www.nas.edu/gridmod

Georgia Tech Center for Distributed Energy

Reducing Emissions from the Electricity Grid

EESI Congressional Camp #2

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GT Center for Distributed Energy

cde.gatech.edu

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Creating holistic solutions in electrical energy that can be rapidly adopted and scaled

WORLD ECONOMIC FORUM
TOP 3 TRANSMISSION GRID INNOVATIONS 2010-2020
"Accelerating the Energy Transition"

Platform Initiatives

Grid Asset Augmentation

7.2 kV 50 kVA Hybrid Transformer | 13 kV 1 MVA Modular Transformer | Smart Wires

- 13 kV/50 kVA FUT
- 13 kV 1 MW Power Router
- 67 MVA Modular LPT
- Improving Grid Resiliency
- Smart Wires
- Meshed Grid VVC

Energy Access in Emerging Markets

- 'Exponential' Tech
- Self Organizing Nano Grid
- Pay-Go Smart Meter
- Low Cost DA for Grids
- Ad-Hoc Bottom-Up Grids
- Empower a Billion Lives

Emerging Technology: D-Light | Top 10 Emerging Markets *Source: Global Intelligence Alliance*

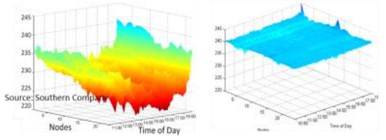
Next Generation Grid Power Electronics

4 kV MVSI for Large PV Farms | 7.2 kV 50 kVA SST

- 5 kV DC Grid Building Block
- 7.2 kV 50 kVA Grid Connected SST
- 4 kV MVSI for Large PV Farms
- Triports for PV/Storage/Grid
- MVSI with Integrated Storage
- Microgrid-Grid Interface Device

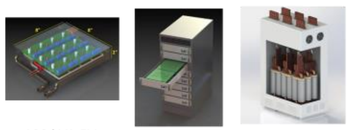
Decentralized Grid Control Techniques & Markets

- Grid Edge Volt VAR Control
- Collaborative Control
- High PV Integration
- DER Micro grid Impact
- Self-Pricing Island Grids
- Virtual Power Plants



Feeder Voltage w/o and with GE Control | Feeder Voltage w/ Grid Edge Control

Next Generation Industrial Power Electronics

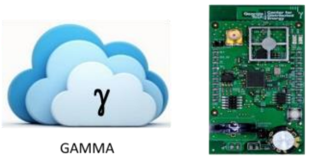


100 kVA EV Drive System | 200 kVA Isolated Drives | 2 MVA Industrial SIVOM

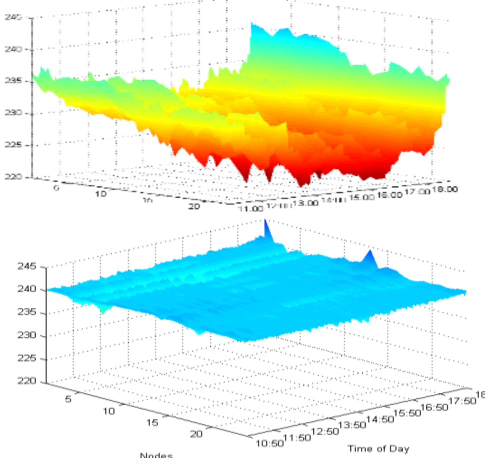
- Industrial CVR Energy Efficiency
- 100 kVA EV Drive System
- 25-500 kVA Isolated Drives
- Energy Hub – DC Fast Charging
- Programmable Load/Source
- Data Center Power Sources

Global Asset Monitoring Management & Analytics (GAMMA)

- Low-Cost Communications
- Cyber-Security
- Data Management
- AMI Data Analytics
- Global Sensor Networks
- Cloud Based GAMMA System

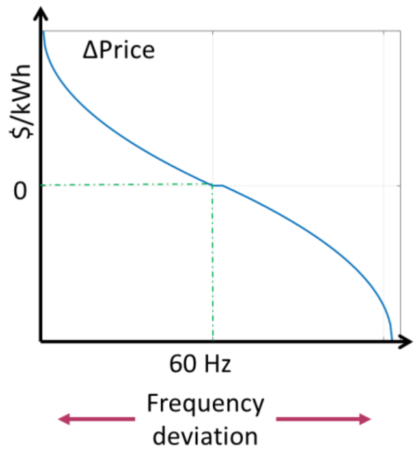


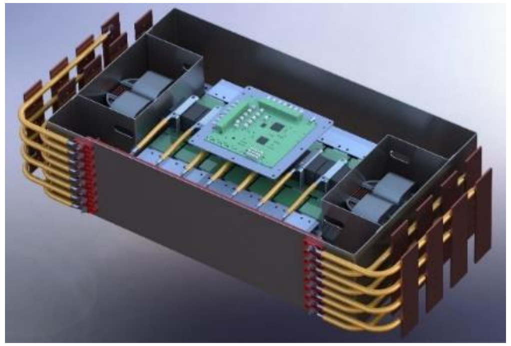
GAMMA Platform | Gamma kernel



COLLABORATIVE CONTROL
Varentec

TRANSMISSION POWER FLOW CONTROL
Smart Wires





SELF-PRICING MICROGRIDS
Transactive/Physical Grid

SOLID STATE TRANSFORMER (S4T)

Exponential Technologies (outside utility influence)

Computation, PV solar, wind, EV, power semis, storage, microcontrollers, prosumers, sensors, IoT, comms, online services, social media, mobile pay, block-chain, cloud, autonomous control, AI, ML, deep learning

Primary Drivers

Digitalization

Decentralization

Decarbonization

Reducing Grid Related Emissions

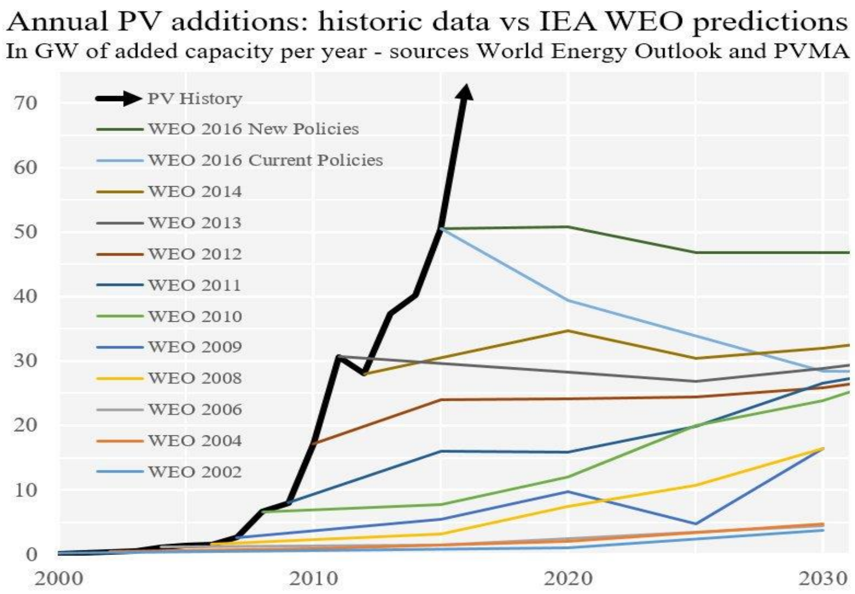
- **Opportunity:** Electricity generation (coal, gas) accounts for 26.9% of US emissions, transportation 55.1% , buildings and industry 35% - key drivers for new solutions are lower cost and emissions
- **Zero Carbon Resources:** Hydro, nuclear, wind and PV – future technologies include clean fuels (e.g. hydrogen) and SMR
- **Resource Adequacy:** YES (100 mi x 100 mi PV farm in Arizona could, in principle, meet US annual energy needs)
- **Challenge:** coordinating time and location of generation and consumption (over milliseconds to seasons all over the grid)
- **Attributes:** dispatchability, fast-ramping, spinning reserve
- **Enablers:** long/medium duration energy storage; AC & DC transmission; power electronics; ICT and cyber; ultra-automation; microgrids; carbon capture & sequestration
- **Approach:** Centralized generation AND distributed generation (microgrids) together meet reliability, resiliency and cost goals
- **New Paradigm (?):** reliability & resiliency from the grid edge; affordability & sustainability from bulk PV/wind/hydro/other

Grid Transformation

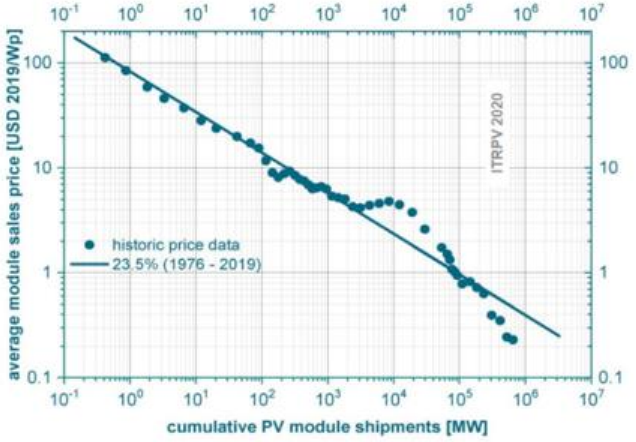
Centralized, Passive & Rigid	→	Decentralized, Dynamic & Resilient

In 2000, IEA forecast for 2030 → RE 4.4% of total
In 2014, RE was 27.7% of total, 58.5% of new build

It is difficult to make forecasts, especially about the future – ***old Danish proverb***



Learning curve for module price as a function of cumulative shipments



2019: PV + 4 hours storage: $32/MWHr

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Fast Growing Sectors are Transforming the Grid

PV and Wind Farms

- PV and wind represent fast global growth – **(120+160) GW/yr**
- With storage, shows much lower LCOE and better dispatchability
- Needs transmission to connect load centers with generation


Energy Storage

- Fast growth for modular battery energy storage – **1100 GW by 2030**
- Hydro to pumped hydro conversion and CAES offer central storage
- Clean fuels – hydrogen, ammonia offer long duration energy storage


DC Fast Charging (DCFC)

- 125 million EVs by 2040,buses, trucks, semis – all going electric
- DCFC at 100 kW to 1 MW will stress the grid (peak load 1000 GW)
- Significant coordination with grid edge resources will be needed

Community Resiliency Microgrids

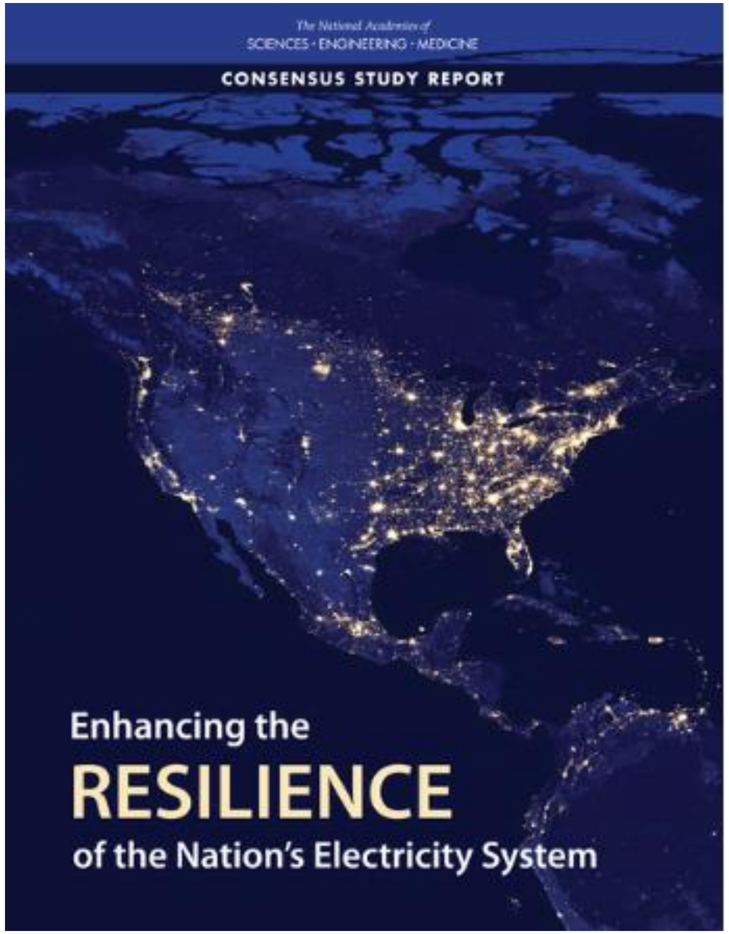
- Hurricanes, wildfires & ice-storms show need for grid edge resiliency
- High cost, complex integration with grid operations, poor scaling
- Will reshape the design of the future grid, technology/cost challenges

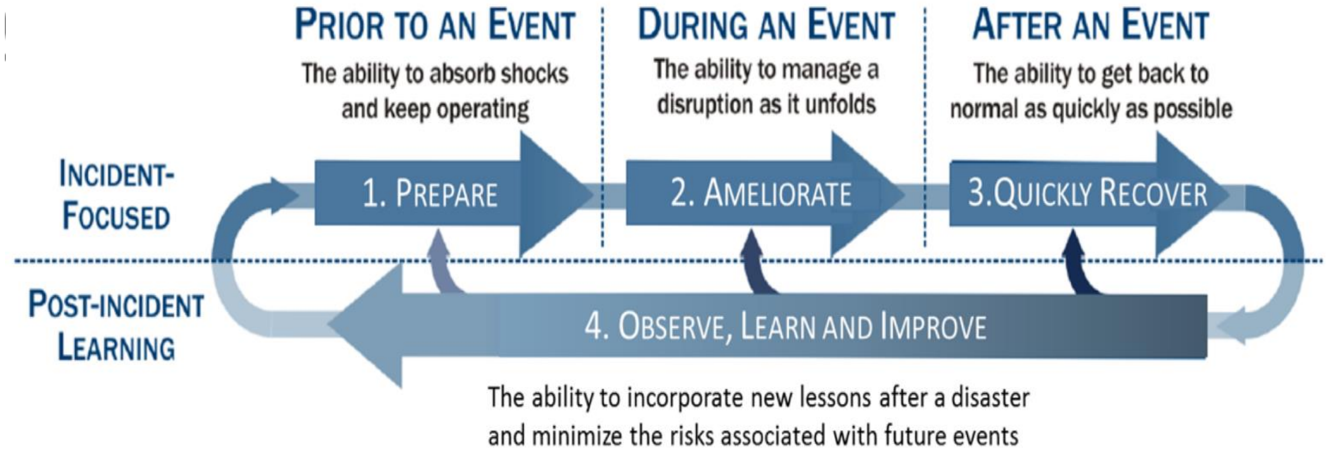

Intersection of forward-leaning incentives and 'exponential' technologies hold the key to this transformation

Recent NASEM Reports - Resilience

Recent Events in Texas Again Emphasize Need for Resilience

2019





Recommendation: The Department of Energy and Department of Homeland Security <u>should jointly establish and support a "visioning" process</u> with the objective of systematically imagining and assessing plausible large-area, long-duration grid disruptions [...]

Recommendation to the electric power sector and DOE: The owners and operators of electricity infrastructure should work closely with DOE in <u>systematically reviewing previous outages and demonstrating technologies, operational arrangements, and exercises that increase the resilience of the grid</u>

Recent NASEM Reports - Decarbonization

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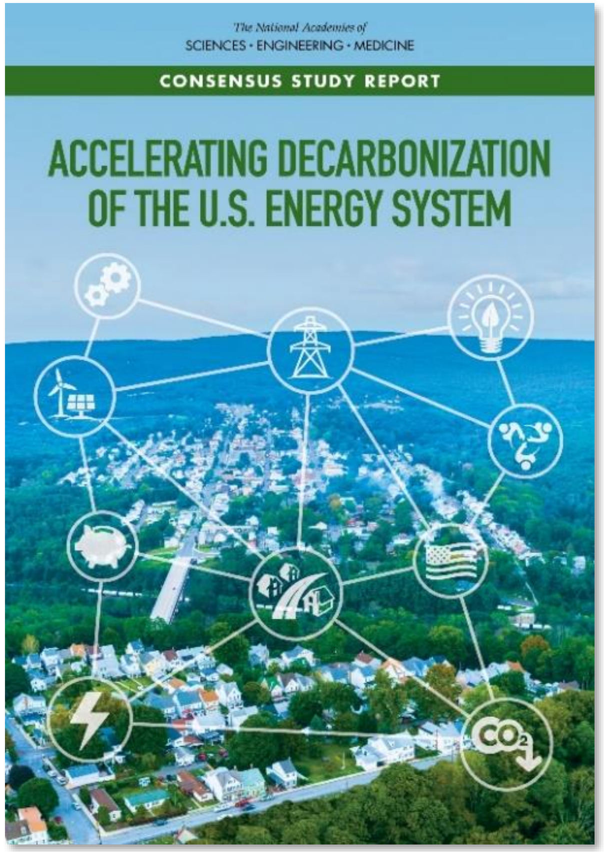
Committee asked to produce two reports that evaluate the status of technologies, policies, and societal factors needed for decarbonization and recommend research and policy needs.

This first report focuses on federal actions over the **next ten years** to put the U.S. on a **fair and equitable path to net-zero in 2050**.



nap.edu/decarbonization
2021

- Set **energy standard for electricity generation** to reach 75% clean electricity by 2030 and net-zero emissions by 2050.
- Enact congressional actions to **advance clean electricity markets**, and to improve their regulation, design, and functioning.
- Set national **zero-emissions vehicle standards** and **manufacturing standards** for zero-emissions appliances.
- Facilitate **new transmission infrastructure** by amending Federal Power Act and Energy Policy Act.
- Triple federal **investment in clean energy RD&D,** including funds for social science research.

Plan, permit, and build critical infrastructure

Produce carbon-free electricity

Electrify energy services in transportation, buildings, and industry

The Future of Electric Power in the US...*new NASEM report*

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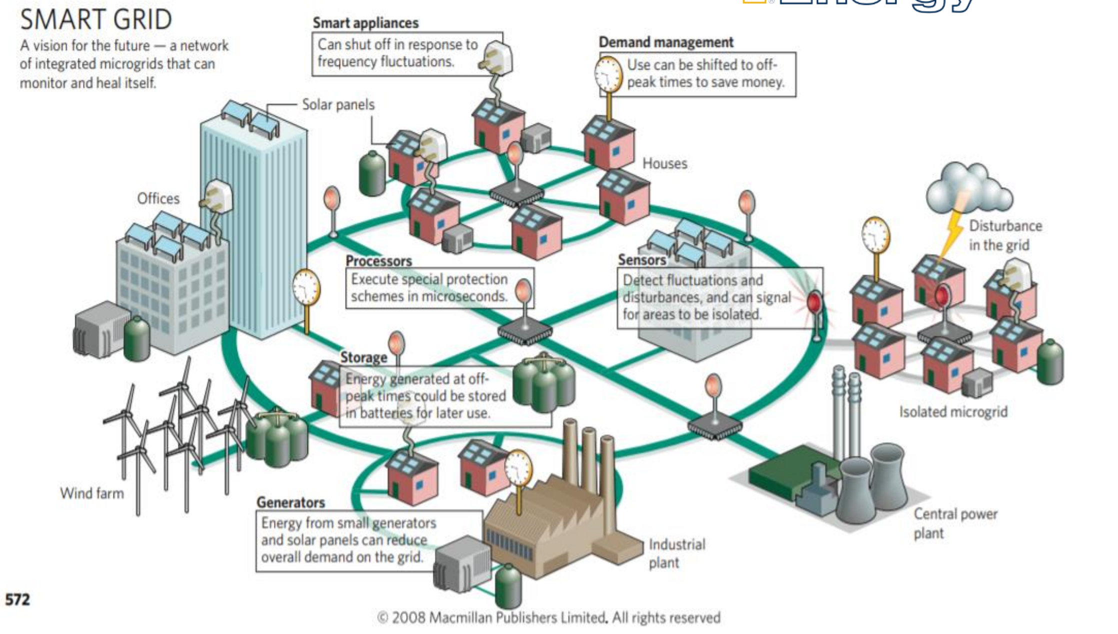
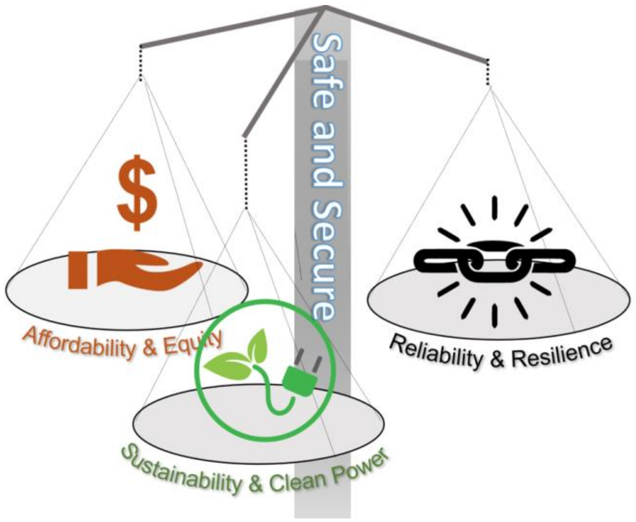
2021

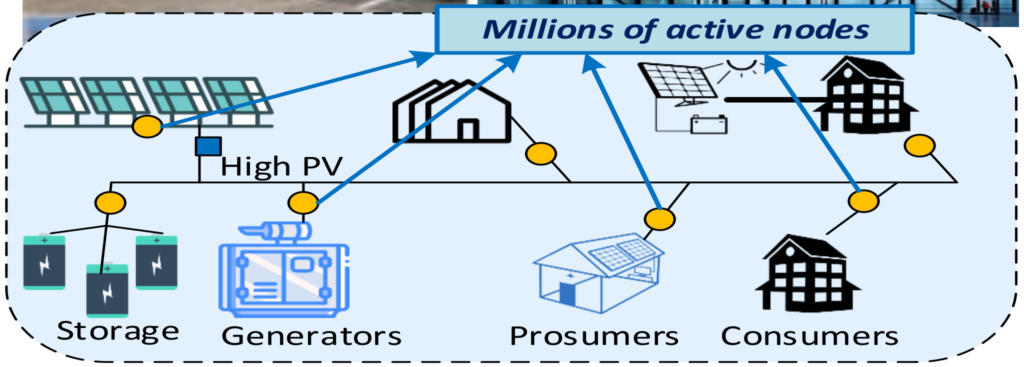
Increasing automation and decentralization



The system is on the cusp of fundamental transformation, many elements of which are not under industry control.

We can identify drivers of future change, but how they will manifest is uncertain – and it will be different in different parts of the country





Grid of the future

The Future of Electric Power in the US – *NASEM Report*

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Paraphrased Recommendation 5.1: To meet the challenge of dramatically lowering U.S. CO_2 emissions, there is a need to develop: generation technologies with zero direct CO_2 emissions; low-carbon technologies with high dispatchability and fast ramping capabilities; storage systems for multi-hour, multiday and seasonal time-shifting; power electronics to enable real-time control of the grid.

Paraphrased Recommendation 5.2: Developments in rapidly growing technologies, such as PV, wind, EV, and energy storage, suggest a new paradigm may be rapidly emerging which is more modular, distributed and edge-intelligent, and which may be able to compete with and outperform the existing grid paradigm in terms of sustainability, reliability, resilience, and affordability. …….

Additional findings and recommendations:

- Decarbonize the U.S. economy, both by transitioning power generation to low or zero-emission sources and by making greater use of decarbonized electricity as a substitute for fossil fuels in transportation, buildings and industry.
- Grid stability challenges arising from high penetration of non-dispatchable sources of generation, such as wind and solar, need to be addressed.
- Addressing nearly all of the fundamental challenges for the grid of the future—from the integration of renewables to deep decarbonization—requires innovation
- The country's investment in innovation is far below what is needed to match the scale of the challenge and what's feasible - At least double public expenditure on innovation, from states and mainly federal government

NASEM Grid Report – Key Technology Recommendations

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Clean Generation and Commercialization

- Develop generation, storage, and distributed energy technologies with no emissions.
- Government and Industry collaborate to develop, fund and de-risk new and critical technologies essential to the future grid.
- Report also recommends tripling federal investment in RD&D

Communication, Automation, and Simulation

- Develop *secure and reliable* ICT technologies to support millions of grid connected devices.
- Develop technologies to enable a high-level of automation in a flexible & resilient system.
- Develop advanced *inter-compatible* simulation tools to analyze evolving grid architectures.
- Explore the use of large field experiments for new grid architectures

Develop Workforce of the Future

- Fund training and retraining of the current and future workforce.

Conclusions

- Achieving low-emissions has always been seen as a trade-off, with higher cost and poor reliability – resulting in the disruption of the electricity system that has been at the heart of human progress
- The last 20 years has seen unprecedented and rapid change in the energy industry – at a time when climate change (and related grid resiliency) has also become a pressing concern
- 'Exponential' technologies with rapidly decreasing prices, driven by forward-leaning incentives and policies, have transformed the energy landscape – with renewables at grid parity in many places
- There is an opportunity to transform the system to a low-carbon system, that is also reliable, resilient and affordable – requires fundamental rethinking, innovation, policies & investments

Thanks to NASEM staff and the committee that authored 'The Future of Electric Power in the US' NASEM report