QUADRENNIAL TECHNOLOGY REVIEW

AN ASSESSMENT OF ENERGY TECHNOLOGIES AND RESEARCH OPPORTUNITIES

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U.S. Department of Energy
Presentation to ASCAC
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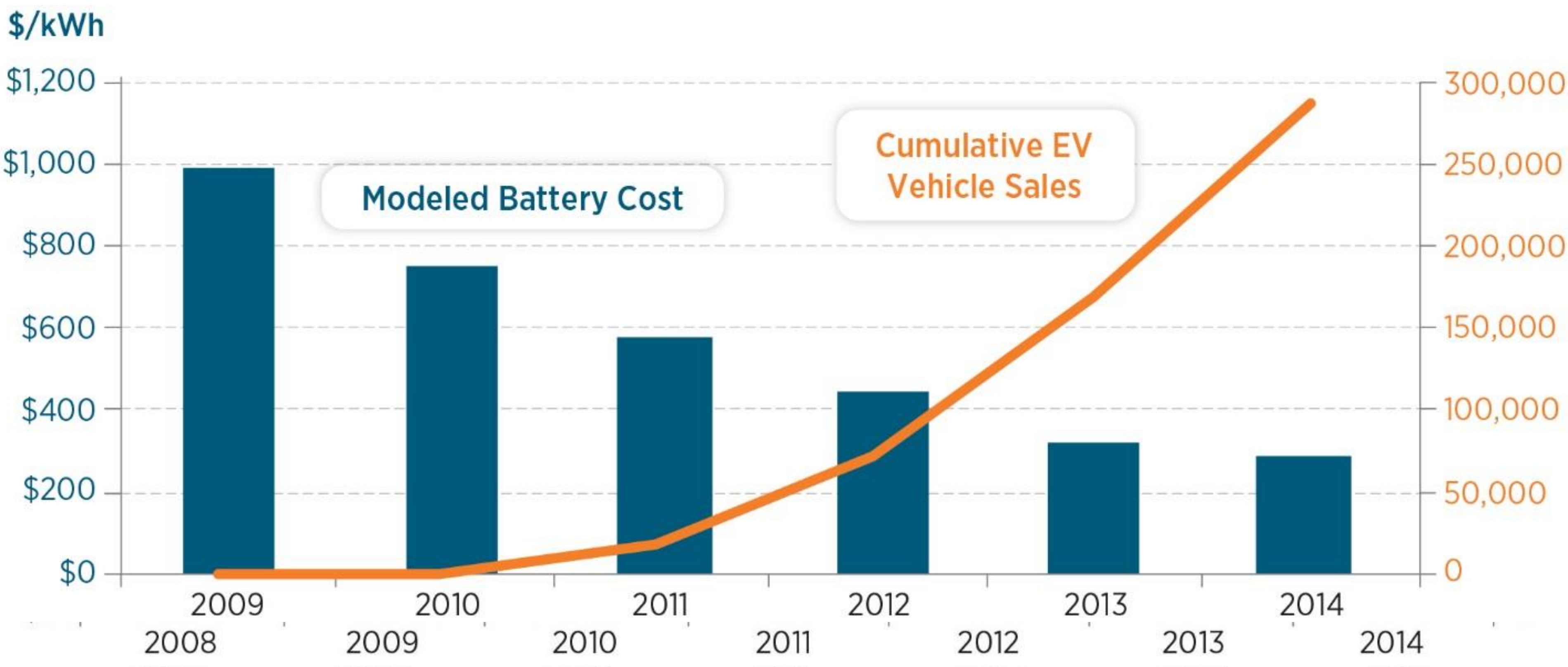
Changes in the Energy Landscape



The Energy Challenge

Economic Security:

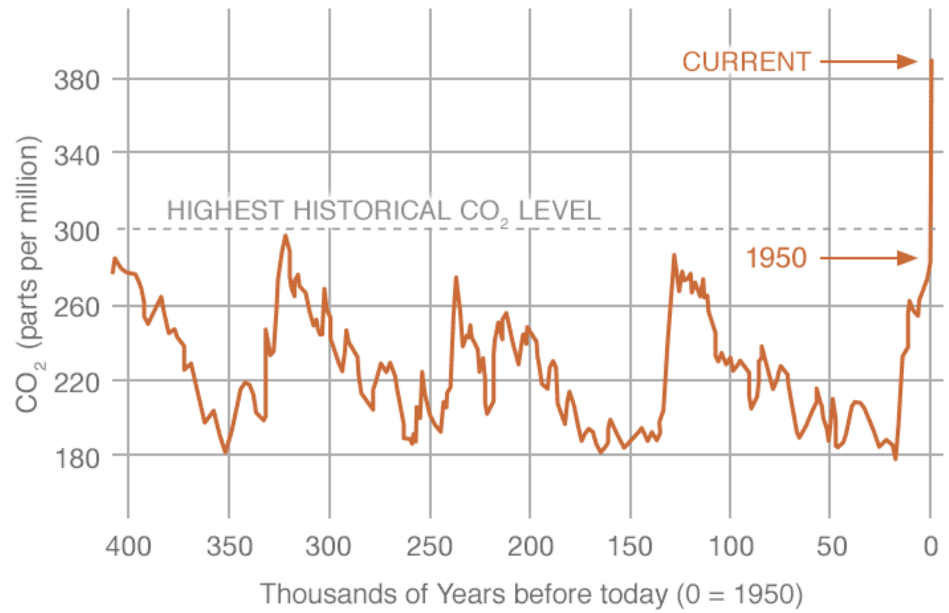
Cost efficient energy systems

Environmental Security:

Much lower GHG emissions and other pollutants

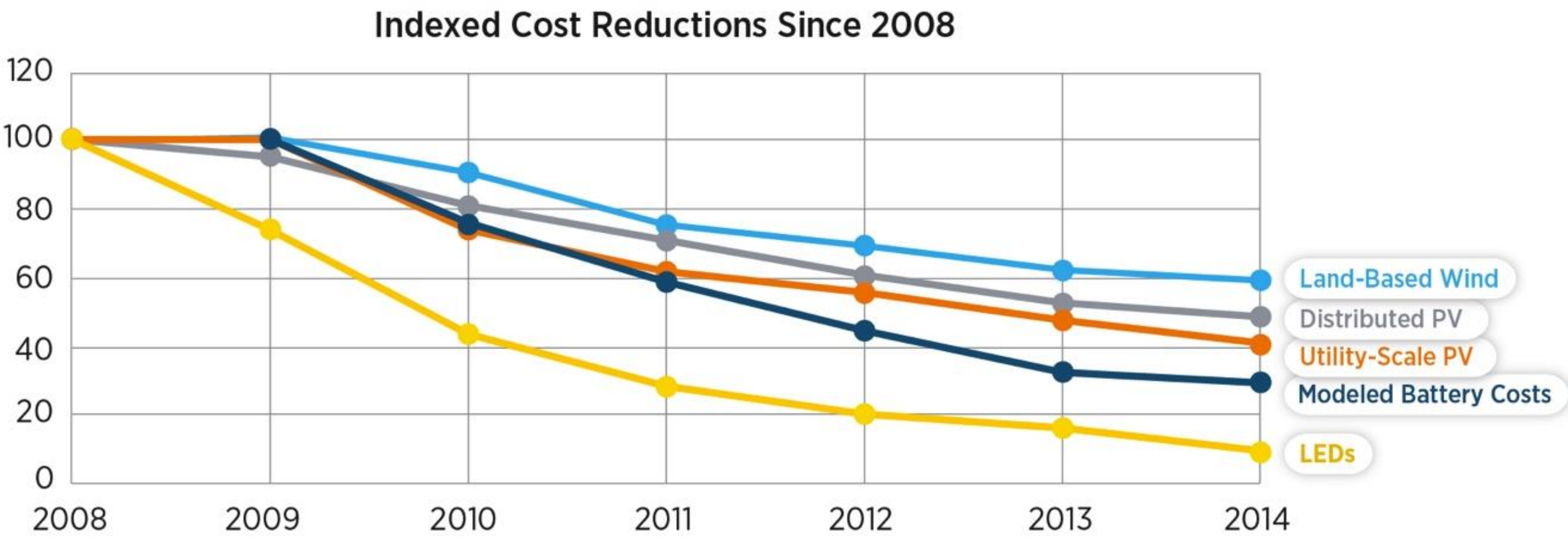
Energy Security:

Multiple supply options and are robust and resilient

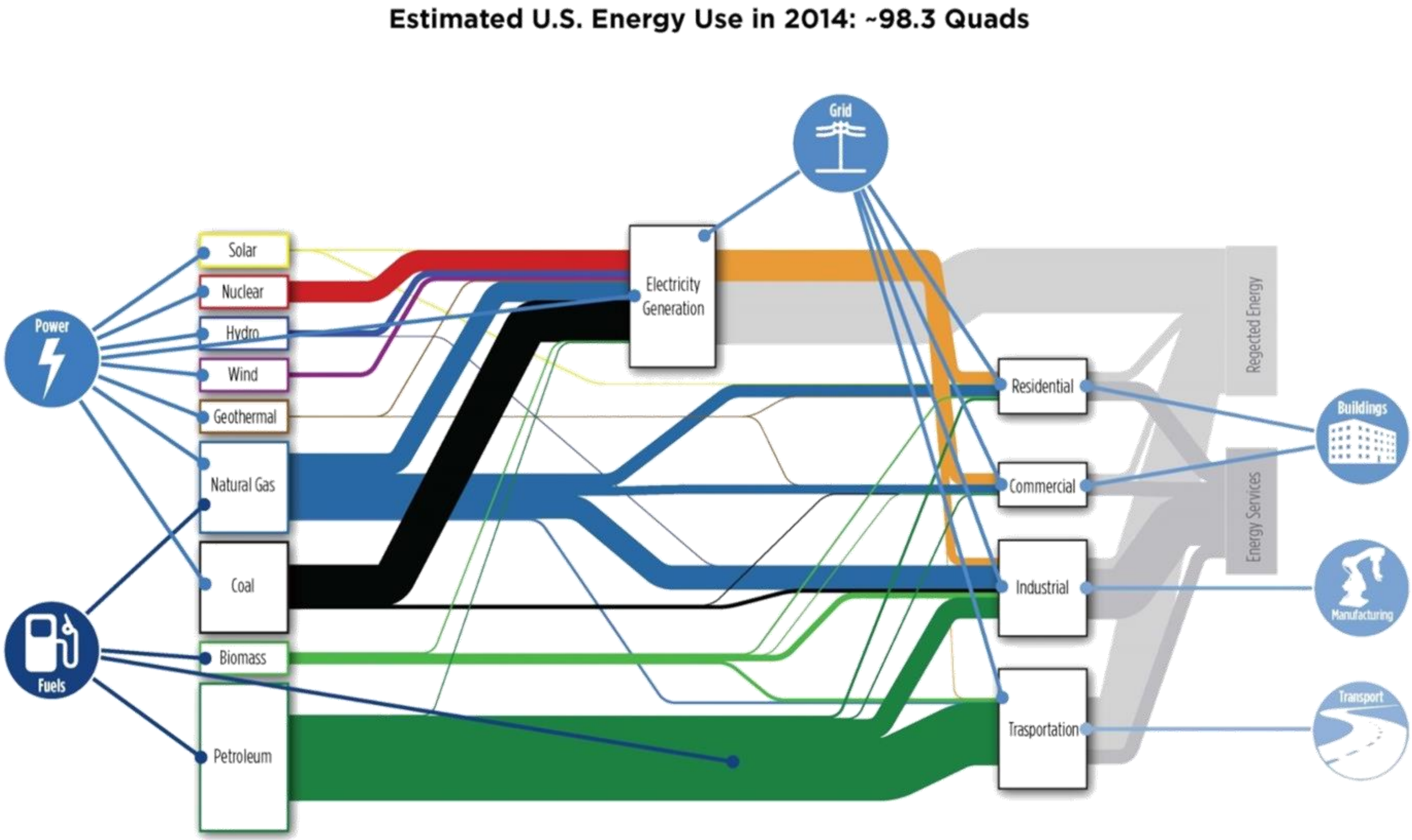


Opportunity: Create and manage linked, complex systems that deal with all three challenges

Learning Curves for Selected Technologies



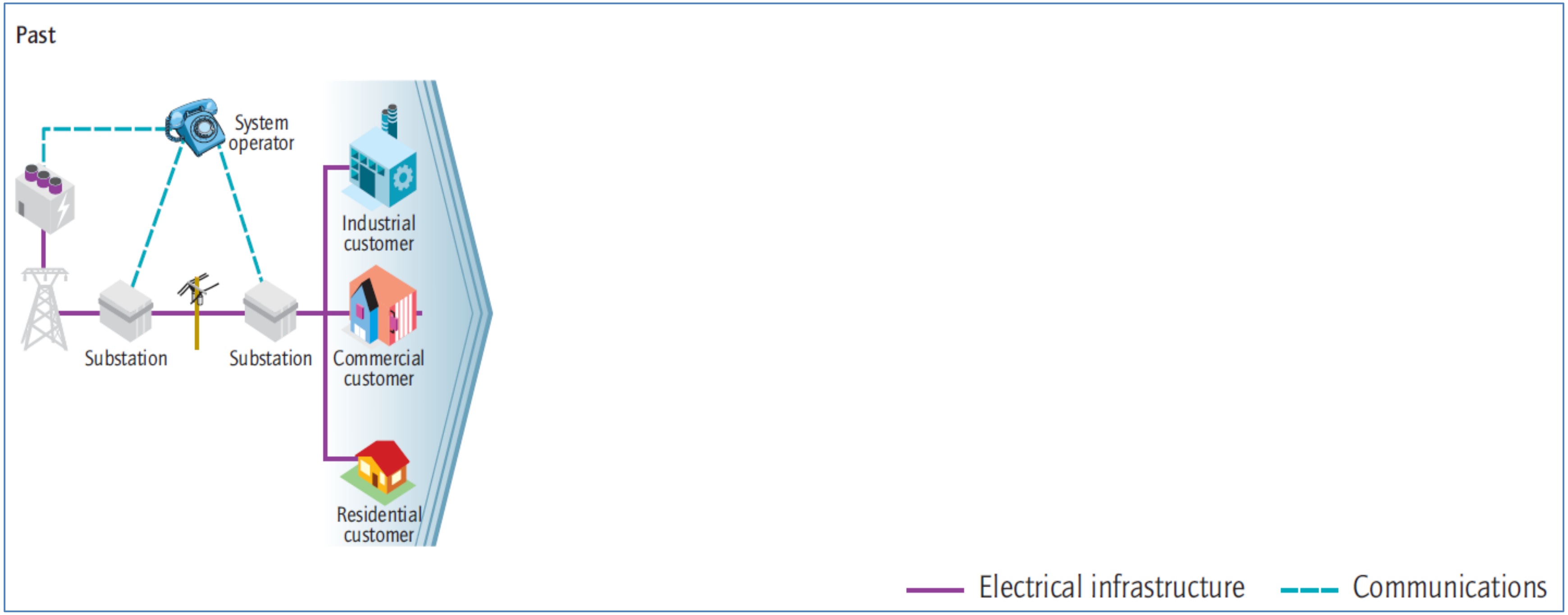
The U.S Energy System—Linkages



The Grid

The Future Grid Differs Radically from the Present

Characterized by More Flexibility and Agility: Prevent local disturbances from spreading, and recover more quickly from storm disruptions



Graphic Source: International Energy Agency

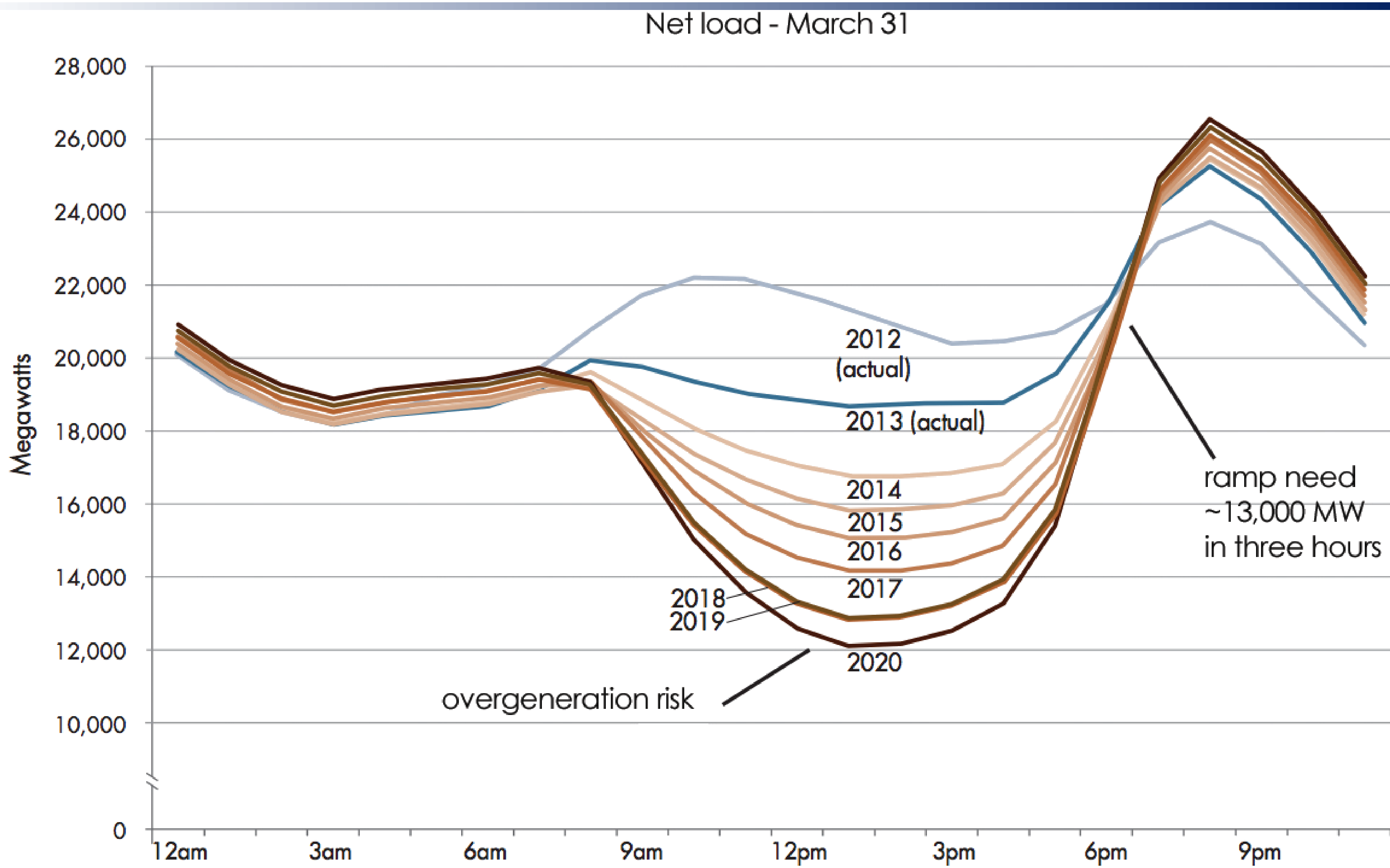
Historical

- *Operator-Based Grid Management*
- *Centralized Control*
- *Off-Line Analysis / Limit Setting*

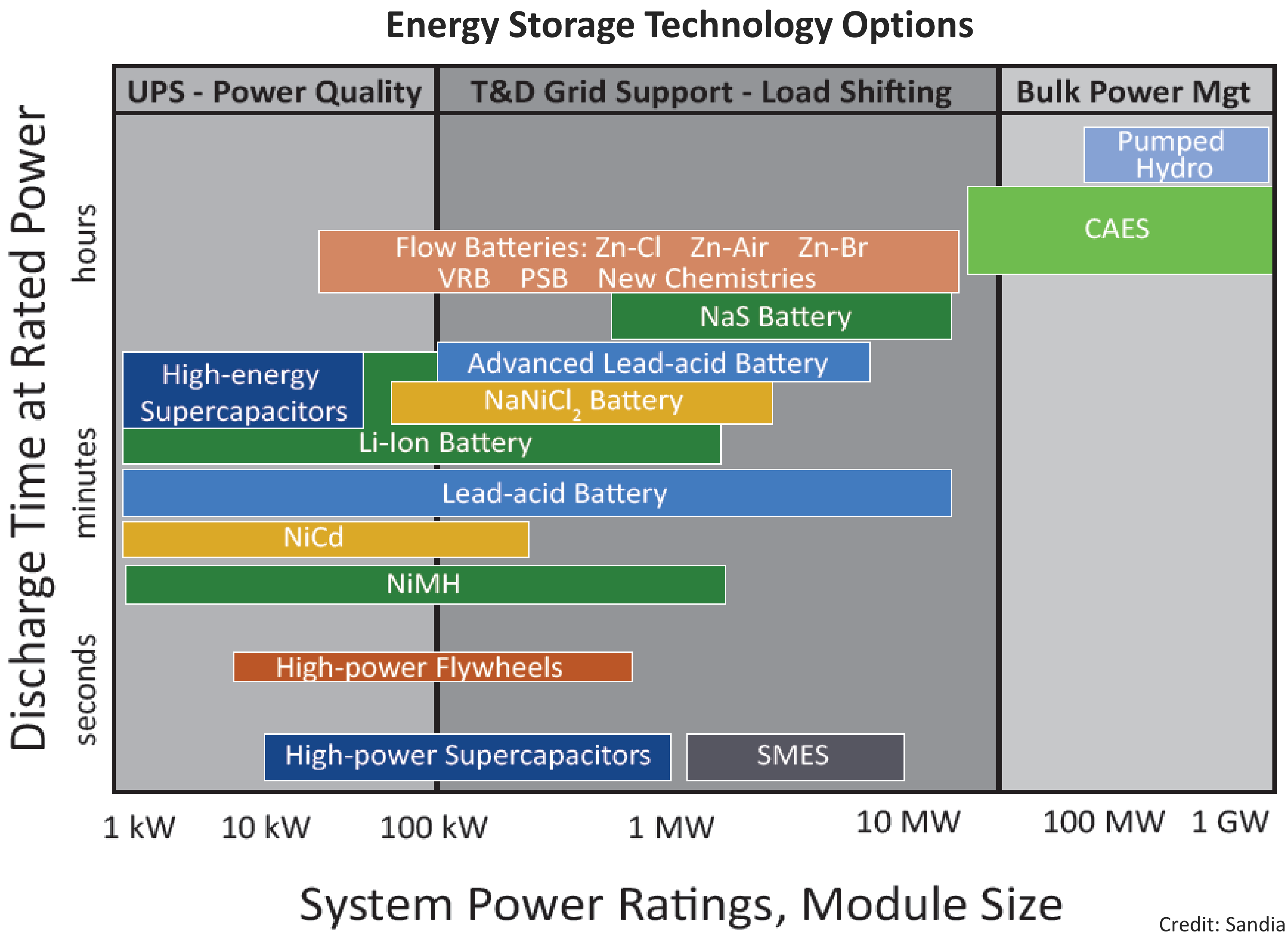
Emerging

- *Flexible and Resilient Systems*
- *Sensors and Data Acquisition*
- *Algorithms and Computer Infrastructure*
- *Multi-Level Coordination / Precise Control*
- *Faster-than-Real-Time Analysis*

Integration of Intermittent Renewables



Energy Storage



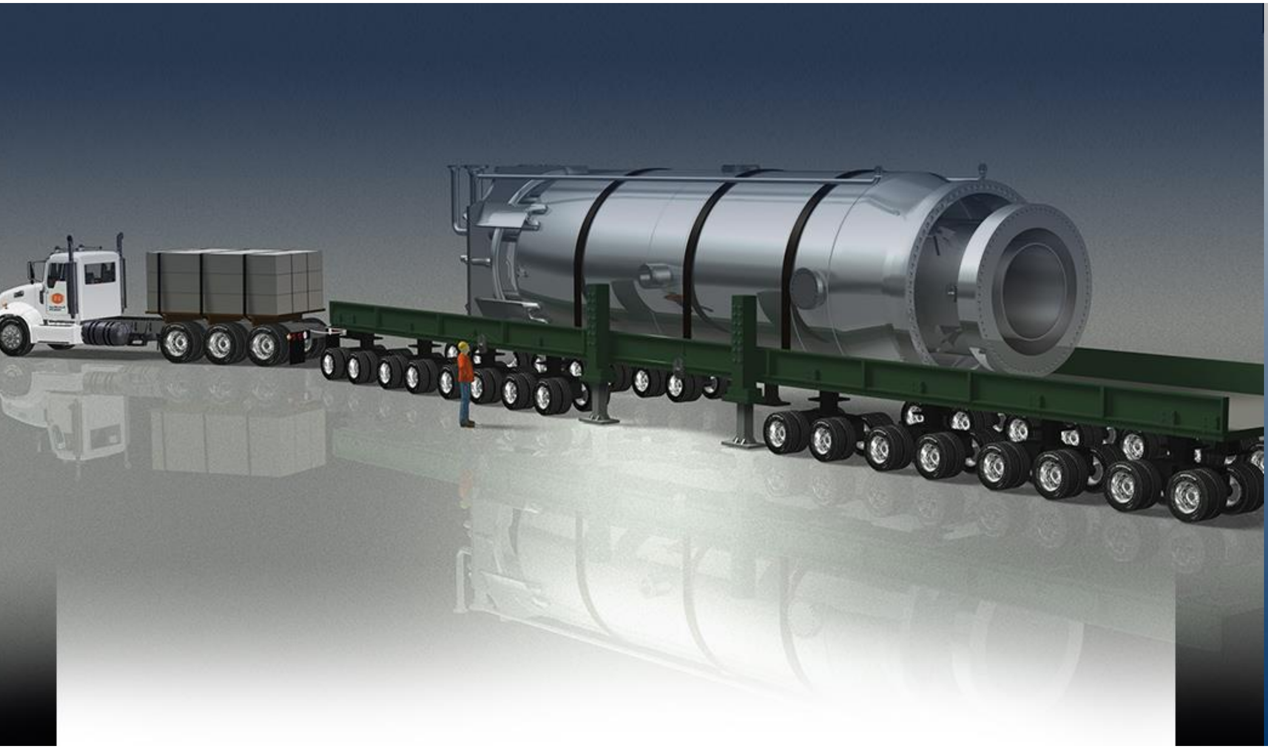
Credit: Sandia Laboratory

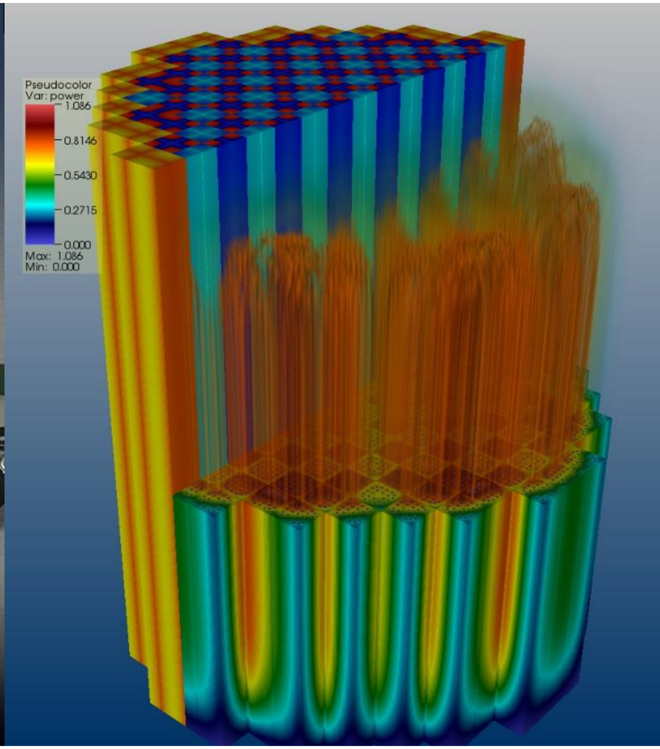
Clean Electric Power

Carbon Capture and Storage

Optimizing CO2 Compression on Titan

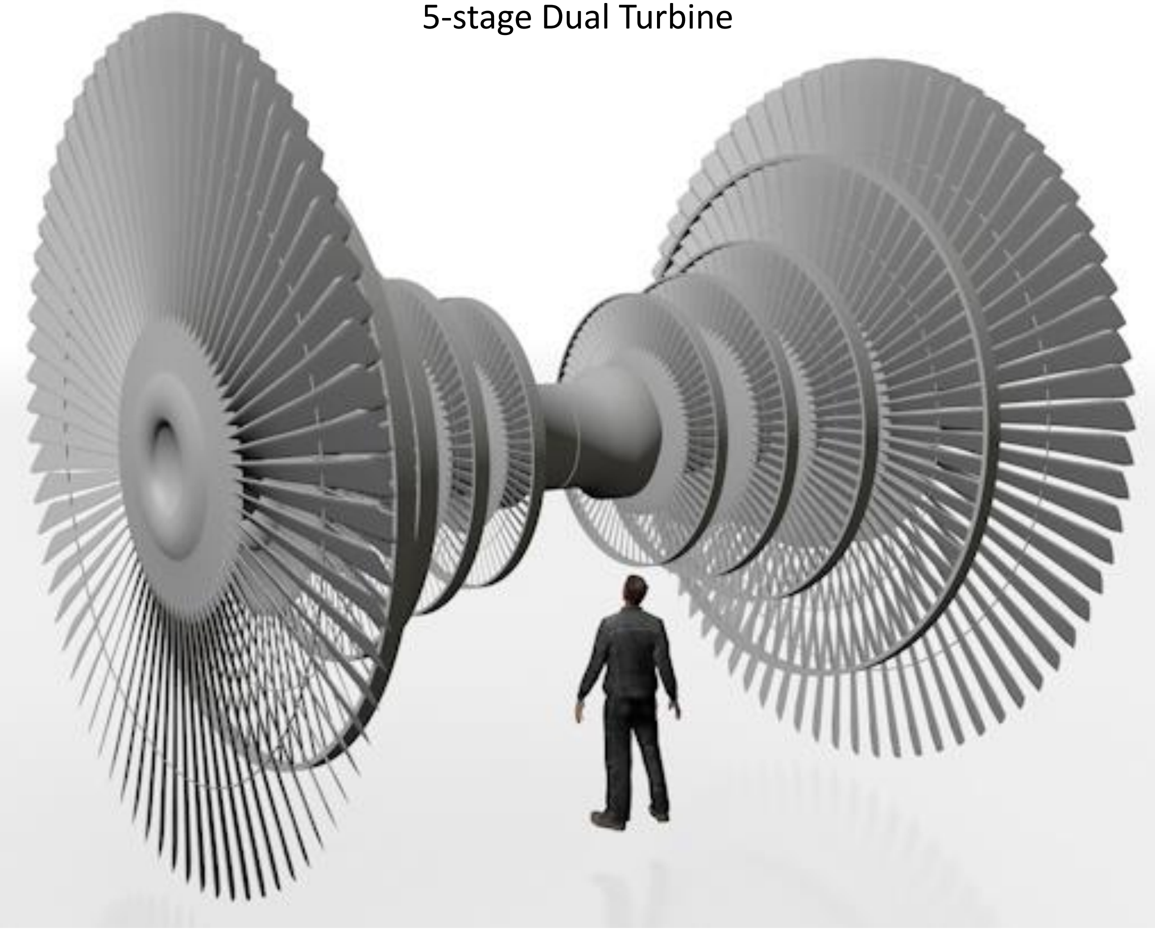
Nuclear Power





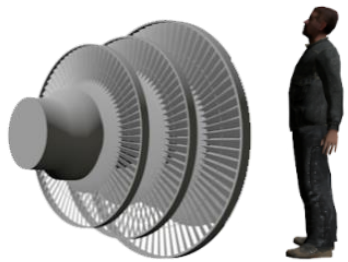
Supercritical CO_2 – Brayton Cycle

5-stage Dual Turbine



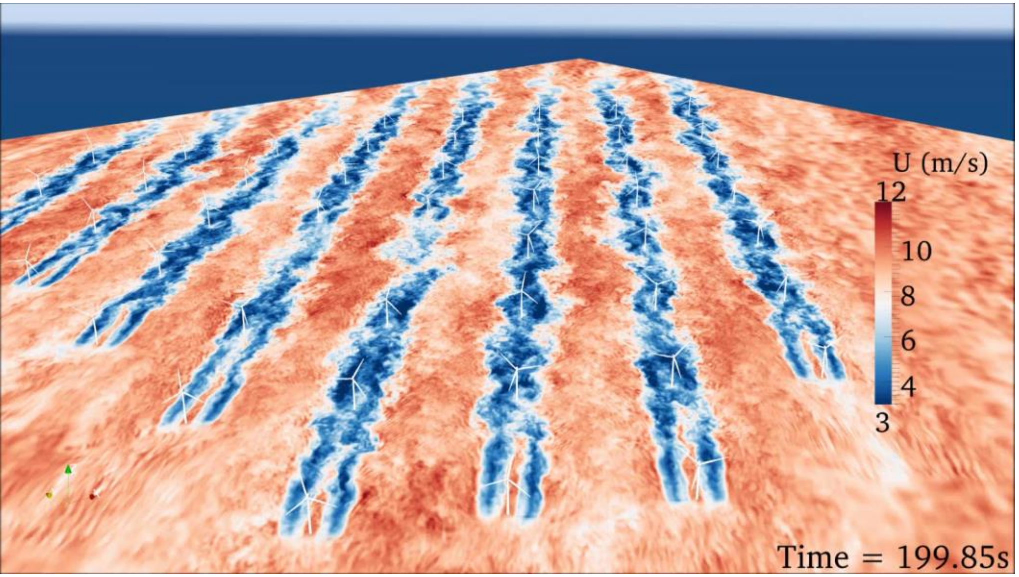
20 meter Steam Turbine (300 MWe)
(Rankine Cycle: ~33% efficient)

3-stage Single Turbine



1 meter sCO_2 (300 MWe)
(Brayton Cycle: > 40% efficient)

Wind Power

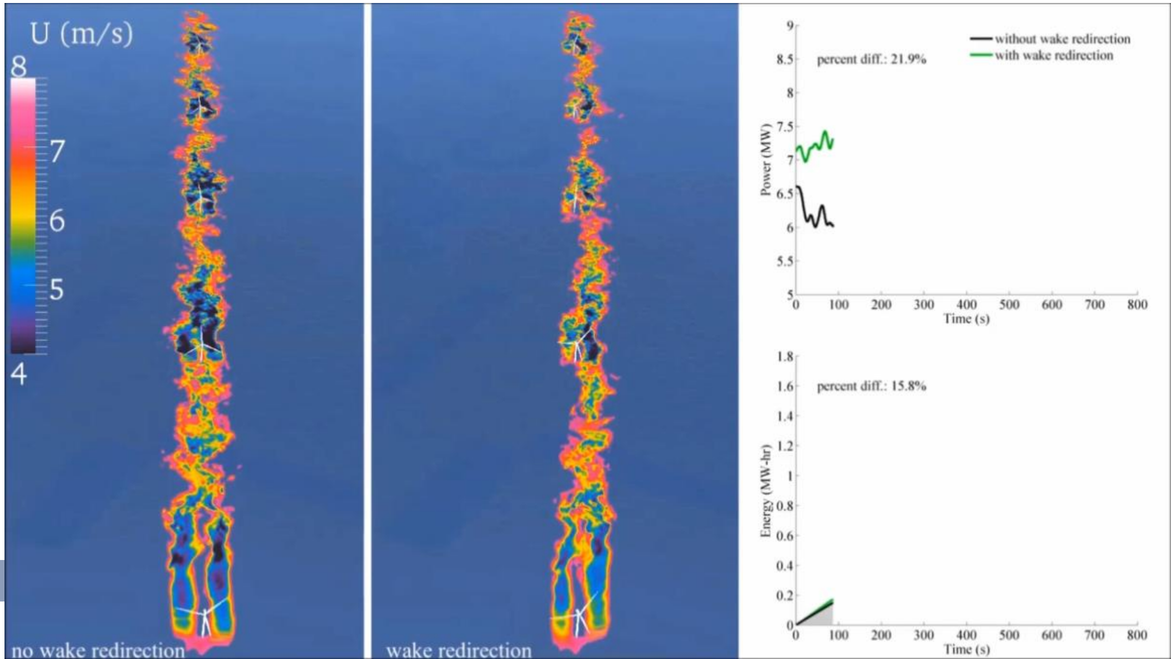


Lillgrund Offshore Wind Plant

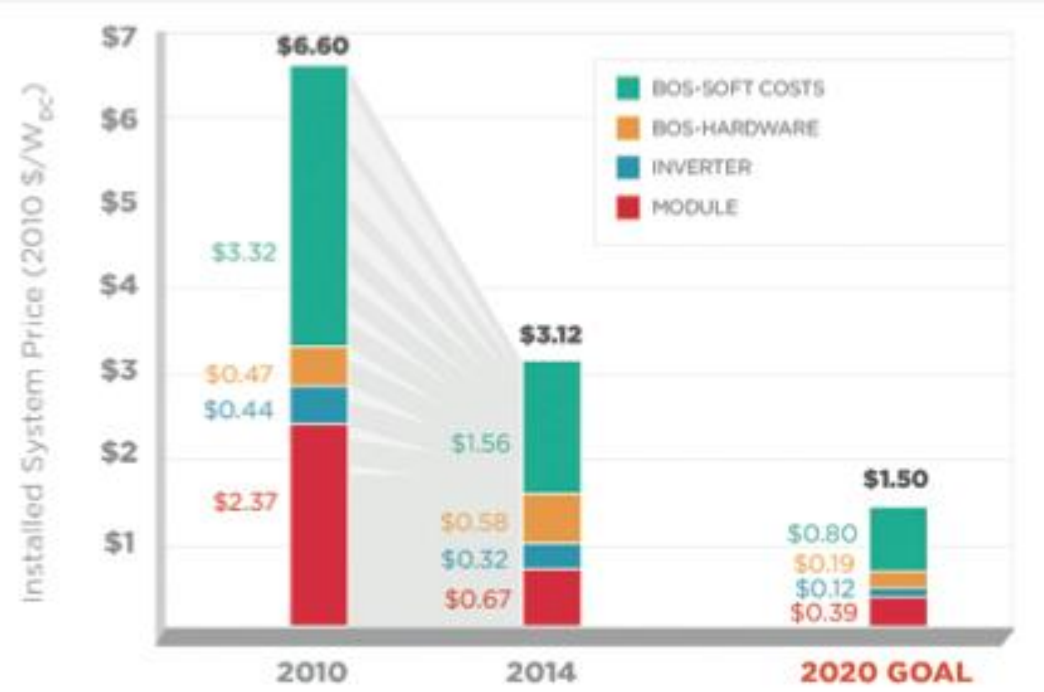
- 48 turbines
- State of the art limited to simplified blade models & flat terrain

Wake-Steering Example

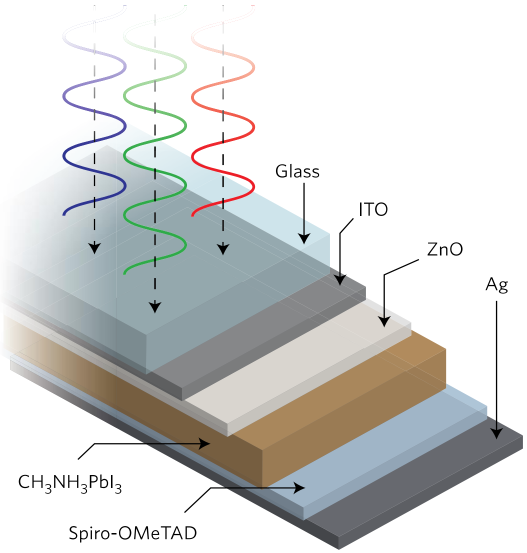
- Redirecting wake away from downwind turbines increases energy capture by 14%



Solar Power



Perovskite efficiencies have increased to > 20% in only 2 years



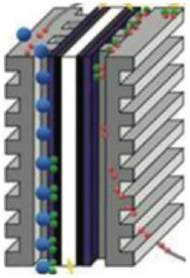
from Liu and Kelly. Nat. Phot. 2013

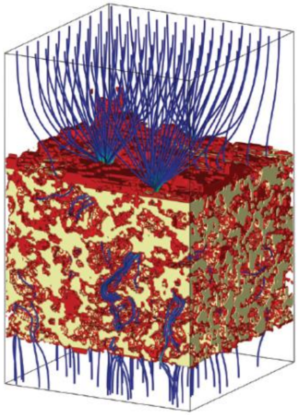
Clean Transportation and Vehicle Systems

Advancing Clean Transportation and Vehicle System Technologies

Figure 8.6 Complex In-cylinder Flow During Intake Stroke in Diesel Engine[23]

- Combustion efficiency
- Co-optimization of fuels and engines
- Lightweighting
- Plug-in electric vehicles (PEVs)
- Fuel cell electric vehicles (FCEVs)
- Other modes (e.g., air, rail, and marine)
- Connected and automated vehicles
- Transportation systems





Advanced Manufacturing


IMTS
2014


Oak Ridge National Laboratory
Department of Energy
Oak Ridge National Laboratory

Enabling Science

Understanding and Controlling Matter at the Atomic Scale

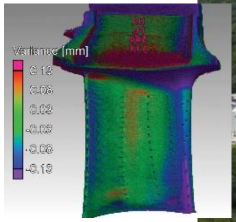
Unique, cutting-edge experimental tools for characterization, discovery, and synthesis of novel materials and energy systems.

X-ray light sources provide a range of wavelengths capable of probing structures as small as atoms to whole cells and beyond.

- LCLS-II and APS-U will provide higher energy and brighter beams.
- Instrument development brings NSLS-II's world-leading beam brightness to more experiments.

Neutron sources are uniquely suited to non-destructive 3D structure determination of real systems.

- The SNS Second Target Station would enable new science in condensed matter, structural biology, and energy materials.



Nanoscale Science Research Centers integrate theory, synthesis, fabrication, and characterization of novel nanomaterials

- New capabilities in *in operando* electron microscopy and accelerator-based nanoscience.
- Novel fabrication techniques in combinatorics and self-assembly.

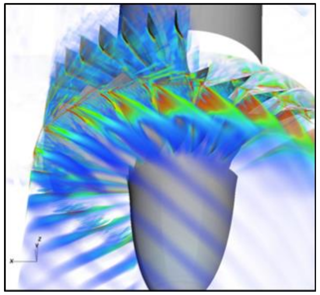
On-going research, development, and upgrades for facilities opens new frontiers in materials characterization (real systems in real time).

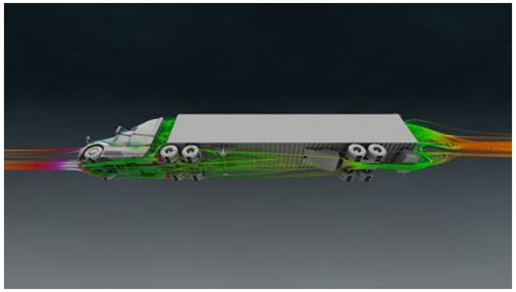
Modeling and Simulation of Complex Phenomena

Accelerating discovery through modeling and simulation of real systems.

- DOE and SC supported supercomputers enable simulation of complex real-world phenomena, putting true "systems-by-design" in reach.
- The *Office of Advanced Scientific Computing Research* supports this push to modeling and simulation of real systems through parallel development of hardware, software, and skilled personnel.
  - *Leadership-class computers*
  - *Production-class computers*
  - *Energy Sciences Network*
- DOE computers - enabled through dedicated outreach from the laboratories - have an enormous impact across the engineering and manufacturing space.
- The development needs of *exascale* computing – hardware, software, and efficiency – are being supported through *co-design* centers.

Name	Performance (pflops/s)	Laboratory
Titan	17.6	Oak Ridge
Mira	8.60	Argonne
Cascade	2.53	Pacific Northwest
Edison	1.65	Lawrence Berkeley (NERSC)
Hopper	1.05	Lawrence Berkeley (NERSC)
Red Sky	0.43	Sandia/NREL





Conclusions

- Considerable progress has been made in energy technologies, but much more remains to be done
- There exists a very wide-ranging opportunity space, for individual technologies and for improved systems
- A portfolio approach is required: fully stocked across primary energy resources, conversion technologies, systems, and time scales for application, with efficiency everywhere
- Enabling science and computing are essential to our energy future success

Energy is the Engine of the Economy

Vast and complex
Touches Everything
Concurrent daunting challenges
in the Face of stunning global growth
A wide range of options exists for future progress