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Disrupting Our Way to a Sustainable Energy Future

May 5, 2015

Council for Chemical Research

Alexandria, Virginia







Hurricane Sandy, 2012

Today's energy system is largely one way



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Generation

Transmission

Distribution

End use

Generation has evolved

Base



Intermittent



Storage

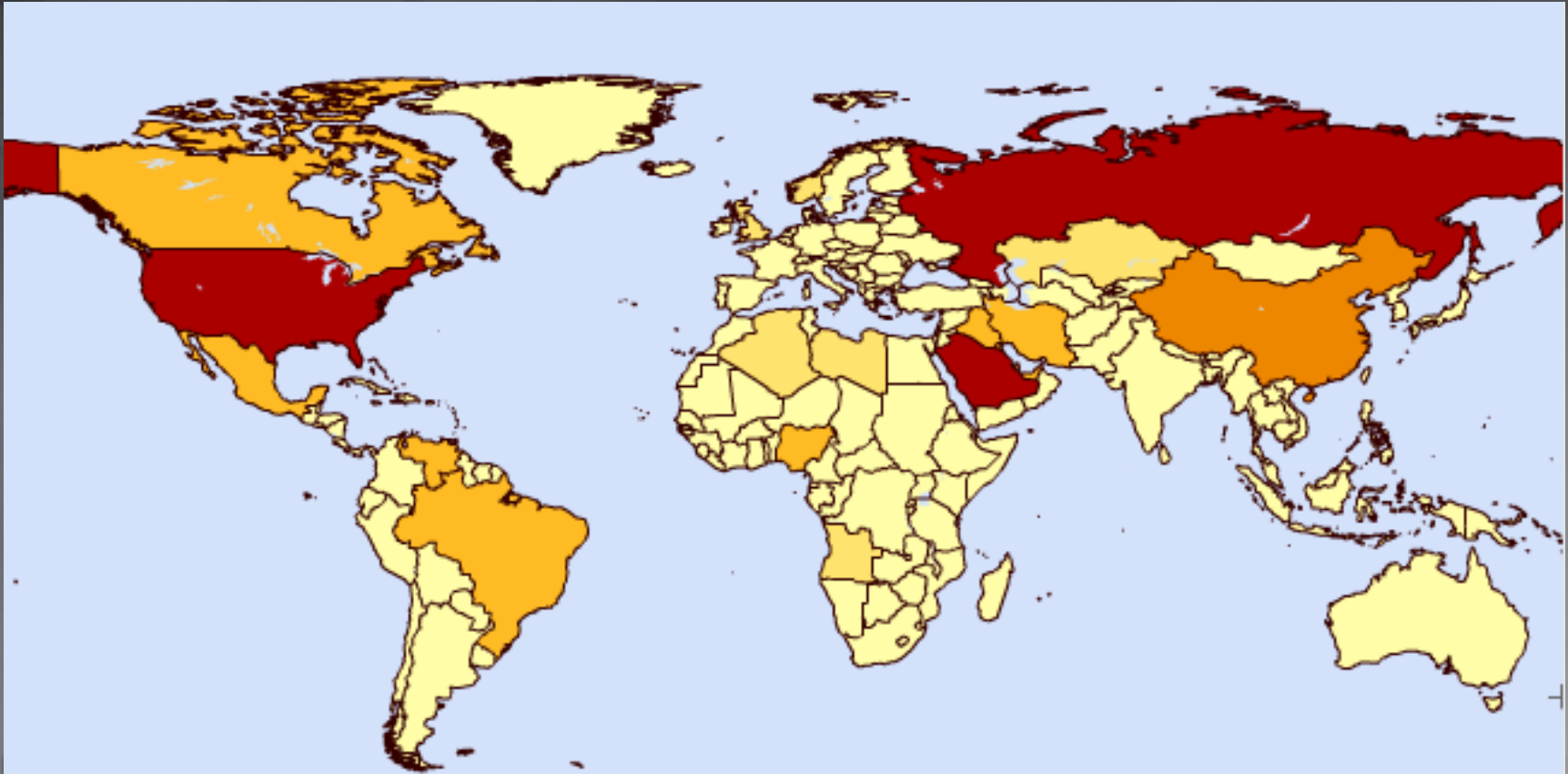


With technology advances, U.S. is now the world's leading oil producer



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Top World Oil Producers (2013)

1 United States

2 Saudi Arabia

3 Russia

4 China

5 Canada

6 United Arab Emirates

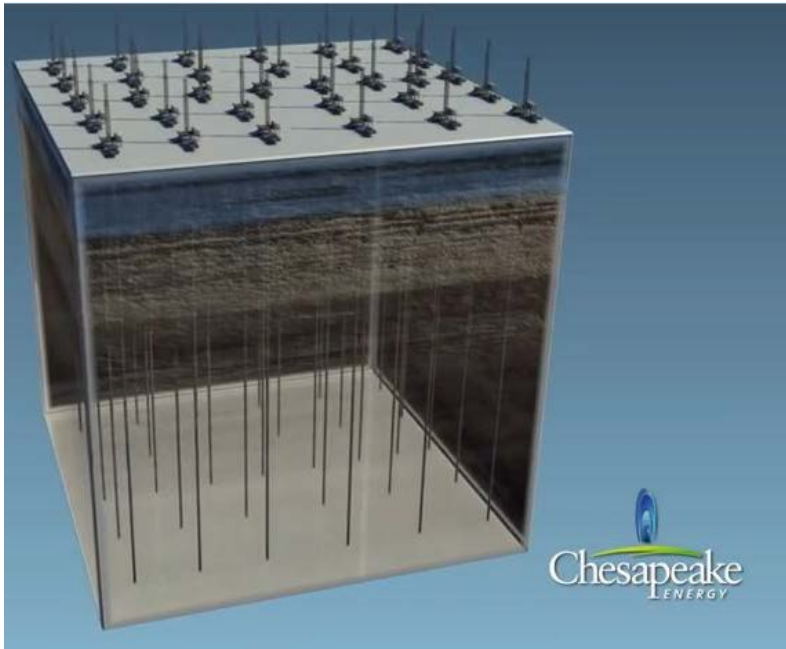
7 Iran

8 Iraq

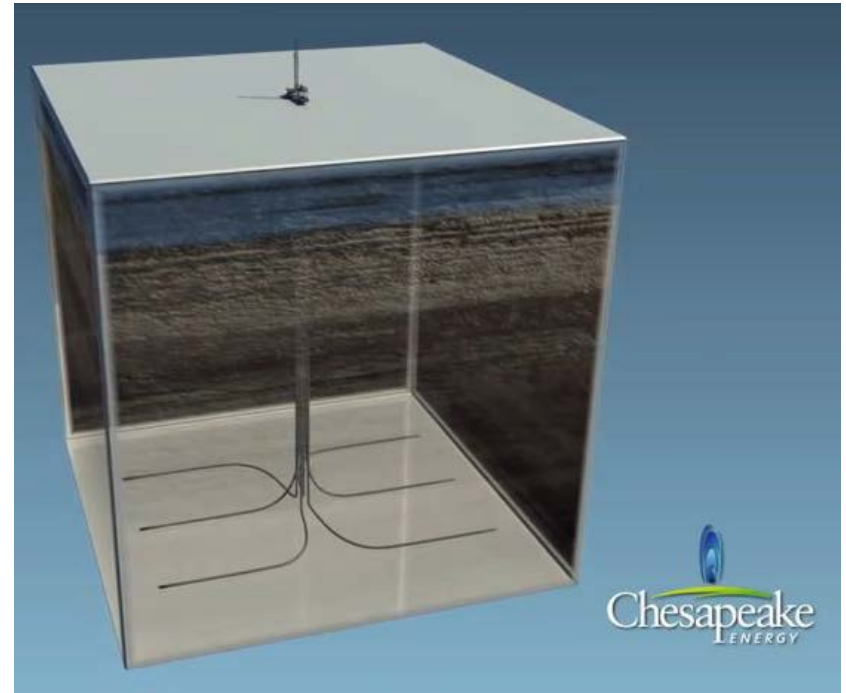
9 Mexico

10 Kuwait

Horizontal drilling: the key disruptive technology behind this change



\$100/barrel



\$60/barrel



Image: Halliburton

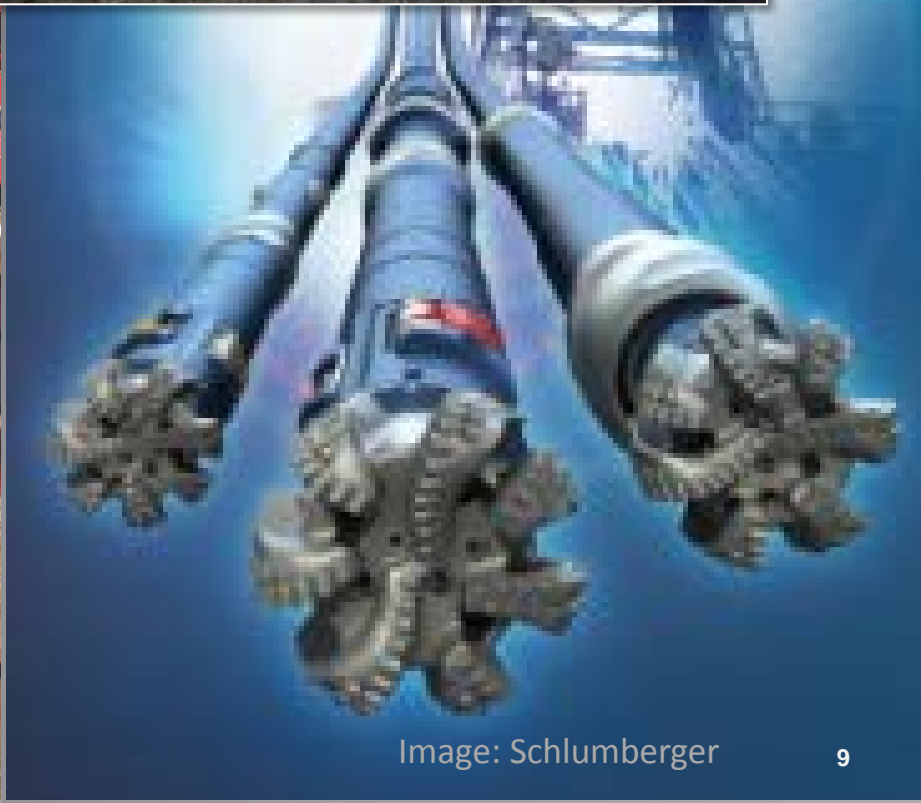


Image: Schlumberger

Thin-film solar voltaics have disrupted solar energy



Solar farms

Conversion rate before 2008: 10%

Now: 22-24%

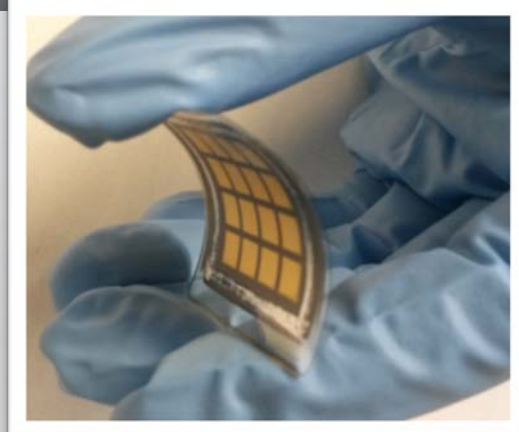


Image: Dow

Solar shingles

Not widely used before 2008

Conversion rate now: 19-20%





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Finding energy in surprising places



Image: Lucid Energy

New battery technologies provide grid-scale storage



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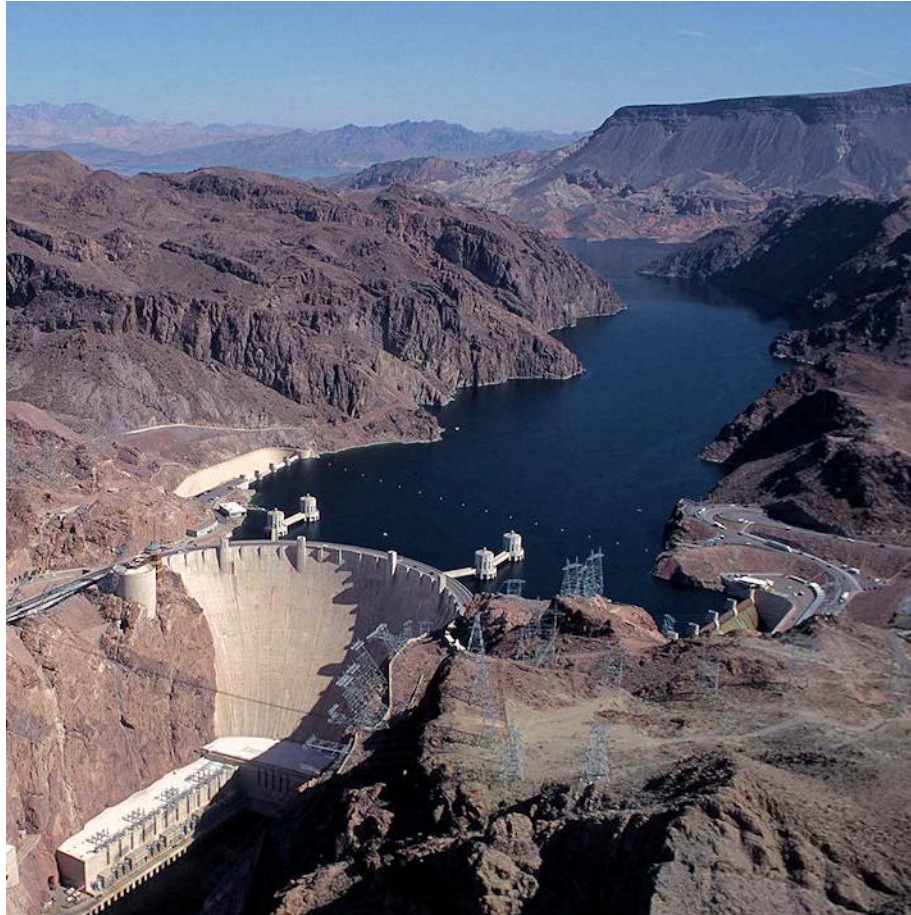
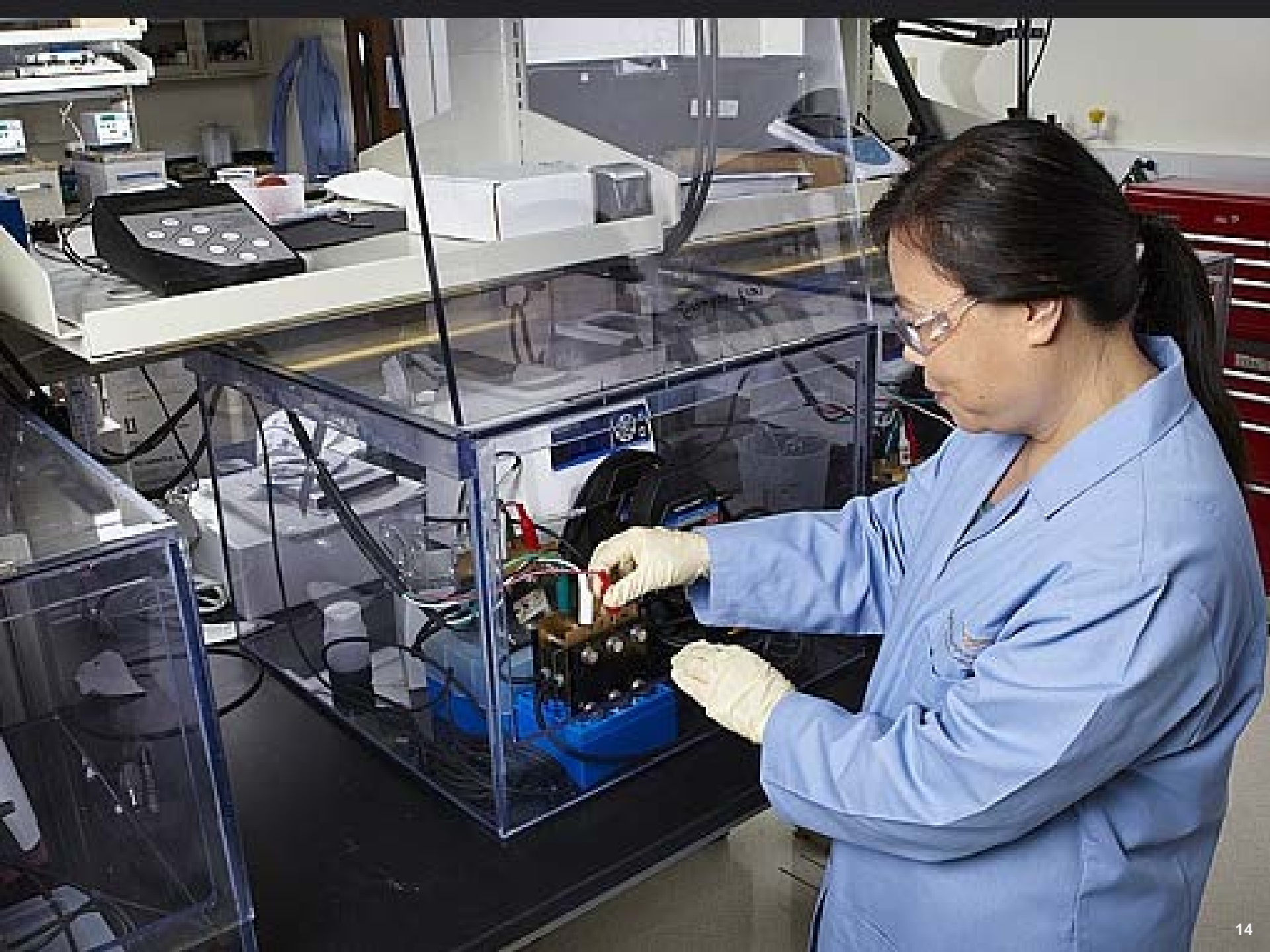


Image: UniEnergy Technologies, Inc.



The amount of energy **wasted** by the US economy in 2012...



could power the United Kingdom for **7 years**.

Lighting technologies are dramatically increasing efficiency

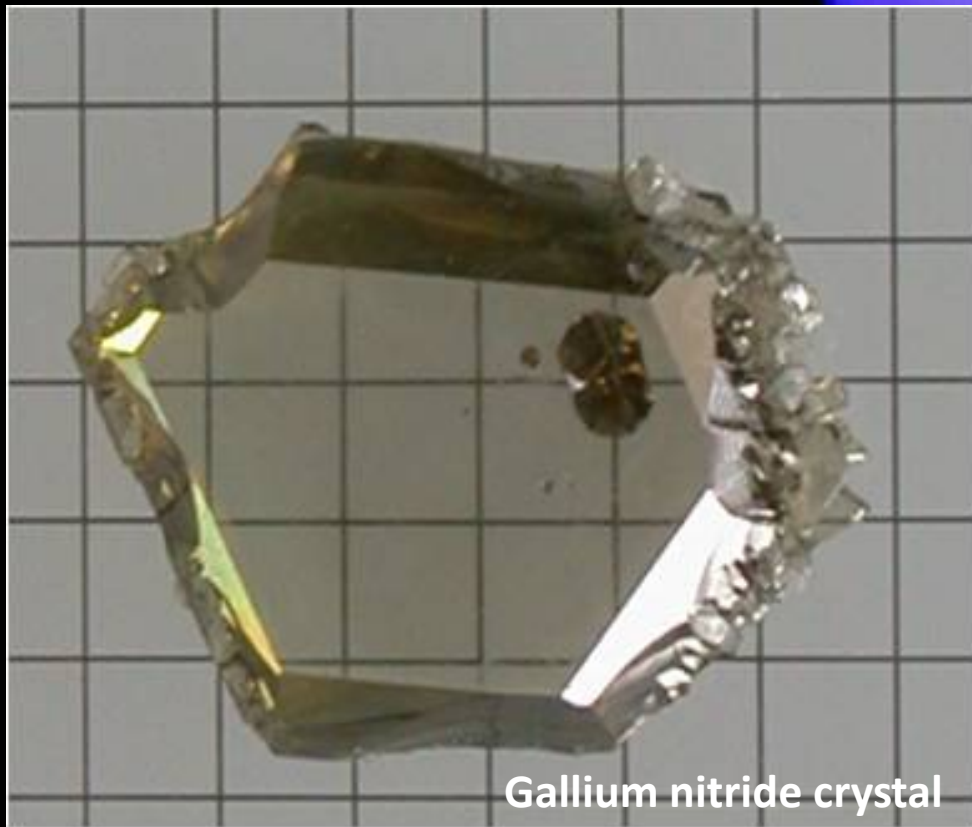


Efficiency: 10%

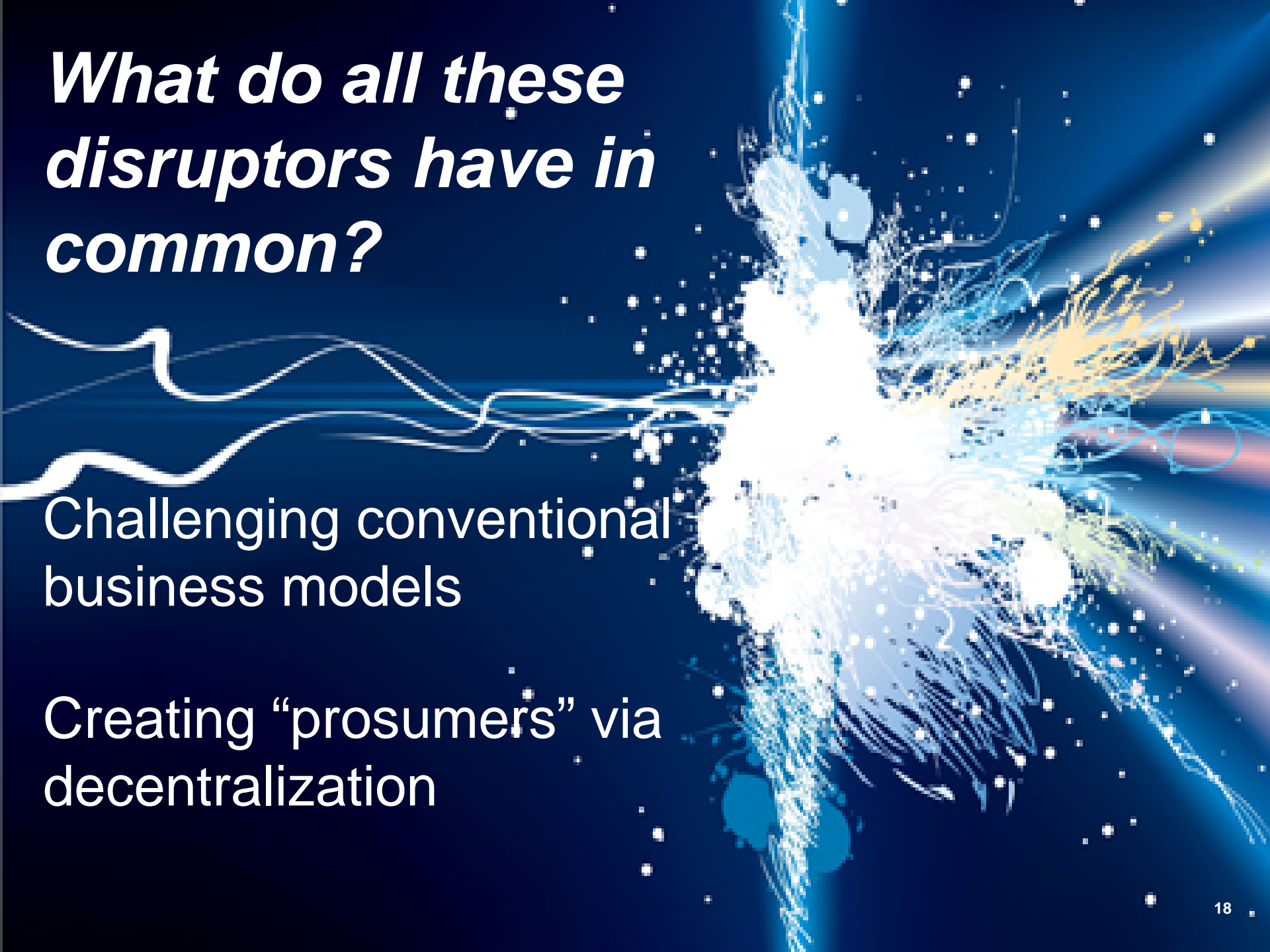


Image: Philips North America

Efficiency: up to 50%



Gallium nitride crystal



***What do all these
disruptors have in
common?***

Challenging conventional
business models

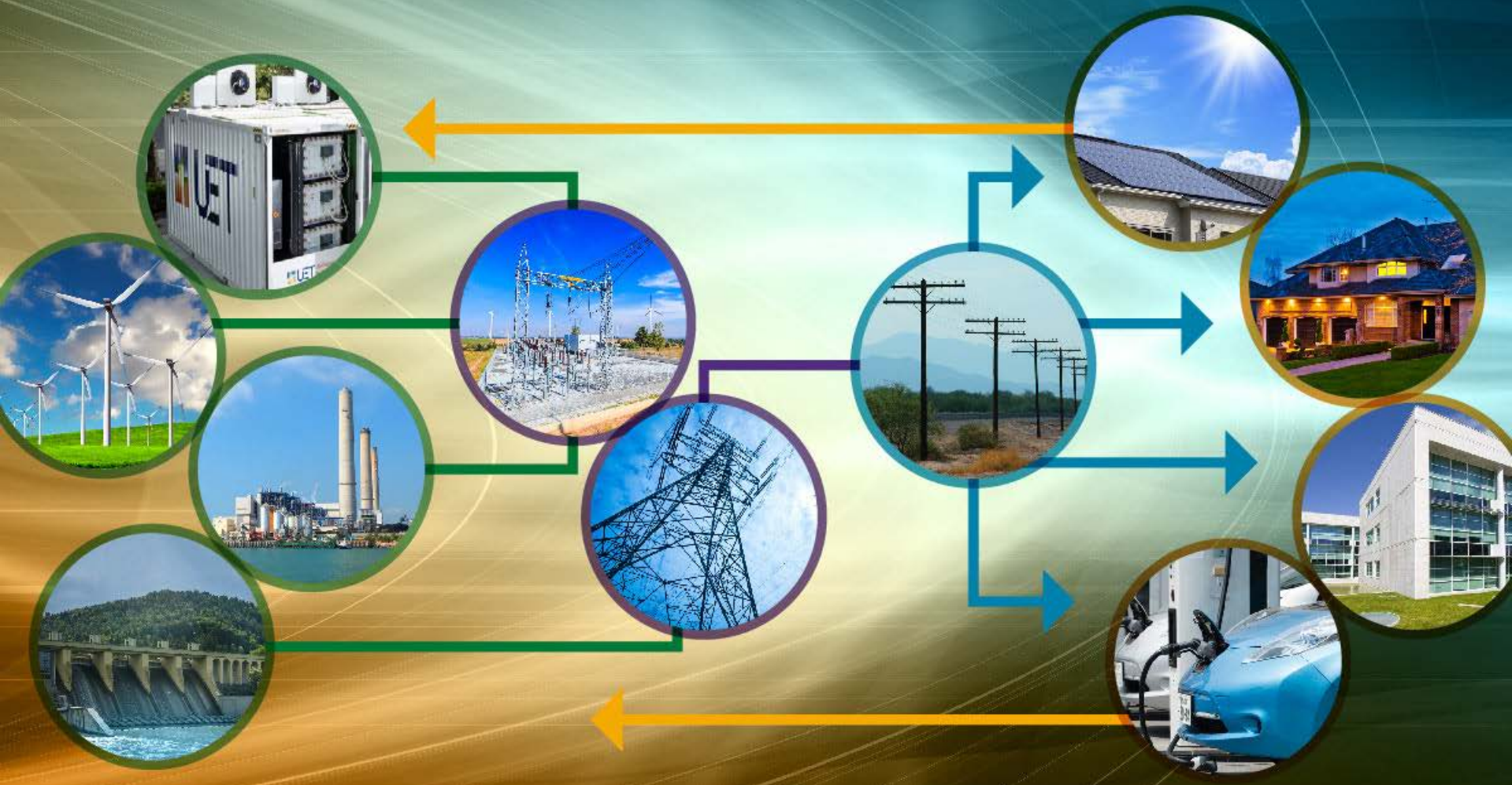
Creating “prosumers” via
decentralization

Future energy system will be two-way



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Research Enabled by Battelle Since 1965



Generation

Transmission

Distribution

End use

Characteristics of the future energy system



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Developed, Operated by Battelle, since 2005

Growing
Asset
Stress



Increased
Variable
Generation



More
Dynamic
Market

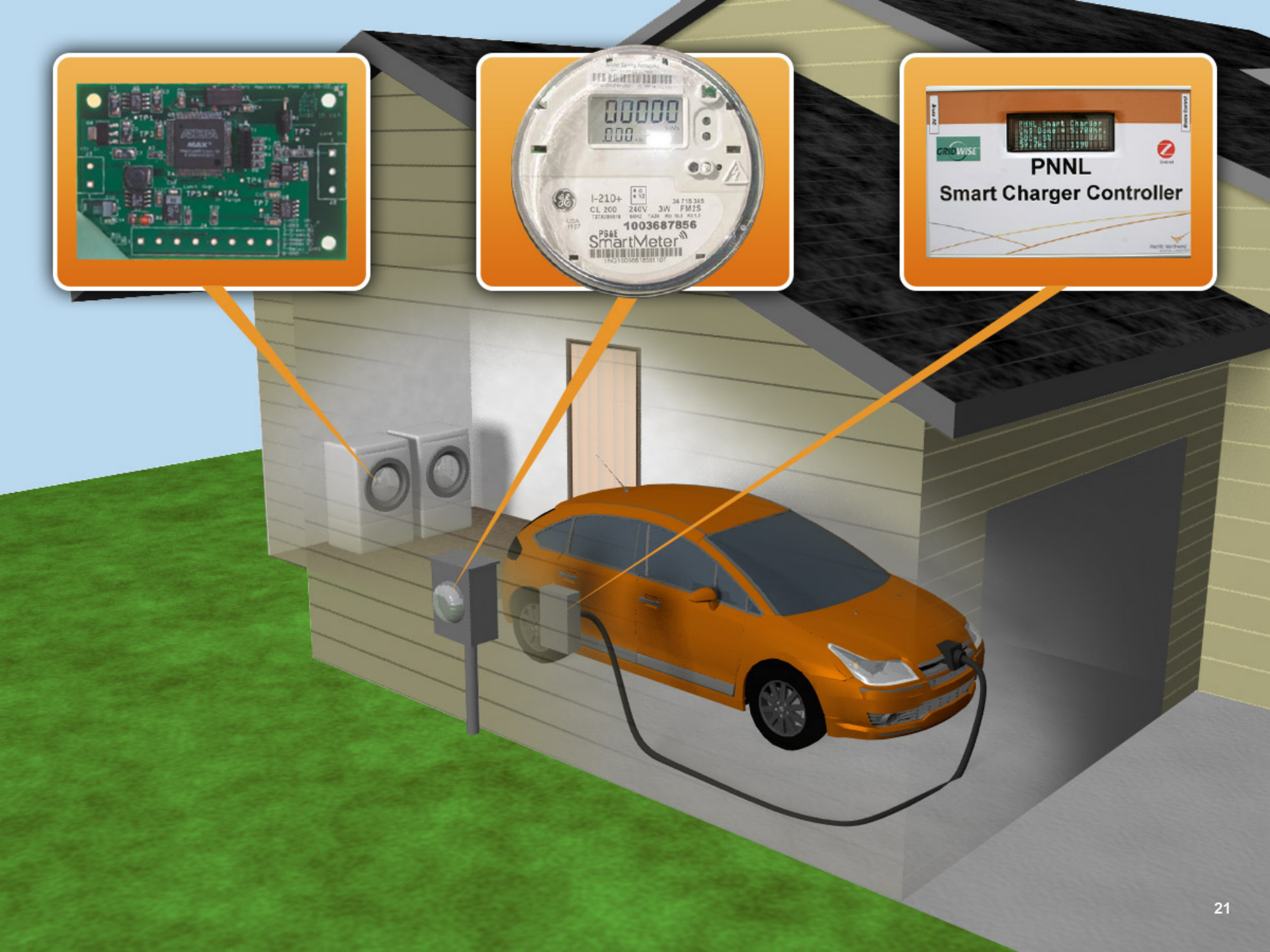
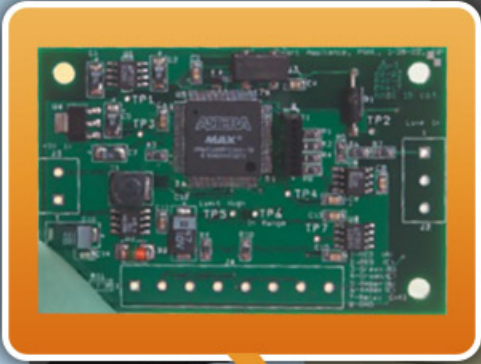


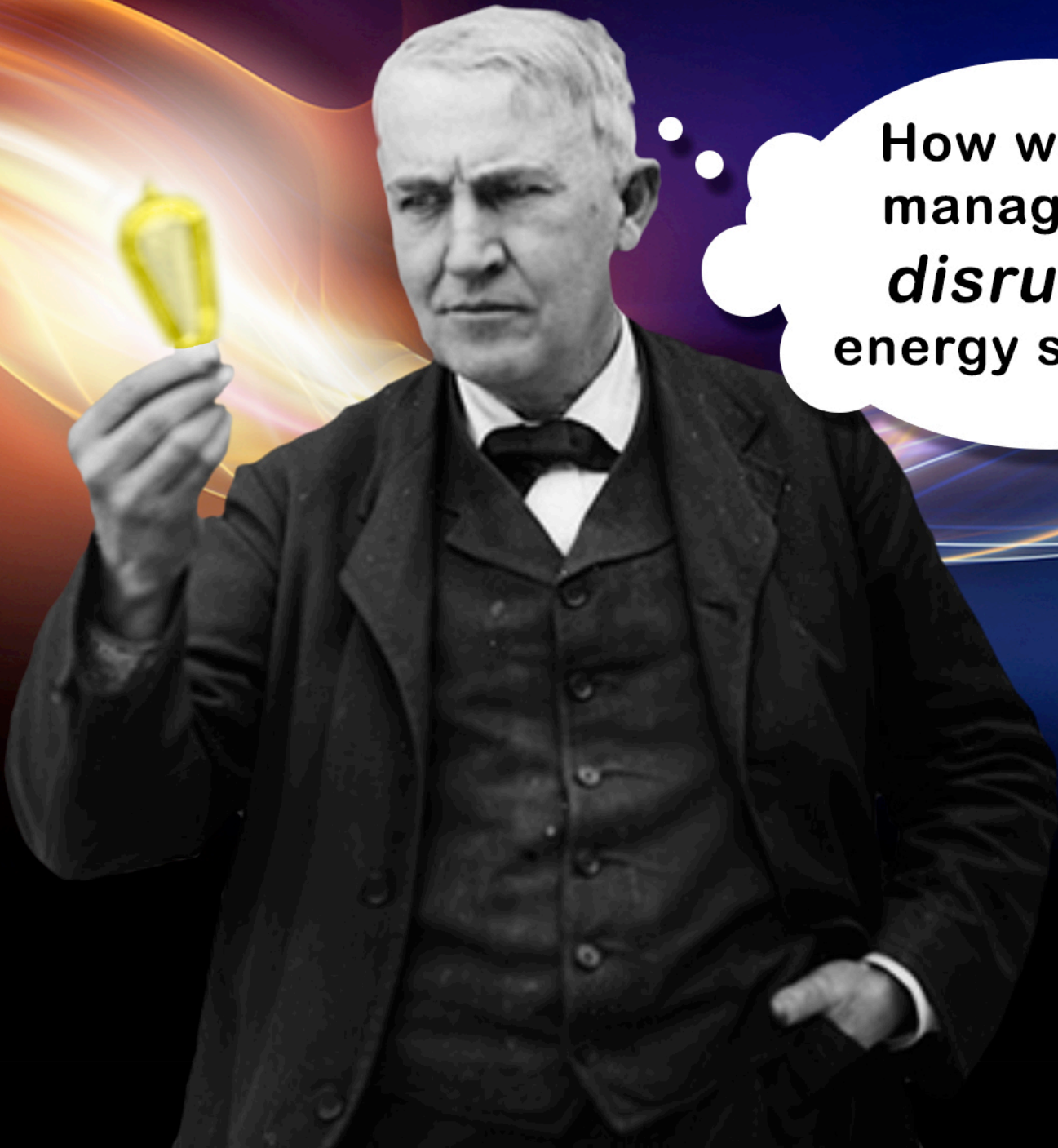
New
Controllable
Assets



Massive
Data







How will we
manage this
disrupted
energy system?

Modernize the Grid



Future power grid must meet new expectations and technical challenges

Historical Expectations

Affordable Power

Reliable Power

Secure Power



Emerging Expectations



Integrate renewable generation



Increase grid-scale storage



Electrify transportation



Dynamic and responsive loads

IT meets ET: Key to realizing full potential of the future power grid



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Data



**Situational
awareness**

Simulation



**Operations and
planning**

Tools



**Real-time
decision support**

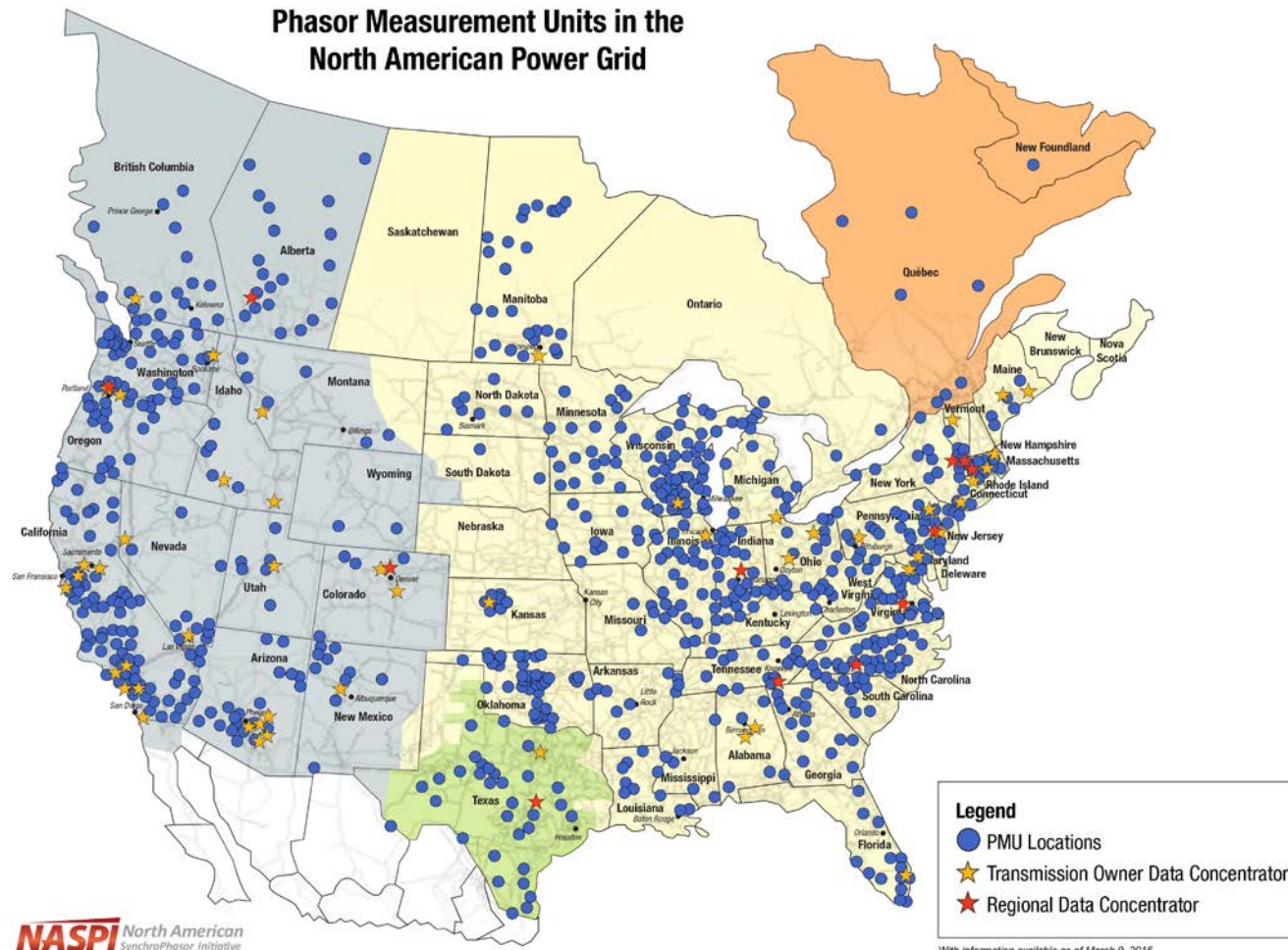
Data

The background features a complex network of white, curved lines that intersect to form a web-like structure. Scattered throughout this network are numerous small, glowing dots in shades of blue and green. Some of these dots are arranged in small clusters or patterns. A dark grey, semi-transparent rectangular box is positioned in the upper-left quadrant, containing the word "Data" in a clean, white, sans-serif font.

Deployment of a vast new sensor network is generating unprecedented real-time data

North American SyncroPhasor Initiative

- ▶ Power companies, utilities, vendors, DOE/labs, and universities
- ▶ High-resolution, time-stamped data



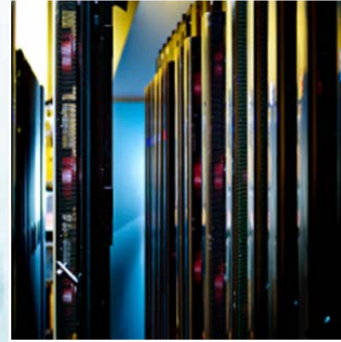
Rich new data streams are transforming grid management



	Today – SCADA data	Tomorrow – Phasor data	Improvement
Variety	voltage + current	+ phase angle	more information
Velocity	1 sample / 4 seconds	30-120 samples / second	~200x faster
Volume	8 terabytes / year	1.5 petabytes / year	~200x more data*
Veracity	unseen ms-oscillations	oscillations seen at 10ms	greater accuracy

Real-time data ingestion from a distributed sensor network with myriad devices

- Cyber-secure sensor network
- Data provenance and privacy
- Real-time ingestion & curation
- Actionable analysis

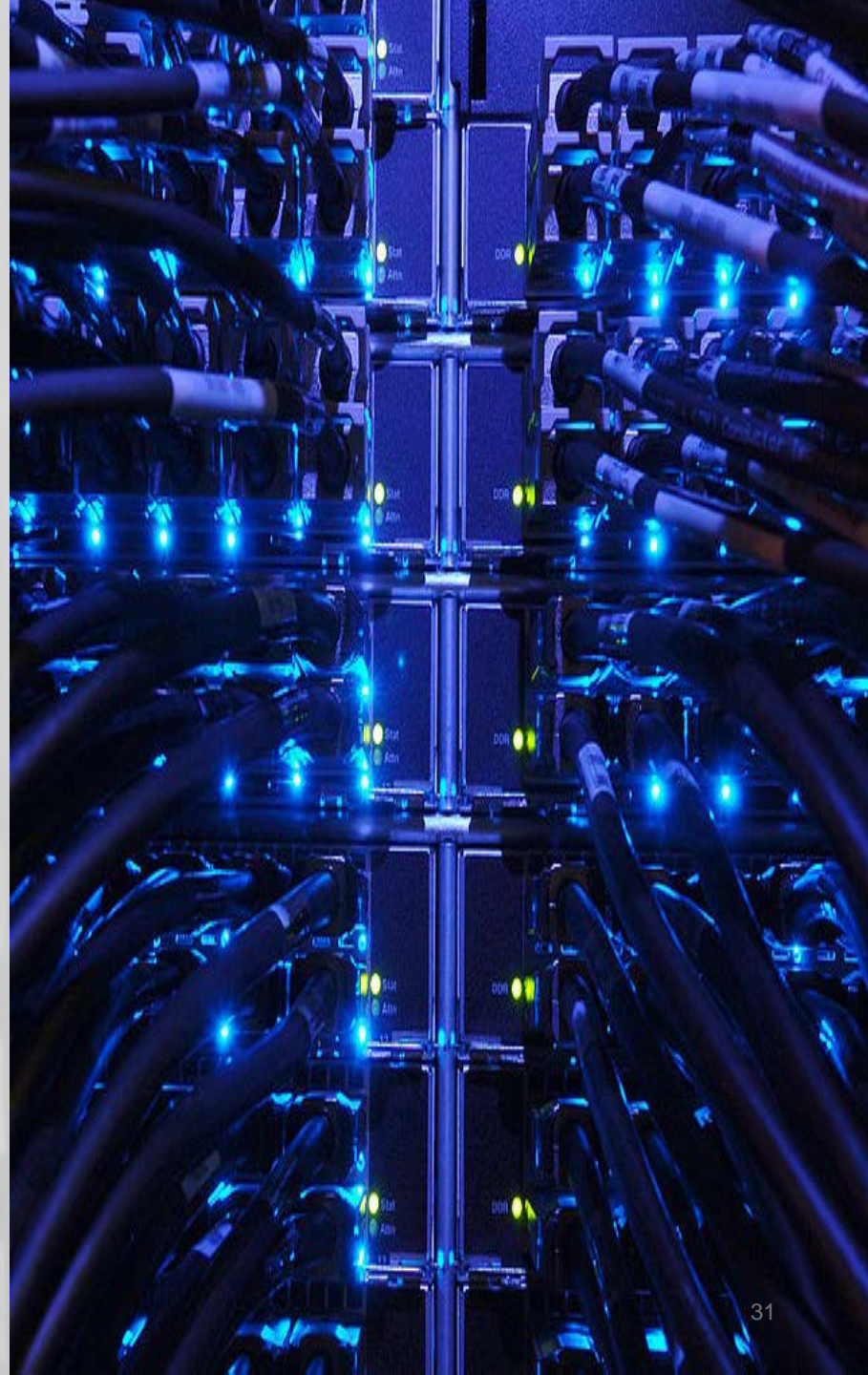


Simulation

A photograph of a server room with blue ambient lighting. The room contains several rows of server racks. A dark grey banner with the word 'Simulation' in white text is overlaid on the left side of the image. The server racks have various labels and indicators, including a prominent yellow label with the number '1'. The floor is a light-colored, perforated metal grating.

Model complexity and time constraints drive use of high-performance computing

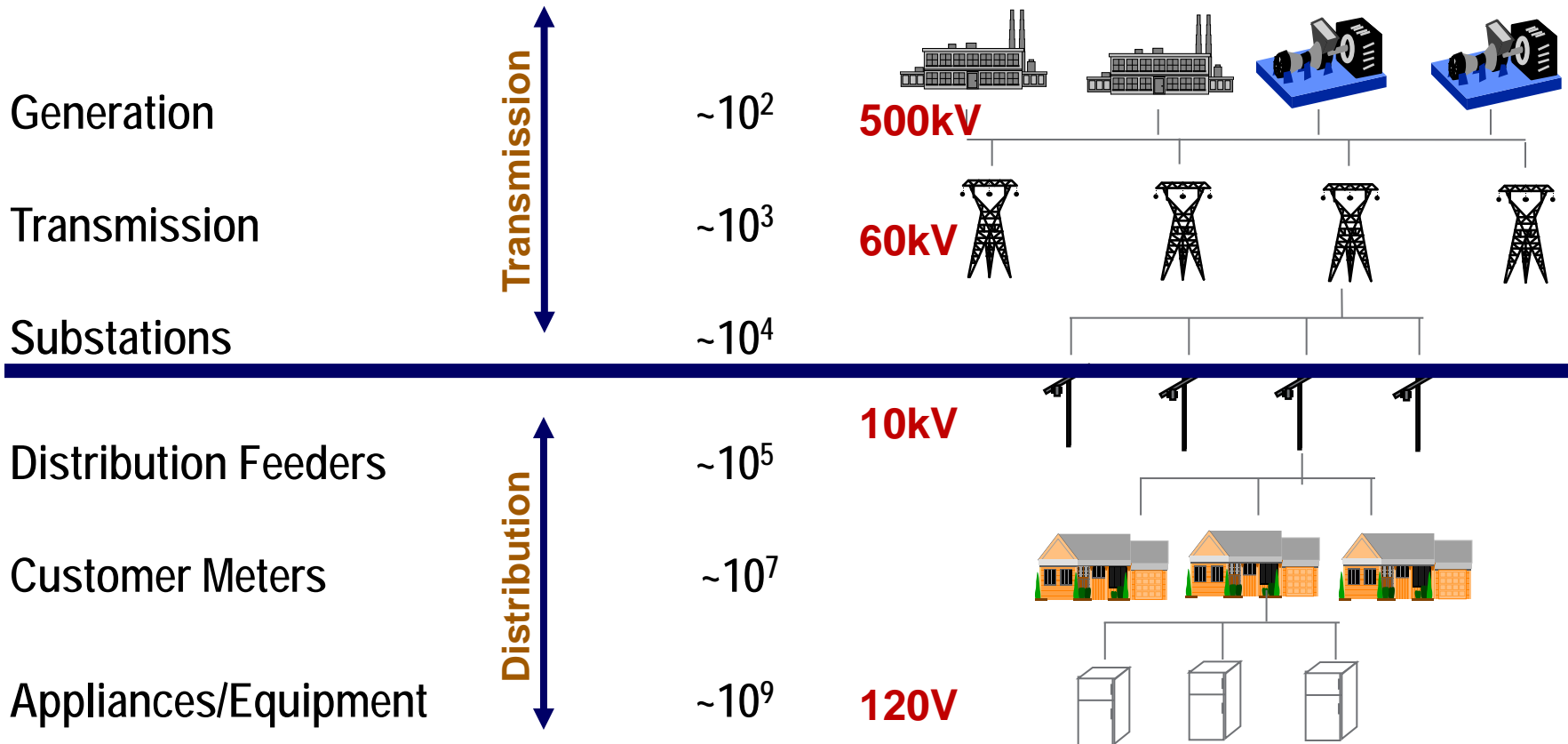
- ▶ **State estimation**
- ▶ **Dynamic simulation**
- ▶ **Contingency analyses**
- ▶ **Stochastic optimization**



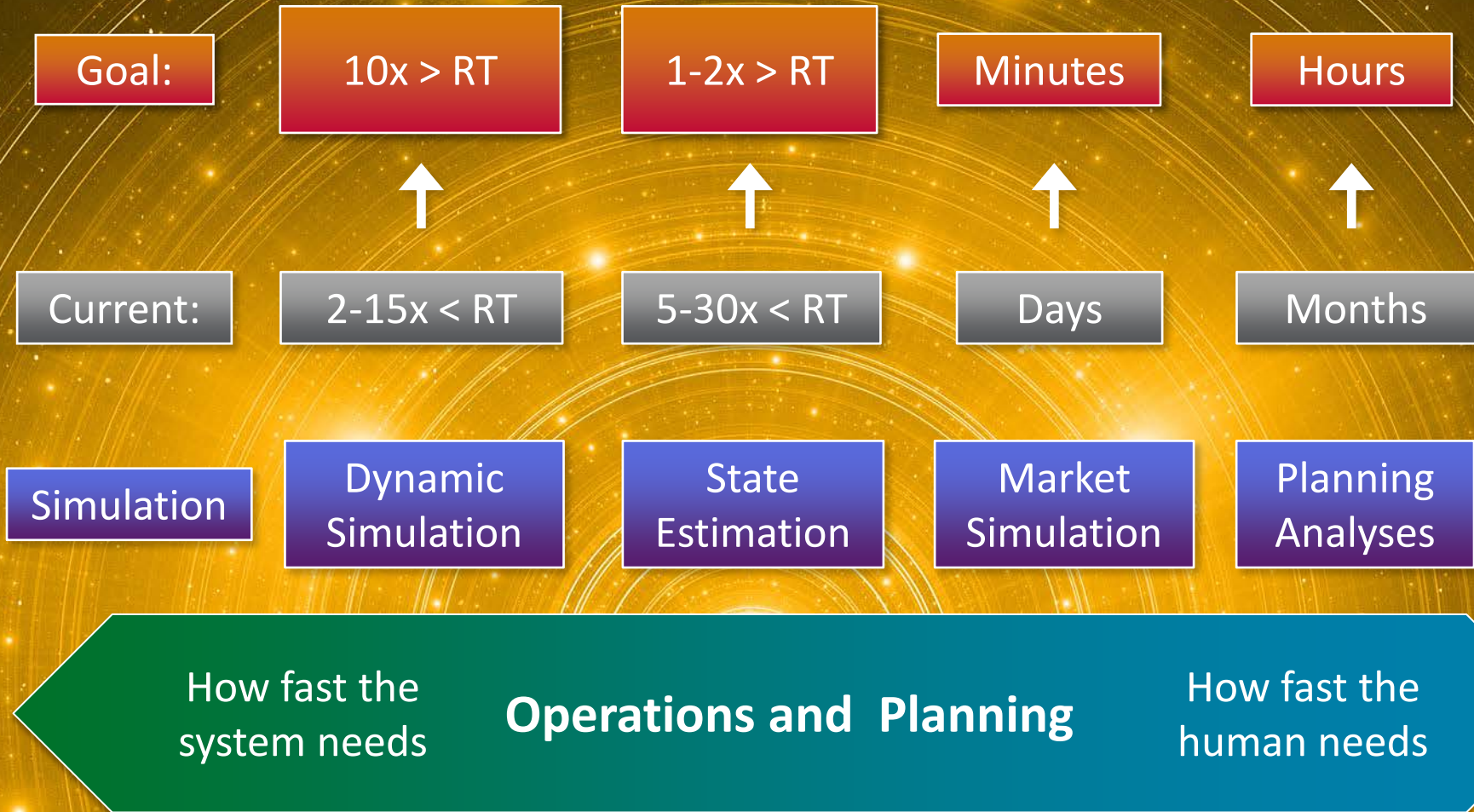
Integrated model of transmission and distribution system requires 1B nodes

Element

Nodes in Western U.S.



Faster simulations will improve operations and planning





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Tools



GridLAB-D provides a unified model of the key elements of the smart grid

Power Systems



Loads



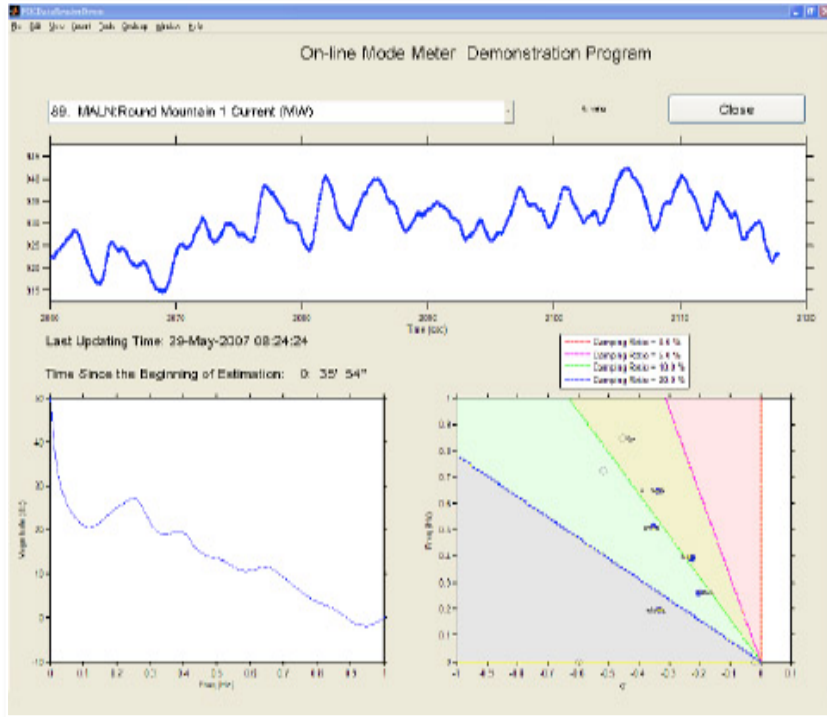
Markets



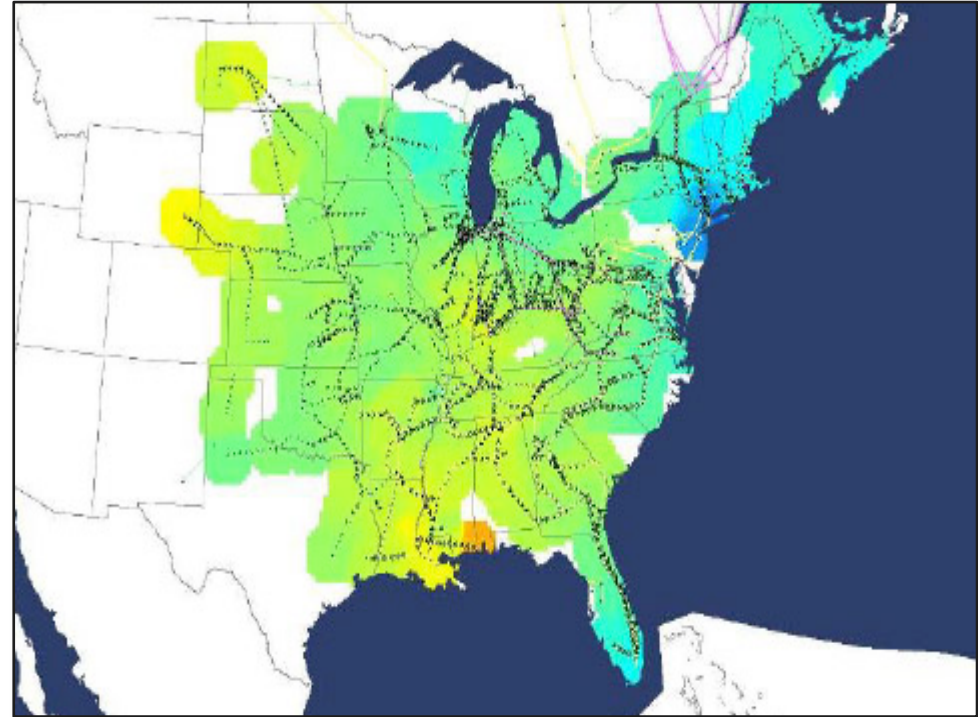
GridLAB-D models:

- Power flow
- End-use load behavior in thousands of homes
- Double-auction markets

Information visualization and decision support tools enable situational awareness



Small Signal Analysis Tool



Wide Area Hybrid Grid Health Tool

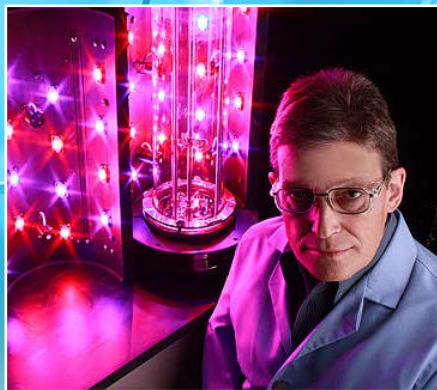


A green highway sign with the text "What's Next?" in white, set against a blue sky with white clouds. The sign is mounted on a metal structure. The text is in a bold, sans-serif font.

What's Next?



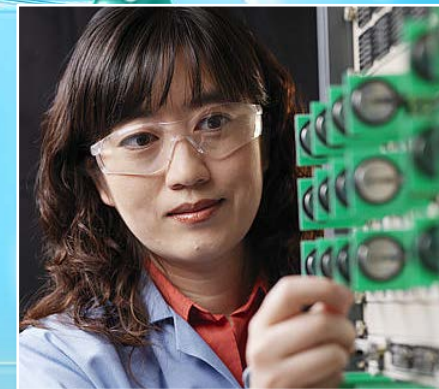
Opportunities in the chemical enterprise



Renewables



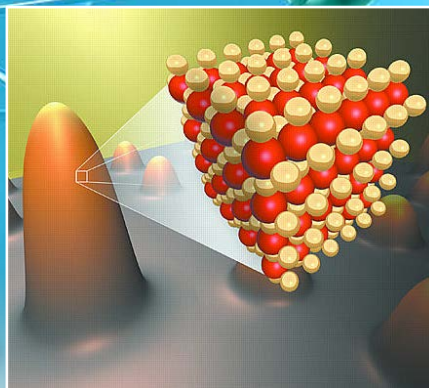
Hydrogen



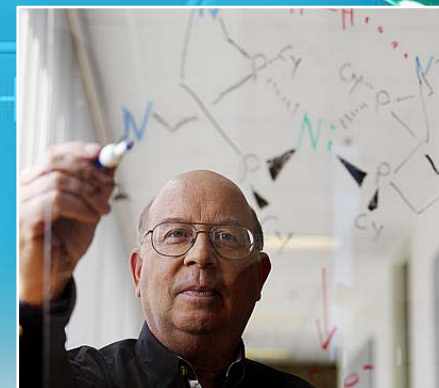
Storage



Catalysis



Materials



Electrochemistry

We invite you to collaborate with us

DISCOVERY *in Action*
Through the years...

At Pacific Northwest National Laboratory, we are advancing science and solutions to solve complex problems in energy, the environment, and national security. We accomplish this mission through the power of our interdisciplinary teams, bringing together experts from multiple disciplines to tackle complex problems. PNNL's science and technology inspires and enables the world to live prosperously, safely and securely.

Collaborate with us as we transform the world through courageous discovery and innovation.

www.pnnl.gov

1965 Scientists discovered a pathway linking health hazards with chemical weapons, pesticides, and other contaminants through and into the food chain. This discovery led to the development of food safety and inspection service laws, including residue testing programs.

1991 Two stages of a new ultra-compact, high-power electron microscope were designed by the U.S. Department of Commerce. Since then, the technology has been used by other agencies.

1998 Researchers engineered the ceramic called SAMMS, self-assembled monolayers on mesoporous supports, to remove hazardous metals from water and other liquids. The product was commercialized and is used to solve global environmental challenges.

2012 Purification systems are critical to thousands of sailors isolated deep underwater in submarines. PNNL's Advanced Carbon Dioxide Removal Unit, developed with support from the Naval Sea Systems Command, captures carbon dioxide directly from the atmosphere within a submarine, that creates a healthier underwater environment.

1974 PNNL invented a technique called digital signal recording that allows information as a track of dots about the accuracy of a design. The invention served as the critical design element for computer chips and copiers.

1999 The award-winning Electrodynamic Ion Funnel, designed at PNNL, significantly improved the sensitivity of certain mass spectrometry tools and other analytical instruments.

2010 Revolutionary ion mobility separations in a microchip, developed at Dowstone Nanotech and PNNL, dramatically improve the ability to rapidly detect specific molecules in complex samples.

2013 A continuous chemical process that produces useful crude oil minutes after harvested algae is added. With additional conventional refining, the crude algae oil is converted into aviation fuel, gasoline or diesel fuel.

