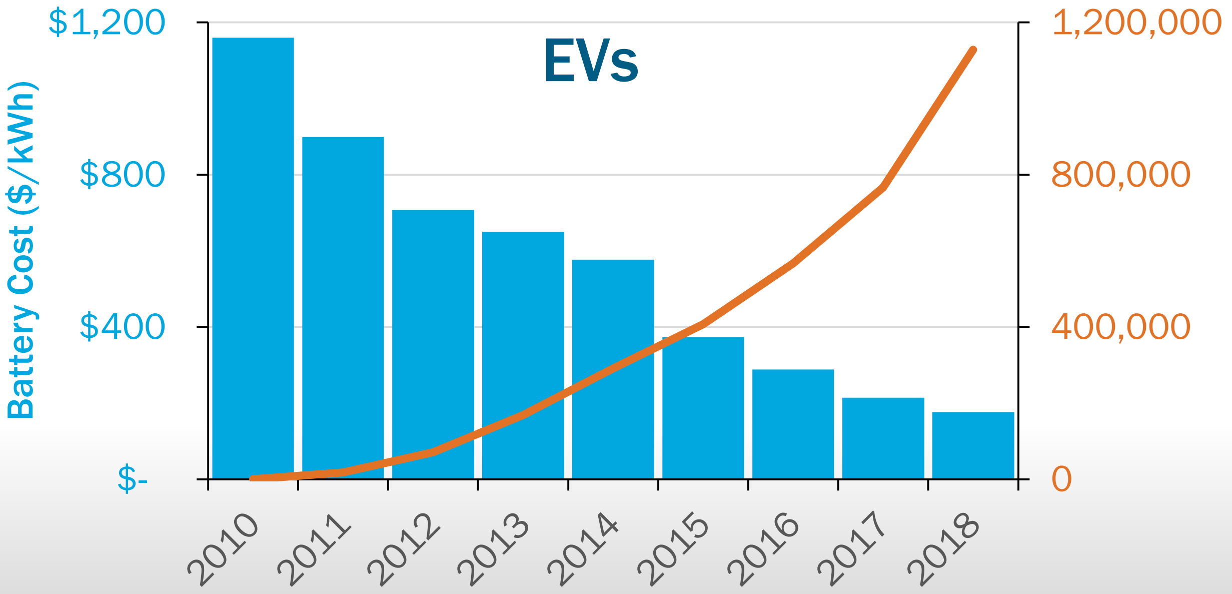
Mainly because it does not capture value and ancillary costs

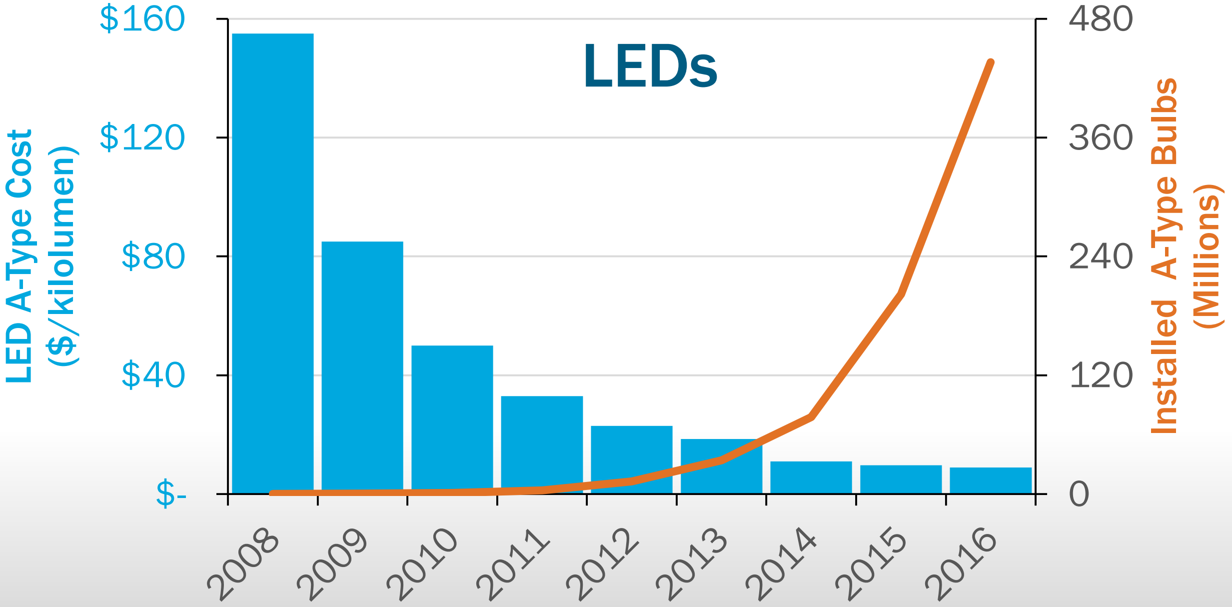
Decision-makers are aware of these limitations and use models to evaluate marginal value and cost to compare technologies

Technology Progress

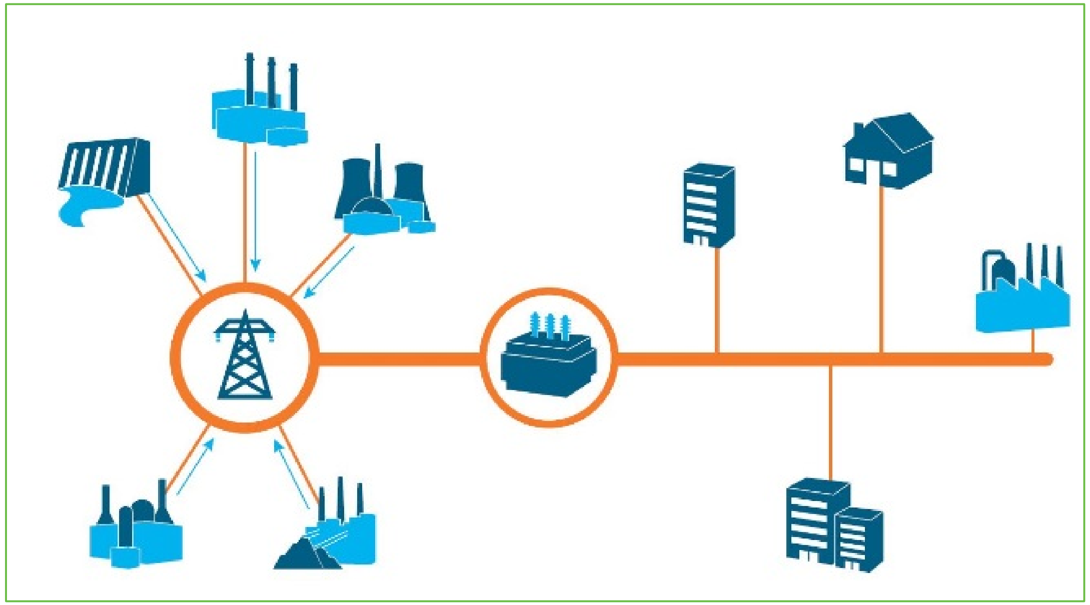






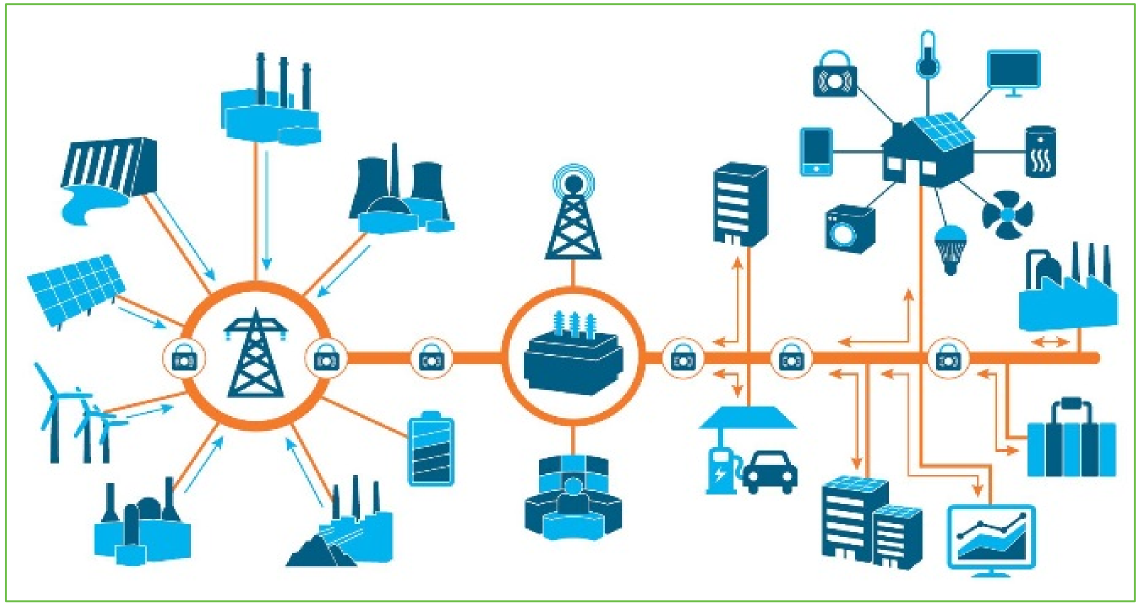


Grid of Today and Tomorrow



The grid of the 20^{th} century

- Centralized generation
- Limited visibility
- Susceptible to extreme events
- Limited consumer options



The modernized grid of the 21^{st} century

- Centralized and decentralized generation
- Visibility from generation to the grid edge
- Resilience,including through microgrids
- Customer choice and participation

What is Beyond Batteries?

An EERE-wide initiative to develop **new technologies and analytical tools** that provide **increased flexibility and grid services from renewable generation, load, and alternative storage technologies.**

Flexibility: *the ability to shift the timing of generation or consumption of electricity to when most valuable to the grid*

Grid services: *in addition to flexibility, the ability to improve the grid's ability to respond to rapid changes in generation or load (e.g. ramping, reserves) or electrical disturbances (e.g. frequency response, voltage support)*

Generation

Storage

Behind-the-meter

What types of projects are part of Beyond Batteries?

1. Flexible Renewable Generation: Projects that increase renewable generation technologies' abilities to provide flexibility or grid services at the bulk or distribution level. *Examples: control strategies and inverters for wind and solar; CSP technology advancements; technologies to increase dispatchability of geothermal, hydropower.*

2. Alternative Storage Technologies: Projects that develop new utility-side non-battery storage technologies or improve the performance of existing ones. *Examples: any projects developing new/improved technologies for pumped storage hydro, CAES, grid-scale thermal storage; grid-scale reversible fuel cells.*

3. BTM Generation, Storage and Load: Projects that develop new technologies that increase the ability of behind-the-meter renewable generation, storage and electricity demand to provide flexibility or grid services to the power system. *Examples: sensors or controls for dynamic loads; thermal storage in buildings; vehicle batteries or charging for grid services; increased flexibility or responsiveness of BTM generation; any BTM storage technology.*

4. Modeling and Analysis: Projects that improve the ability to predict, plan, or manage EERE resources on the grid to maximize their value as an integrated system. This can include system-level analysis of how renewable generation or load provide flexibility or reliability, technology-specific attributes under different conditions, as well as improved models or data. *Examples: BLCOE; analysis wind/solar/hydro integration; analysis buildings/solar/vehicles integration, technology characterization.*

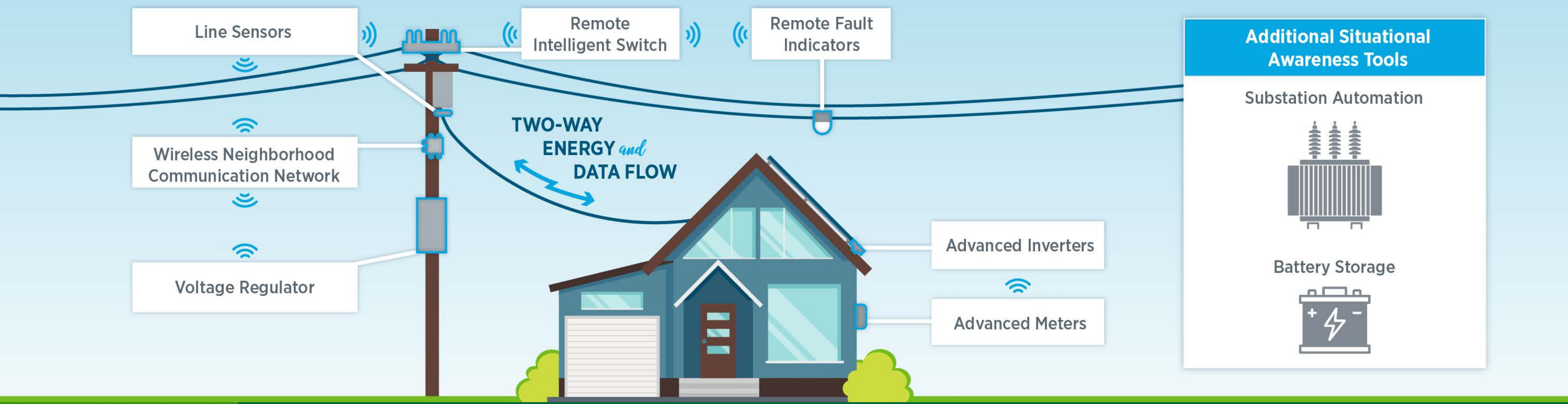
5. Enabling Technologies: Projects to develop technologies that can be applied to multiple topic areas above to improve flexibility or provide grid services, or infrastructure to test them. *Examples: Broadly-applicable power electronics technologies; technologies that enable communication or interoperability.*

Advanced Systems Integration for Solar Technologies

Improving the integration of solar on the electricity grid, especially at critical infrastructure sites, strengthening the resilience of the nation's electricity grid, and streamlining technology transfer challenges.

Situational Awareness: *Sensors and other tools allow grid operators better understand how energy moves along the grid.*

Resiliency: *Reducing vulnerabilities, minimizing consequences, identifying and disrupting threats, and hastening response and recovery efforts.*



BPA/Bosch Advanced HEMS and Battery

Description

Develop cyber-secure Home Battery System (HBS) controls that deliver high-reliability demand response while avoiding negative homeowner impacts.

Technologies

Connected home appliances, rooftop solar, grid, energy storage.
Designed for future integration of other technologies: EVs, wind, fuel cells, etc.

Final Deliverable

Methodology for selecting and sizing smart home equipment, including batteries, with plan to formalize it into a design process. Aggregation study showing local grid impacts of home controls which deliver local and bulk grid services.

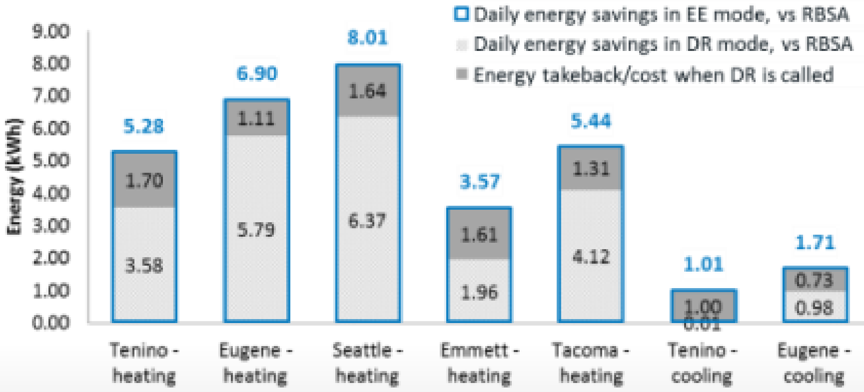
Project Impact

Enables design approaches for connected home energy systems that is applicable to developers, appliance manufacturers, regulators and utilities nationwide as home automation is adopted.

Partners

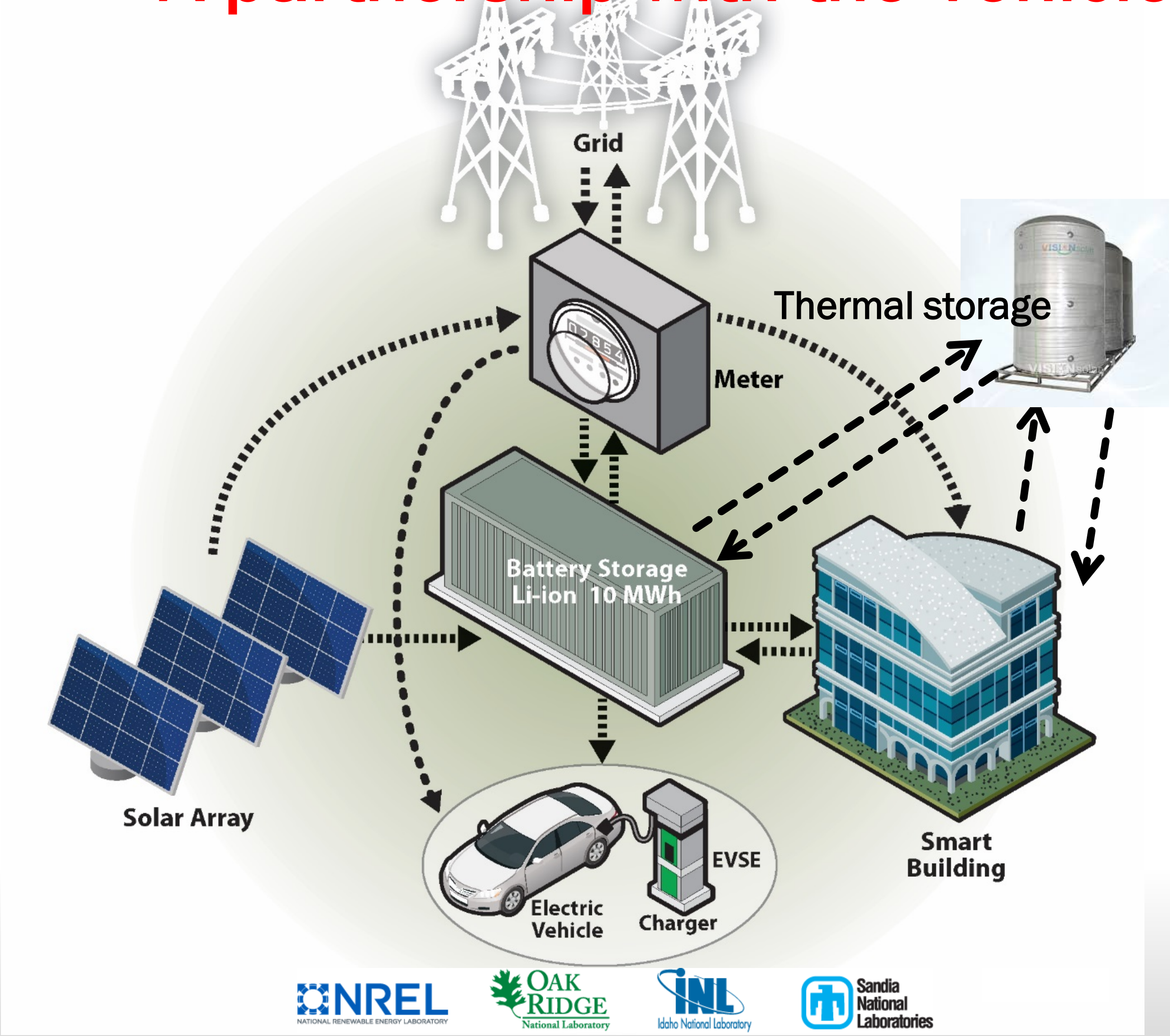
Industry Advisory Board

Daily Energy Savings in EE & DR modes



Behind-The-Meter Storage (BTMS)

A partnership with the Vehicles, Buildings, and Solar Offices



Fundamental research based upon a systems understanding.

- Integration of PV.
- Buildings are the largest electrical users.
- EVs will be charged at buildings.
- Avoid high demand charges.
- Grid impacts minimized.

- Store both electrons and heat.
- New battery chemistries and new thermal storage materials may be needed depending on application

Integration of Responsive Residential Loads into DMSs

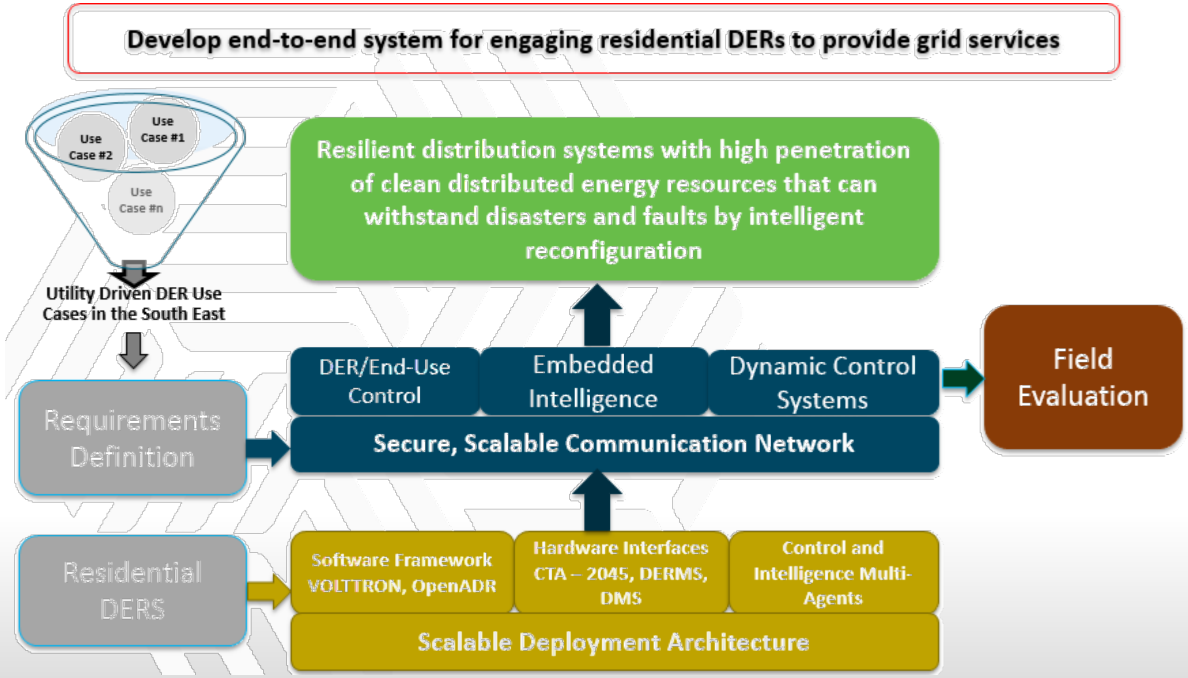
The goal of the project is to engage residential loads and distributed energy resources (DERs) to increase distribution system resiliency. This will be achieved through interoperable end-to-end system architecture employing hierarchical control and optimization technology to demonstrate coordinated response from large number of assets in time and magnitude.

Value Proposition

- Increasing number of smart residential-level assets including controllable loads, rooftop solar, and storage technologies imposing new challenges in distribution operations
- These assets can be leveraged for enabling resilient rapid reconfiguration of the distribution circuits by managing demand, voltage, and power flows
- An end-to-end solution establishing interoperability across the meter and coordinated control technology is needed to engage residential loads for grid services
- The end-to-end system performance and resilience has to be validated in field for adoption

Project Objectives

- Develop interoperable home energy management system (HEMS) as an interface to distribution-level integration of Residential loads and DERs to provide distribution resiliency services
- Develop transactive control system to co-optimize Loads/DER performance to satisfy grid requirements and residential needs
- Deploy and validate the technology in field with utility partners



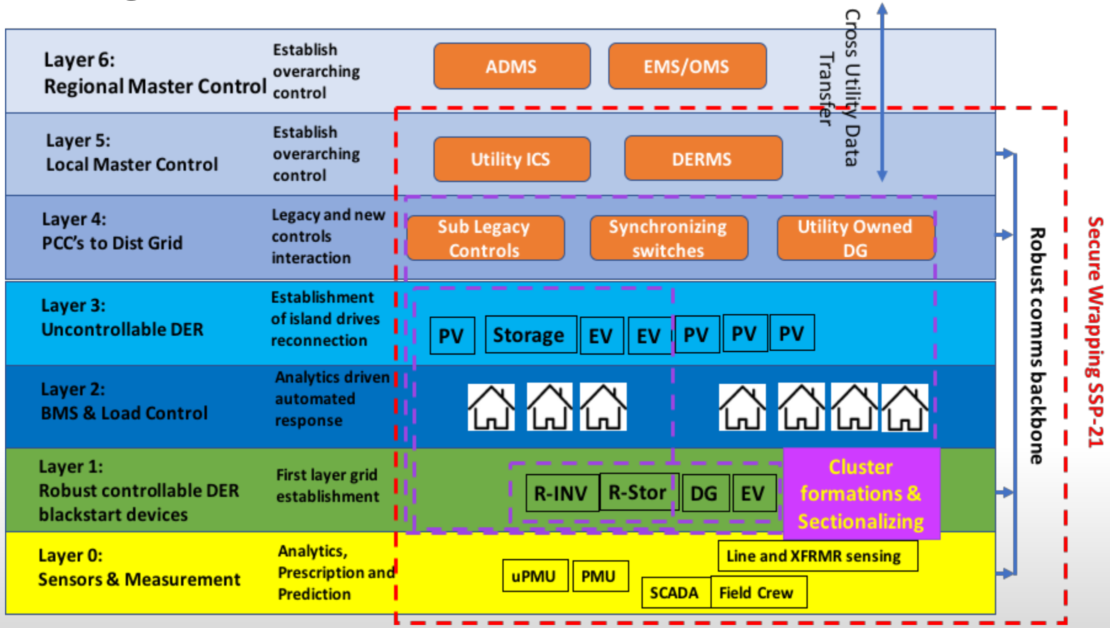
CleanStart DERMS

Project Description
Develop and implement a DER Management System integrated application, which provides a separate communications, analytics and control layer, purely for a black-start and restoration application.

Solution will demonstrate the start of a microgrid following an outage (cyber or physical)

Value Proposition
- Black start and restoration at present is a centralized bulk system driven solution whereas DER is by nature decentralized
- Key innovations
    - DER controls as a mechanism for black start and restoration
    - Cross utility coordination and effective useful information/resource transfer
- Product will be transformational to utilities experiencing a rapid DER influx, considering both controlled and uncontrolled resources as part of the resilient resources to be utilized in widescale events

Project Objectives
- Minimize the outage time for the maximum number of customers using the greatest contribution from distributed and clean energy resources
- Implement methods for coupling and validation of predictive analytics and advanced controls for resilience
- Provide support services from DER back to the transmission system during critical outages
- Demonstrate a CEDS funded cybersecurity technology showing integration with the resilient DER architecture (CES-21/SSP-21)



SDG&E: Borrego Springs High Penetration Microgrid

Description

Demonstrate the viability of a microgrid to manage high amounts (up to 100%) of renewable energy to meet the community load while avoiding adverse grid impacts. Advanced testing methods and a testbed that can be configured to utilize electrical signals from SDG&E through remote hardware in the loop (HIL) will be developed at ESIF.

Technologies

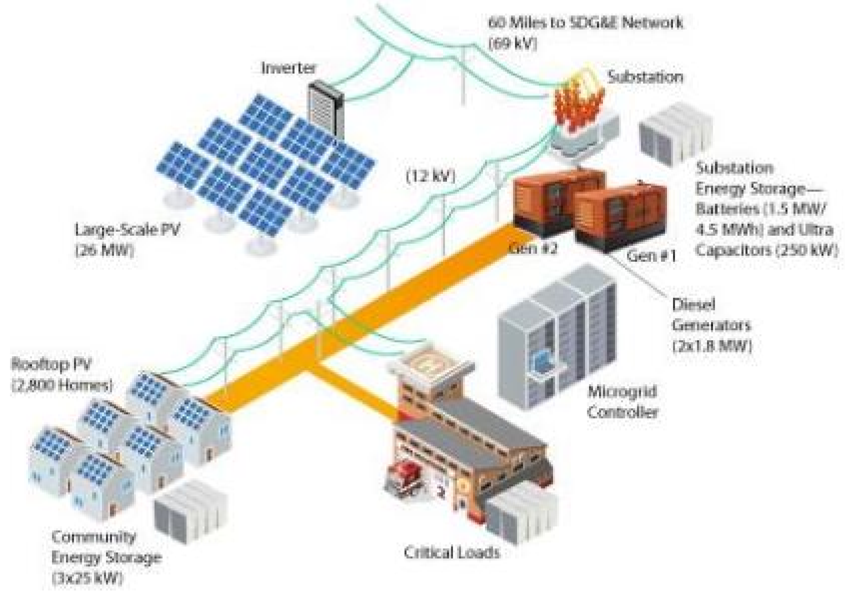
Solar (large-scale plants and residential rooftop); Storage (substation and community-scale batteries; ultra-capacitors

Project Impact

Successful implementation of the largest microgrid in North America will prove that a community-scale, highly renewable microgrid can be implemented with economic benefits.

Partners

SDG&E, Spirae, UCSD, OSISoft, SMA, NRG.



Borrego Springs community microgrid in SDG&E territory

HIl test setup with RTDS digital real-time simulators, PV inverter and advanced microgrid controller

RADIANCE

Project Description

To perform a full-scale regional deployment of advanced technologies and methods for **resiliency-enhanced operation** of regional distribution grid in the City of Cordova, AK under harsh weather, cyber-threats, dynamic grid conditions using early-stage technologies such as micro-PMUs, energy storage, loosely- and tightly-networked microgrids, multi-dimensional metrics-based approach for resiliency, zonal reconfiguration, and cyber-vulnerability analysis.

Value Proposition

- Field validation of **resiliency-driven** distribution grid operation through **networked microgrids**, **zonal reconfiguration**, energy storage, real-time **cyber-secure** communication and control
- Field demonstration, best practices to utilities to adopt microgrids as a resiliency resource

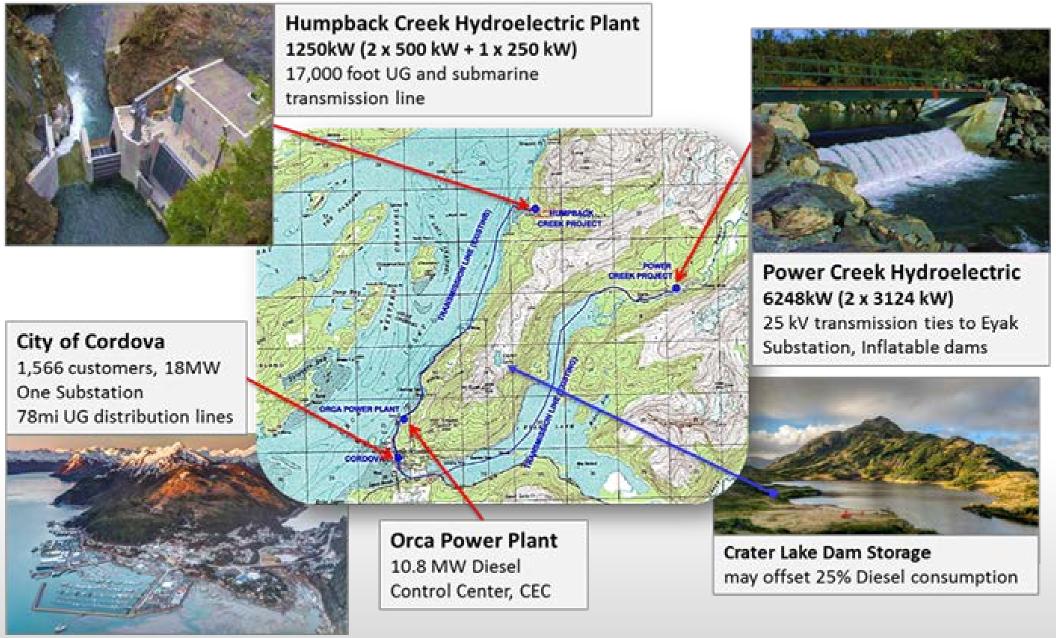
Project Objectives

Cultivate a better fundamental understanding of resiliency for networked microgrids

- Application of <u>*resilience-by-design*</u>
- Develop a systematic framework for quantification, and practical use of <u>multi-dimensional resilience</u> framework

Regional field validation of resilience enhancement methods for distribution grids

- Coordinated operation of multiple networked microgrids, micro-PMUs for real-time controls
- De-risking field deployment <u>by iterative HIL testing,</u> evaluation of energy storage technologies

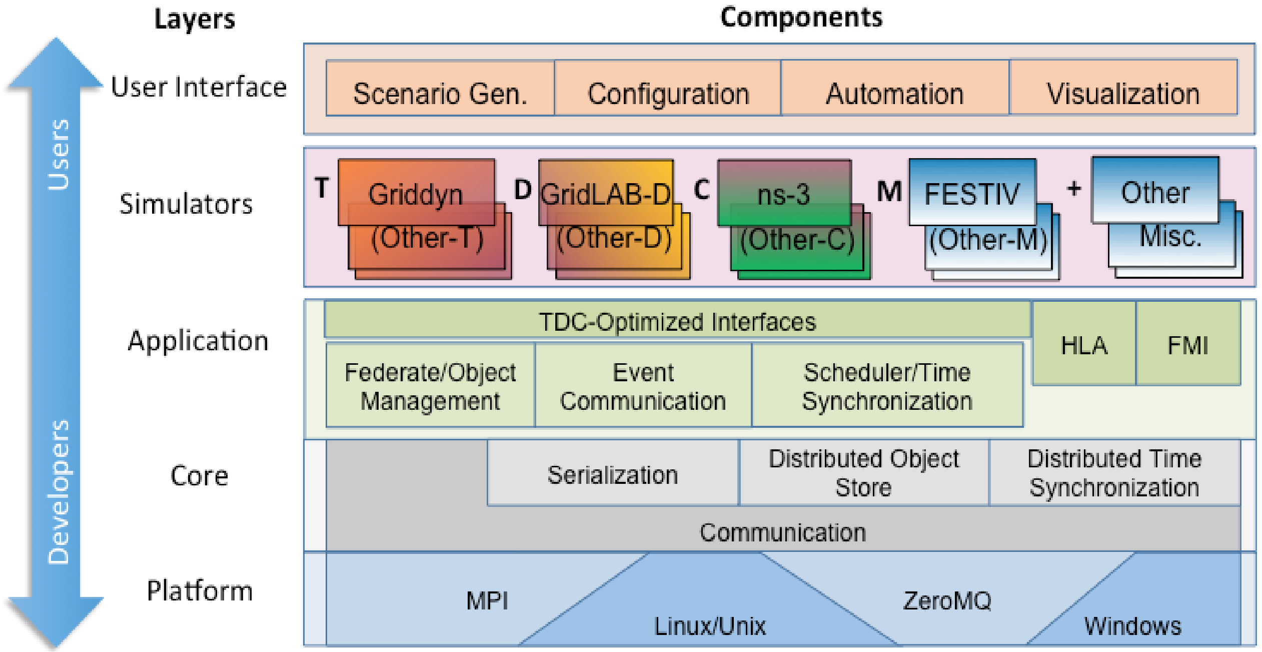


Transmission, Distribution, and Communication Models

Project Description
This project aims to enable large-scale TDC interdependency studies through a flexible and scalable, open-source co-simulation platform for the following industry drivers

Project Objectives
- Provide foundational capabilities for grid planning, operation, and control
- Engage and educate grid developers on the value of multi-domain planning

Value Proposition
- There is currently a gap in simulation and modeling technology that inhibits integrated planning across multiple domains
- Left to it's own devices, the grid community is unlikely to develop capabilities to overcome planning stovepipes (in near term)
- The DOE plays a unique role in initiating this effort and creating foundational tools that support both research and industry



HELICS – Hierarchical Engine for Large-scale Infrastructure Co-Simulation

SoCalGas: Power-to-Gas Renewable Electricity to Natural Gas

Description

Produce pipeline quality renewable natural gas (RNG) using biocatalysts (methanogens) that convert carbon dioxide and hydrogen generated with grid-scale low-cost renewable electricity for short- and long-term energy storage in the NG grid.

Conduct daily operations under steady-state and varying (e.g., solar, wind) profiles to characterize system performance parameters like; pressure, temperature, agitation, gas flow rates to inform next generation reactor design, modeling and TEA to;

1. Identify optimal P2G site selection within the WECC
2. Inform public policy and energy leaders about benefits of P2G

Technologies $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

PV- and wind-generated electricity produce hydrogen via water electrolysis. Then, a biocatalyst converts CO_2 and H_2 to make CH_4

FY17 Notable Outcome

Successfully install, commission and conduct dailt operations of the **first** bio-methanation reactor in the U.S. at the ESIF prior to demonstrating a pilot-scale renewable power-to-hydrogen-to-natural gas systems in southern California.

Impacts

Sets the foundation for large-scale P2G (10 – 100 MW) systems and show the potential of P2G to enable higher levels of renewable energy and carbon-neutral synthetic fuel production.

Single-cell bacteria convert ~3 kg/hr H_2 and CO_2 into 4 scfm of CH_4 (RNG) in a 700 L pressurized bioreactor

Looking Ahead in FY 2019

- **Advanced Manufacturing**
  - Cybersecurity Institute
  - Medium-voltage power conditioning systems to enable grid-dispatchable facilities
- **Buildings**
  - Grid-interactive, efficient, flexible building technologies
  - Sensors, controls and communications for secure grid integration
- **Hydrogen and Fuel Cells**
  - Reversible fuel cells
- **Geothermal**
  - Robust cements to enable flexible operations of geothermal plants
  - Direct use and thermal storage applications
- **Solar**
  - Grid services from BTM solar, PV inverter controls, cybersecurity
  - Distributed PV integration: curtailment, reliability, enhanced flexibility
  - CSP flexibility, pumped thermal storage, CSP for industrial process heat
- **Water**
  - Improved grid services from hydropower and PSH, valuation
  - Assessment and quantification of hydroelectric flexibility
- **Wind**
  - Reliability services from wind plants, integration with multiple other technologies
- **Vehicles**
  - Extreme fast charging interoperability, grid impacts, cybersecurity, smart charging
  - Behind-the-meter storage and integration

DISCUSSION

Backup: Grid Modernization Initiative (GMI)

An aggressive and urgent five-year grid modernization strategy for the U.S. Department of Energy (DOE) that:

- Aligns existing base activities across DOE offices
- Defines a vision for the modern grid through an integrated Multi-Year Program Plan (MYPP)
- Establishes new activities to fill major gaps in the existing base
- Leverages strategic partnerships through a laboratory consortium with core scientific abilities and regional outreach

Design and Planning Tools	• Create grid planning tools that integrate transmission and distribution and system dynamics over a variety of time and spatial scales
System Operations, Power Flow, and Control	• Design and implement a new grid architecture that coordinates and controls millions of devices and integrates with energy management systems
Sensing and Measurements	• Incorporate information and communications technologies and advance low-cost sensors, analytics, and visualizations that enable 100% observability
Devices and Integrated Systems	• Develop new devices to increase grid services and utilization and validate high levels of distributed energy resources at multiple scales
Security and Resilience	• Develop resilient and advanced security (cyber and physical) solutions and real-time incident response capabilities for emerging technologies and systems
Institutional Support	• Provide tools and data that enable more informed decisions and reduce risks on key issues that influence the future of the electric grid/power sector