ENERGY TRANSITIONS

2022 NAE Annual Meeting

October 2-3, 2022 | Washington, DC

Transitioning to Net-Zero Carbon: Engineering Challenges and Opportunities

Moderated Panel Discussion

NATIONAL ACADEMY OF ENGINEERING®

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NATIONAL ACADEMY OF ENGINEERING®

Gavin P. Towler

Sarah Kurtz

José N. Reyes, Jr.

Kathryn A. McCarthy

Amy Halloran

Moderator

Deanne Bell

NATIONAL ACADEMY OF ENGINEERING®

Moderated Panel Discussion

Navigating the Energy Transition

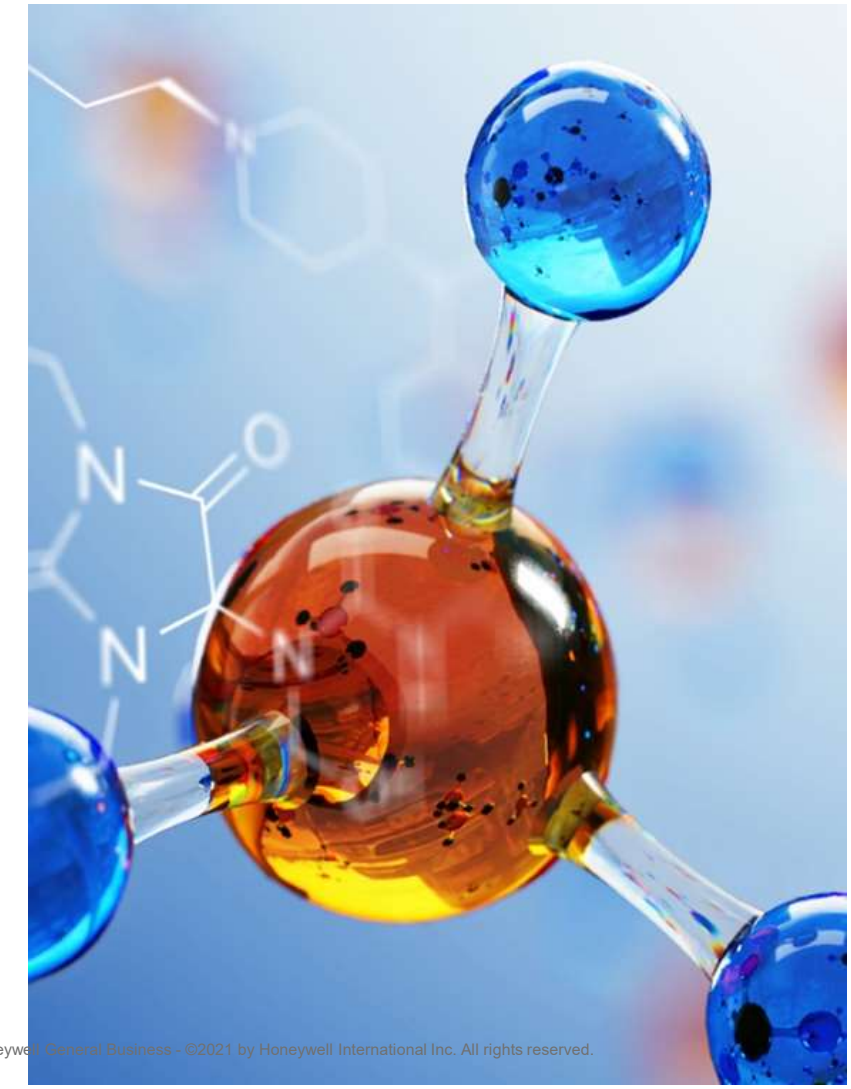
Gavin P. Towler

CTO & Vice President of Research & Development, Honeywell, Inc.

NAVIGATING THE ENERGY TRANSITION

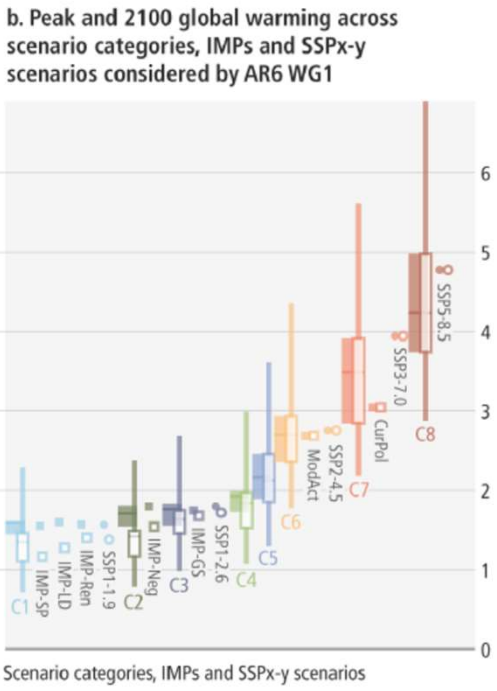
Gavin Towler

Chief Technology Officer
Honeywell UOP
Honeywell Performance Materials and Technologies



THE ENERGY TRANSITION:

The problem …

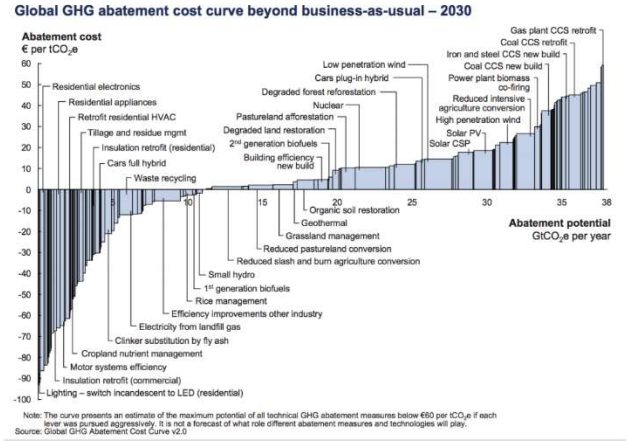


Source: IPCC AR6, WG3 (2022)

The solution …

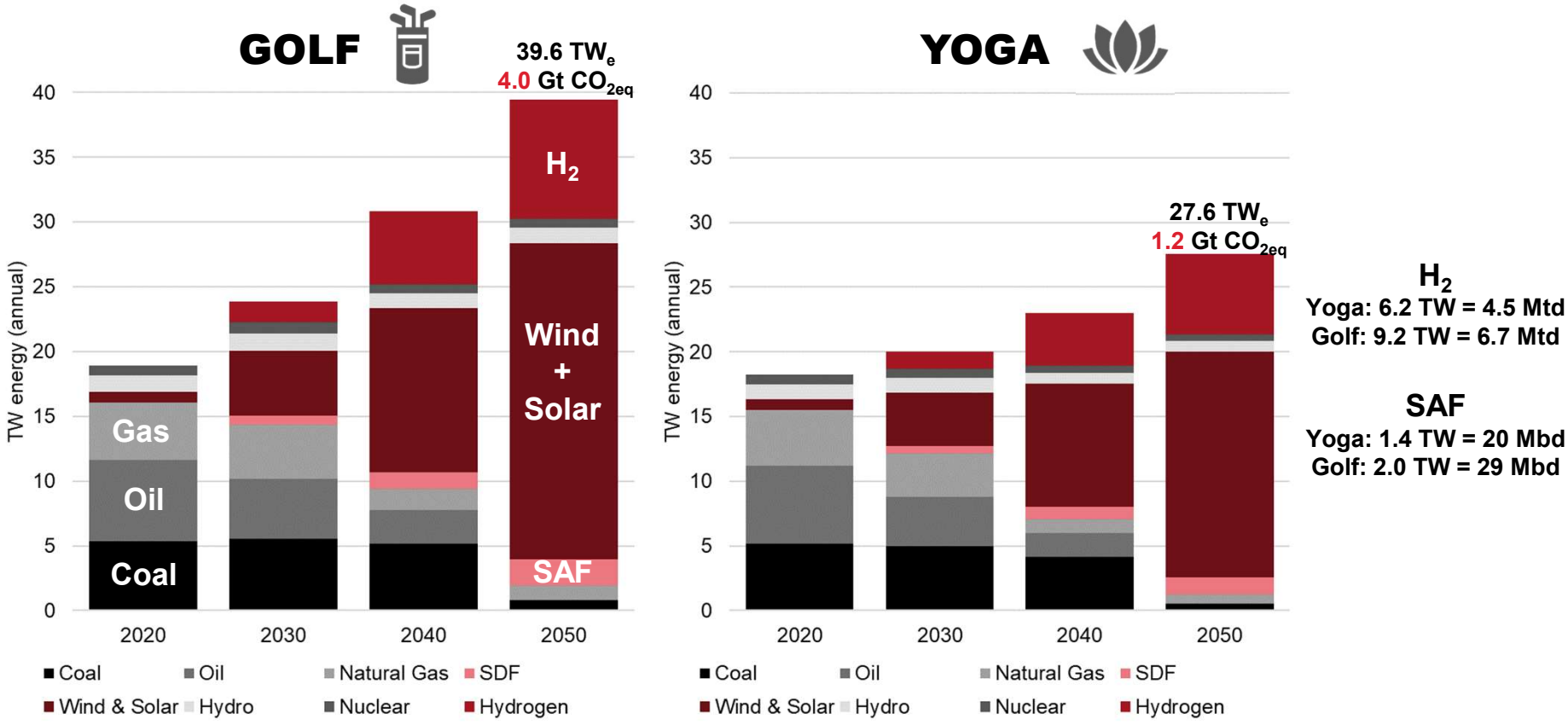
Electricity	
Coal Nat Gas	Wind, Solar Nuclear, Hydro BECCS
Residential Heating	
Nat Gas	Electricity Hydrogen
Industrial Heating	
Nat Gas Coal	Electricity Hydrogen
Light Duty Vehicles	
Gasoline	Electricity (BEVs)
Freight and Off-Road Vehicles	
Diesel	Electricity Hydrogen
Aviation	
Jet Fuel	SAF Electricity Hydrogen

The challenge …



Source: McKinsey (2009), reproduced with permission of McKinsey & Company.

TWO VISIONS OF THE FUTURE



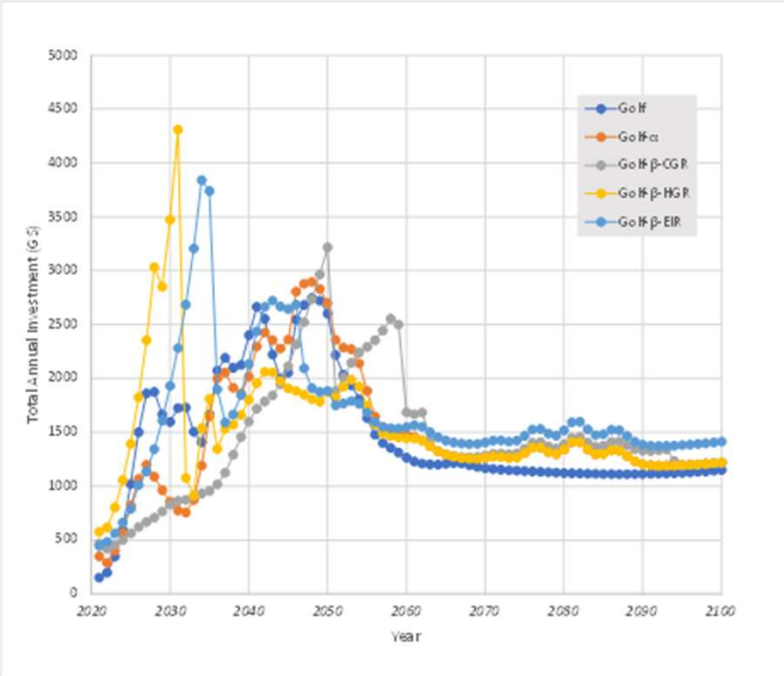
H_2
Yoga: 6.2 TW = 4.5 Mtd
Golf: 9.2 TW = 6.7 Mtd

SAF
Yoga: 1.4 TW = 20 Mbd
Golf: 2.0 TW = 29 Mbd

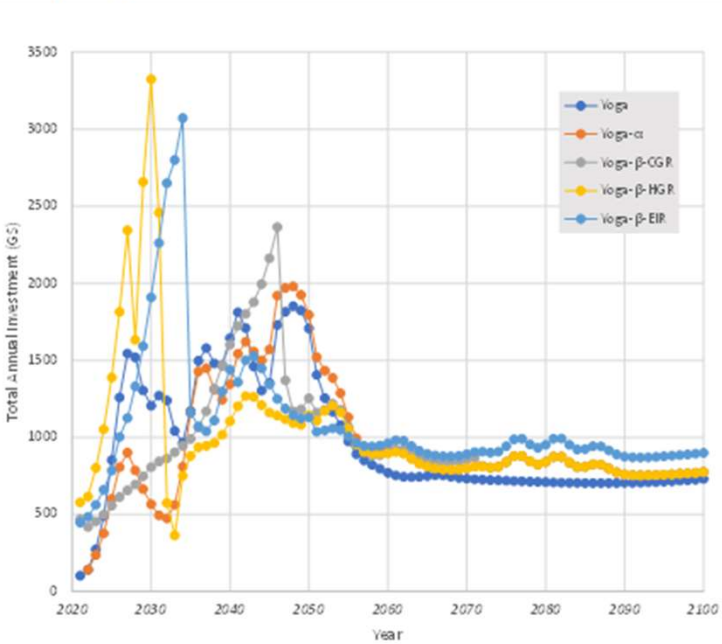
Note: renewables show primary energy consumed, not installed capacity

WHY ARE WE BEHIND PACE?: INVESTMENT NEEDED

1) Golf



2) Yoga



Total investment to 2050: T$33 to T$59

QUESTION & ANSWER

Moderated Panel Discussion

Solar Power – Today's Success Poised to be Tomorrow's Solution

Sarah Kurtz

Professor at the University of California

Solar Power –
Today's Success Poised to be Tomorrow's Solution

National Academy of Engineering

Sarah Kurtz, Oct. 3, 2022

UNIVERSITY OF CALIFORNIA
MERCED

Solar technology is demonstrated!

Solar power

CLEAN POWER

Solar Power = "Cheapest Electricity In History"

The fossil-friendly International Energy Agency indicates that solar power is now the "cheapest electricity in history."

By Zachary Shahan Published October 26, 2020 117 Comments

https://cleantechnica.com/2020/10/26/solar-power-cheapest-electricity-in-

In 2020, IEA concluded that solar power can provide the cheapest electricity

TW of solar deployed – this spring's news!

World has installed 1TW of solar capacity

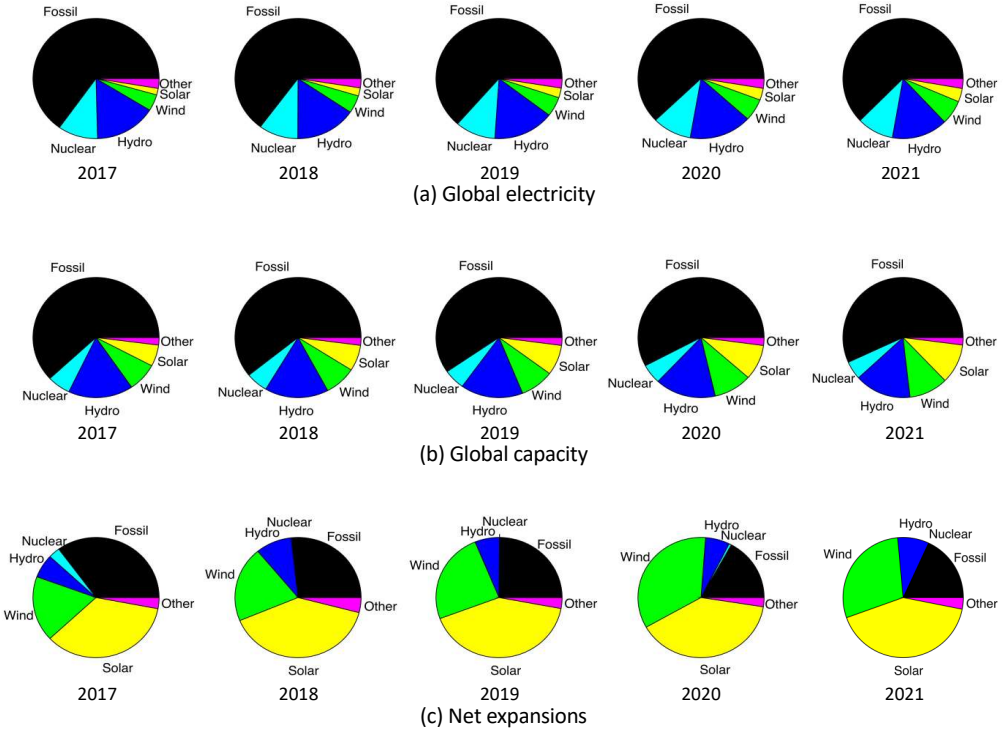
The world has installed its first terawatt of hardware on Earth to generate electricity directly from the sun.

MARCH 15, 2022 JOHN FITZGERALD WEAVER

https://www.pv-magazine.com/2022/03/15/humans-have-installed-1-terawatt-of-solar-capacity/

How big is a TW?
The US total electricity generating capacity is 1.2 TW

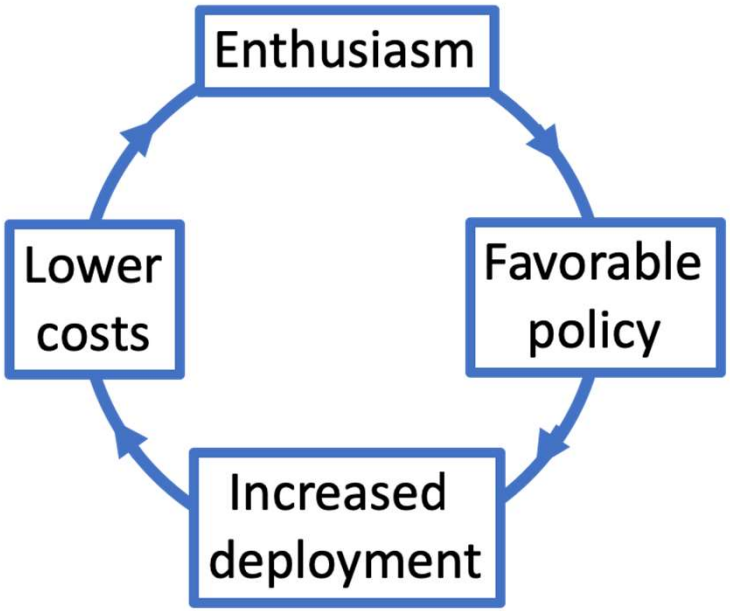
Solar is small, but growing quickly!



Solar currently provides only 4% of world's electricity, but is half of the new renewable-energy capacity (which is ~80%)

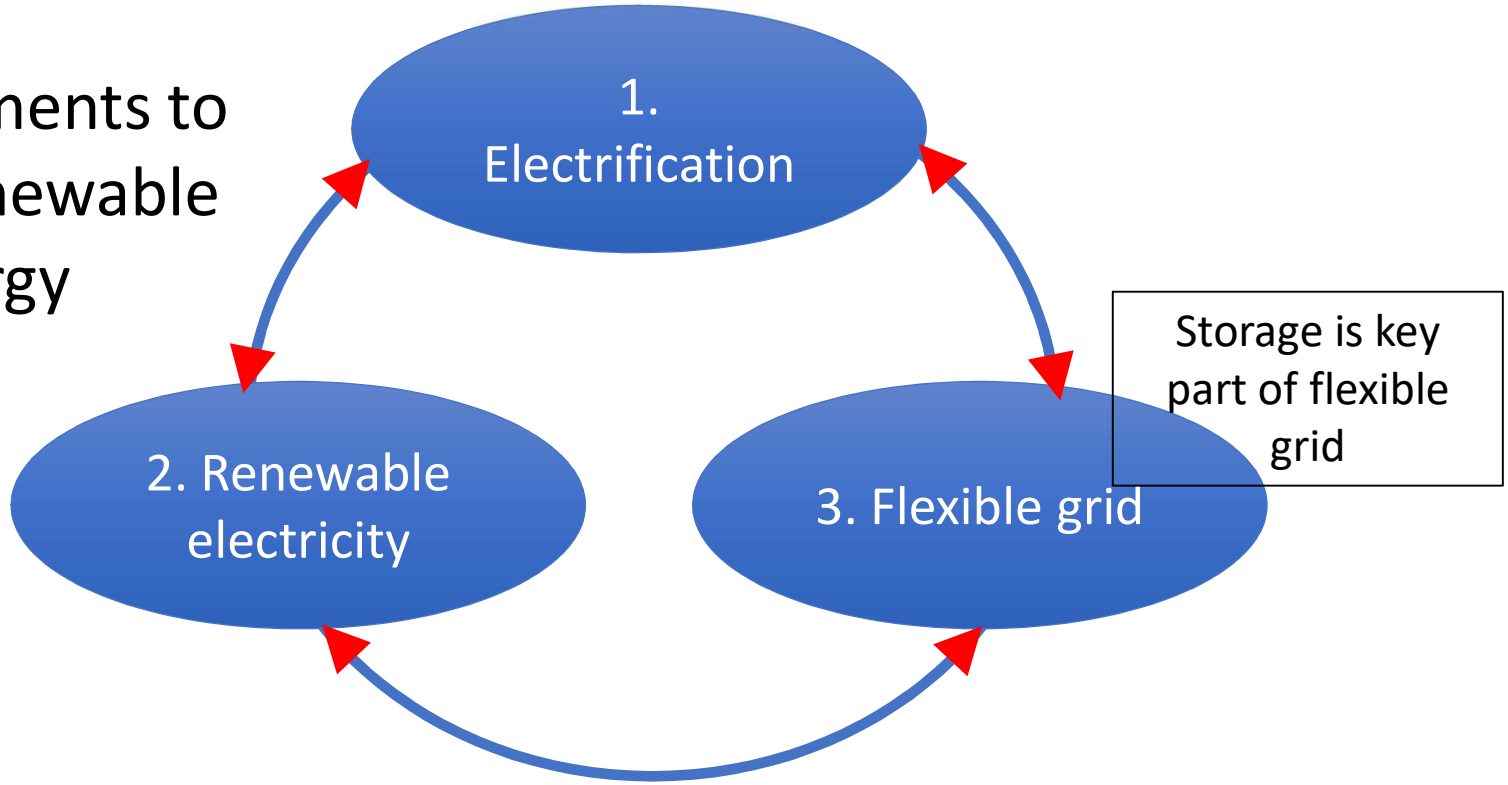
Haegel, et al, IEEE Journal of PV

Positive feedback enables rapid change

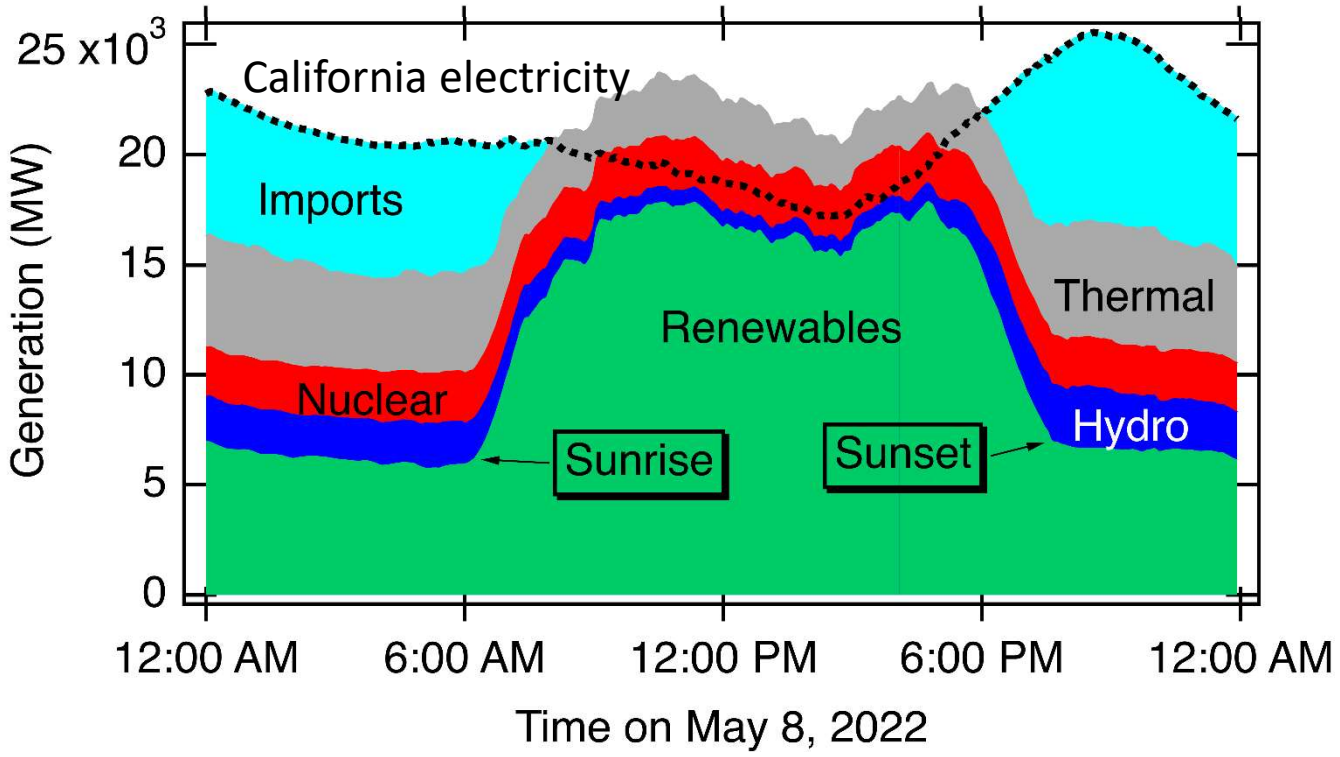


Clean *energy* will benefit from positive feedback

3 key elements to 100% Renewable Energy



Solar as a primary electricity source



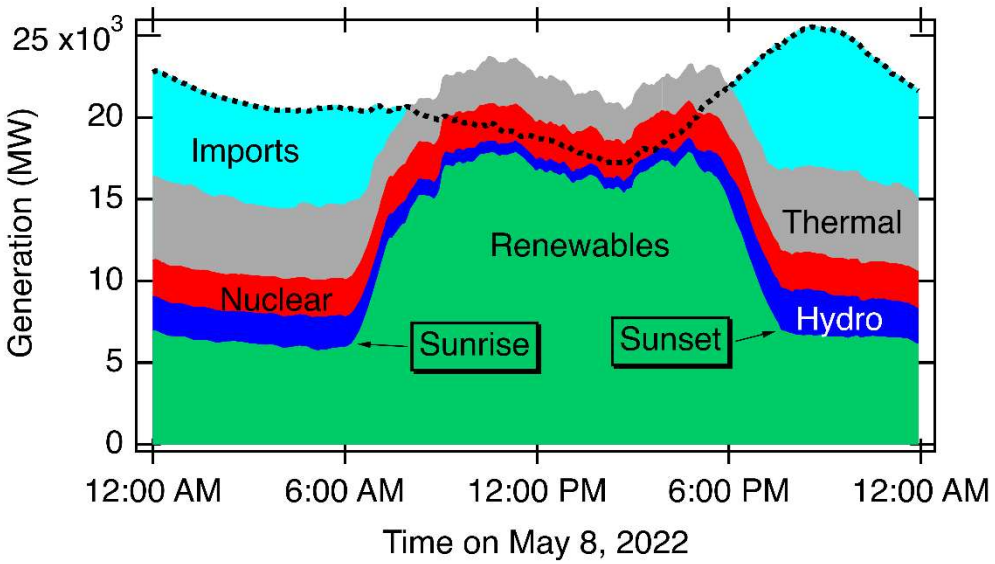
http://www.caiso.com/TodaysOutlook/Pages/supply.htm

Solar's biggest challenge: what to do when the sun sets?

Storage

But, there are other options, too

When do we charge electric vehicles?



Utilities today offer special charging rates to EV owners who charge at night

Wouldn't it be better if EVs are charged during the day?

Let's be smart and invest in infrastructure that will provide a low-cost solution: EV charging in daytime parking lots

Moderated Panel Discussion

Nuclear Innovations – Beyond Baseload Power

José N. Reyes, Jr.

Co-founder and Chief Technology Officer, NuScale Power, LLC

NUSCALE™
Power for all humankind

Nuclear Innovations – Beyond Baseload Power

2022 NAE Annual Meeting Technical Forum

Transitioning to Net-Zero Carbon:

Engineering Challenges and Opportunities

October 3, 2022

Dr. Jose N. Reyes, Jr.
Co-founder and Chief Technology Officer

A New Approach to Construction and Operation

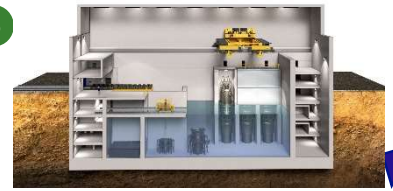
NuScale has revolutionized the nuclear supply chain with modular manufacturing of NPM units in-house that are shipped to sites

1

Factory fabrication

2

NuScale Power Module including containment and reactor vessel



5

Housed in a 6-module reactor building

Low carbon, secure electricity

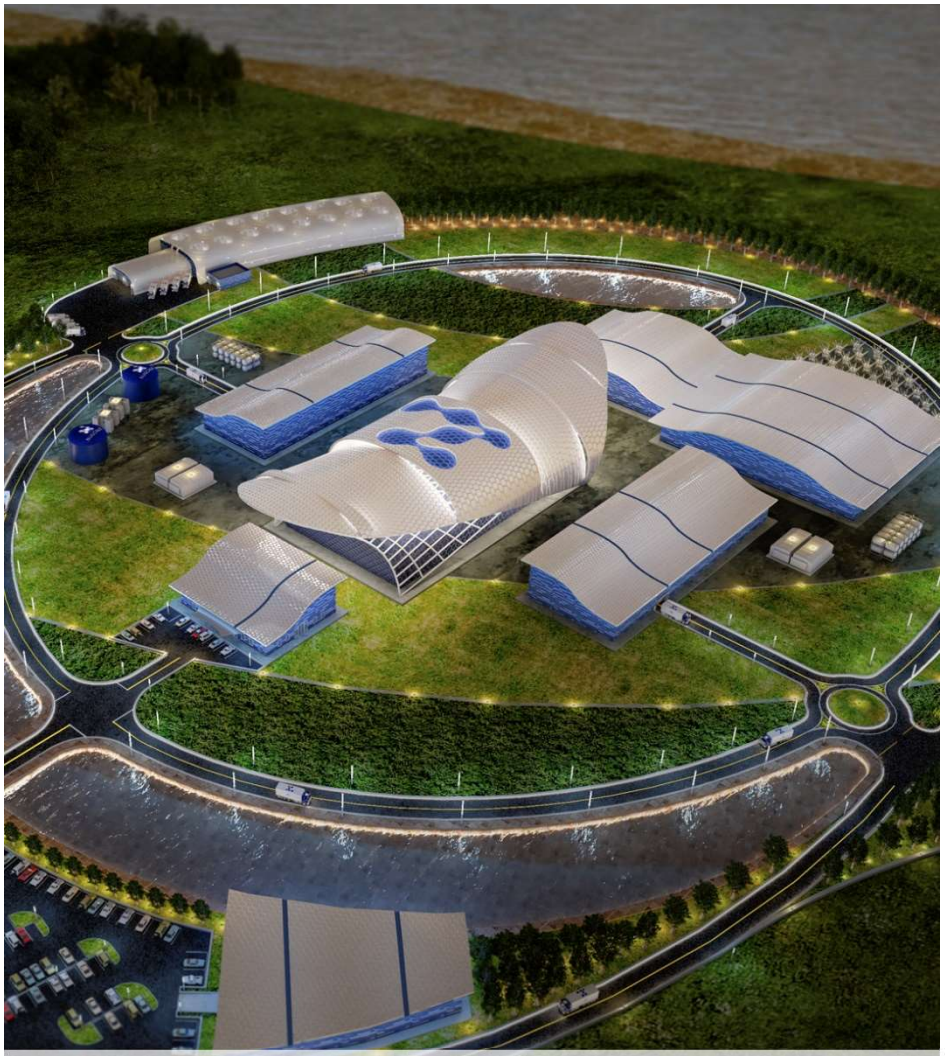
4

To the plant site

3

Shipped by truck, rail, or barge

NUSCALE Power for all humankind



Artistic concept of the NuScale Power Plant

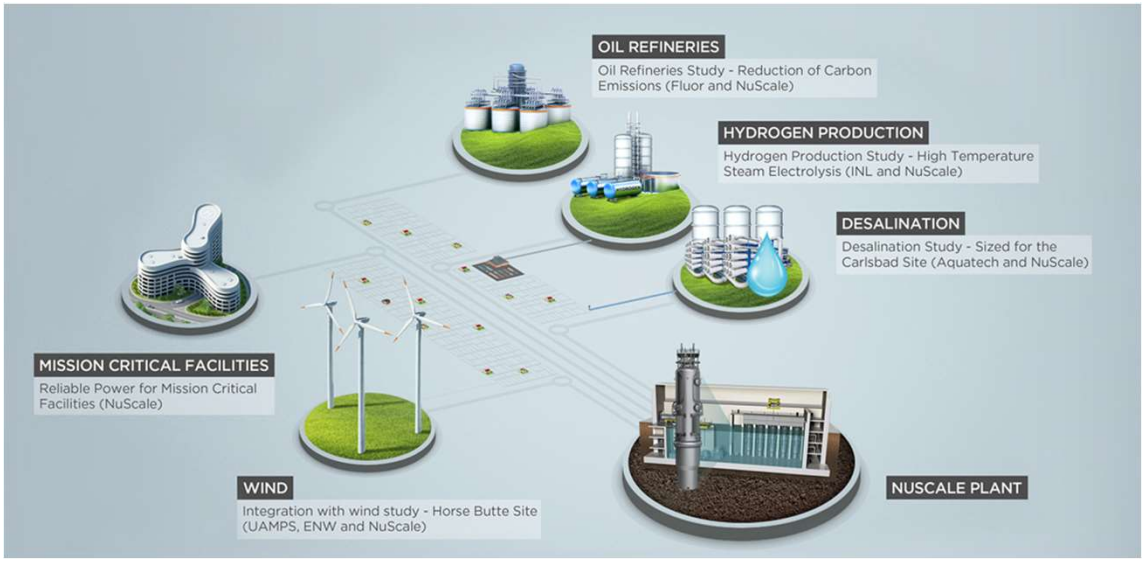
Small Modular Reactors for the Modern Grid

- **Enhanced Level of Safety**
  - ***No operator action, or AC/DC power needed to shut down reactors and no need to add water to keep reactors safe and cooled for an unlimited time.***
  - Capable of achieving site boundary EPZ.
  - No connection to the grid required for safety.
- **"Off-Grid" Operation**
  - New applications
  - Long-term Reliable Power for Mission Critical Facilities
- **Grid Support and Resilience**
  - Black-start capability
  - First Responder Power for Severe Weather Events
  - Load Following Renewables and frequency hunting for grid stability
  - Seismic events, hurricanes, flooding, tornados, aircraft impact.
- **Advanced Control Systems**
  - Simplified, Automated, Control Rooms
  - Unique cyber resistant FPGA based Module Protection and Plant Protection Systems.
- **Sized to repurpose coal fired plants**

NUSCALE™ Power for all humankind

Beyond Baseload Power

- **Role in De-carbonizing the Power Sector**
  - Replacing 200 GWe of retiring coal plants with plants through 2050
- **Role in Decarbonizing the Transportation Section**
  - Commercial Scale Hydrogen Production
  - Fuel Cell vehicles and Energy Storage
  - Clean power for electric vehicles
- **Role in enabling multiple off-grid applications**
  - Desalination
  - Hydrogen, Oxygen, Ammonia Production, Fertilizers
  - Process Heat



Need Big Impact on a Short Time Scale

- **The Clock is Ticking** – California, Colorado, Maine, Nevada, New Mexico, Oregon, Virginia, Washington, Guam, and Puerto Rico have established 100% Clean Energy Mandates with deadlines ranging from 2040-2050. https://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx
- ***Least-Cost Path** to meeting Clean Energy Mandates – Renewables + Nuclear
- **Inflation Reduction Act** Includes energy tax credits benefits that create an emissions-based incentive that will be neutral and flexible between clean electricity technologies.
  - Customers can choose between a production tax credit or an investment tax credit, which is based on the carbon emissions of the electricity generated.
  - Any power facility of any technology can qualify for the credits, so long as the facility's carbon emissions are at or below zero.

IRA Benefits to Nuclear

- $40 billion for DOE loan commitments
- $3.6 billion for DOE loan guarantees
- $1.5 billion for national lab support
- $700 million for supporting HALEU fuel
- Zero emission power PTC of $0.003/kwh and bonus credit of $0.015c/kwh for electricity sold before 2033 and adjusted as the sale price of such electricity increases
- Clean energy PTC of $0.025/kwh or ITC up to 30% of qualifying investment with potential for direct pay

**Pacific Northwest Zero-Emitting Resources Study,* Energy + Environmental Economics, January 2020. https://www.ethree.com/wp-content/uploads/2020/02/E3-Pacific-Northwest-Zero-Emitting-Resources-Study-Jan-2020.pdf
Least Cost Carbon Reduction Policies in PJM, Energy + Environmental Economics, October 2020. https://www.ethree.com/least-cost-carbon-reduction-in-pjm/
New Jersey Energy Master Plan Pathway to 2050, analysis by the Rocky Mountain Institute, January 2020. https://rmi.org/new-jersey-charts-a-practical-affordable-course-to-a-decarbonized-economy/
MIT, The Future of Nuclear Energy in a Carbon-Constrained World (2018) http://energy.mit.edu/wp-content/uploads/2018/09/The-Future-of-Nuclear-Energy-in-a-Carbon-Constrained-World.pdf

NUSCALE Power for all humankind

Dr. Jose Reyes
Co-founder & Chief Technology Officer
jreyes@nuscalepower.com

Moderated Panel Discussion

Fusion and Advanced Fission Energy – Key to Transitioning and Sustaining Net Zero Carbon

Kathryn A. McCarthy

US ITER Project Director

OAK RIDGE National Laboratory

Fusion and Advanced Fission Energy

Keys to Transitioning and Sustaining Net-Zero Carbon

Dr. Kathy McCarthy

US ITER Project Director

Oak Ridge National Laboratory

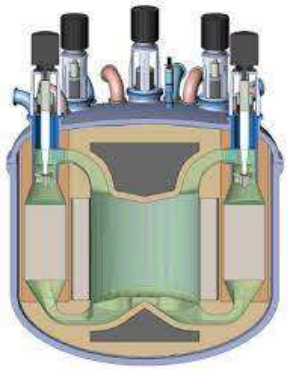
ORNL is managed by UT-Battelle LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Nuclear energy, advanced reactors and fusion are allies for carbon-free energy

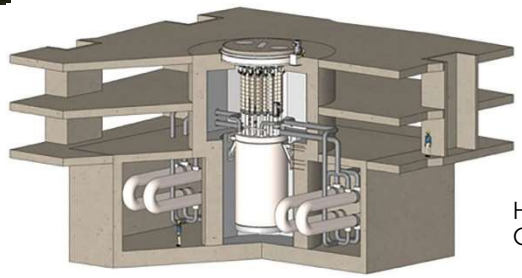
Nuclear energy's carbon-free, reliable baseload power intersects effectively with renewable sources

Watts Bar Plant. Credit: TVA



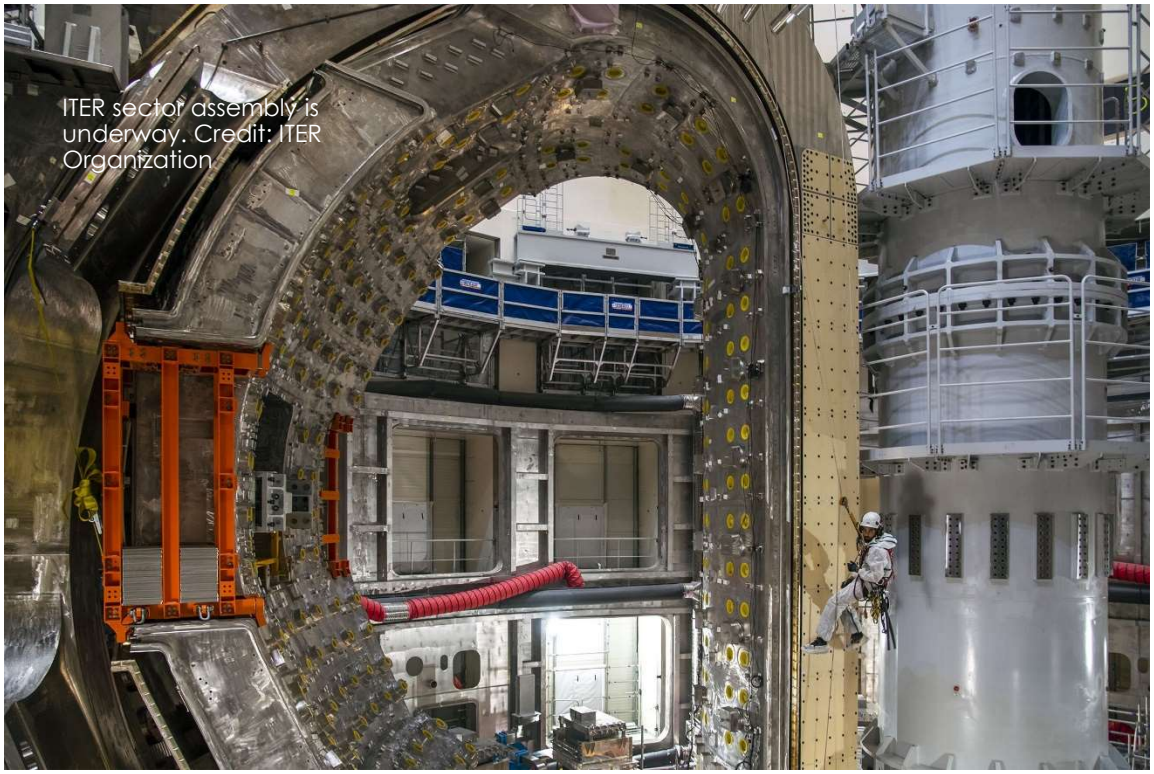
Molten chloride fast reactor
Credit: Terra Power/Southern

DIII-D research tokamak. Credit: GA



HERMES demonstration reactor design.
Credit: Kairos

We are building a path to fusion energy now



ITER sector assembly is underway. Credit: ITER Organization

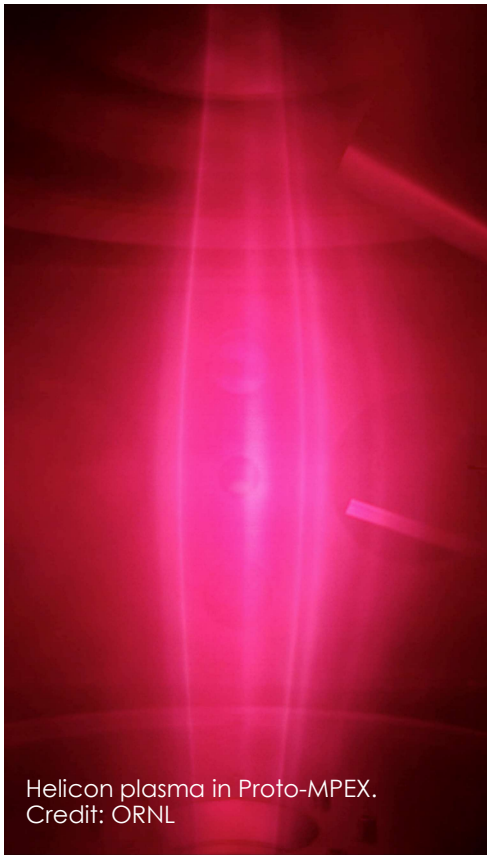
JET 2022 record.
Credit: EUROfusion

We can engineer the solutions for fusion energy

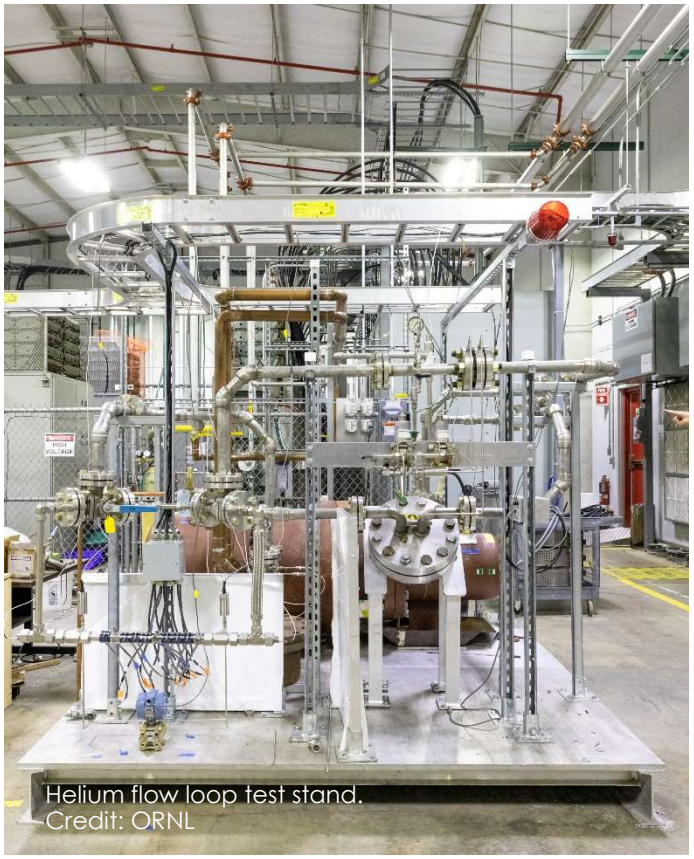
The National Academies of SCIENCES ENGINEERING MEDICINE

Bringing Fusion the U.S. Grid

2021



Helicon plasma in Proto-MPEX.
Credit: ORNL



Helium flow loop test stand.
Credit: ORNL

OAK RIDGE National Laboratory

Thank you

Dr. Kathy McCarthy

US ITER Project Director

Oak Ridge National Laboratory

2022 NAE Annual Meeting Technical Forum

Transitioning to Net-Zero Carbon: Engineering Challenges and Opportunities

Moderated Panel Discussion

Next Generation Electric Grid: Transitioning the Grid to Net-Zero Carbon

Amy Halloran

Director, Nuclear Fuel Cycle and Grid Modernization, Sandia National Laboratories

Sandia National Laboratories

Exceptional service in the national interest

Next Generation Electric Grid: Transitioning the Grid to Net-Zero Carbon

Amy Halloran

Director of Nuclear Fuel Cycle and Grid Modernization Sandia National Laboratories

SAND2022-12951 PE

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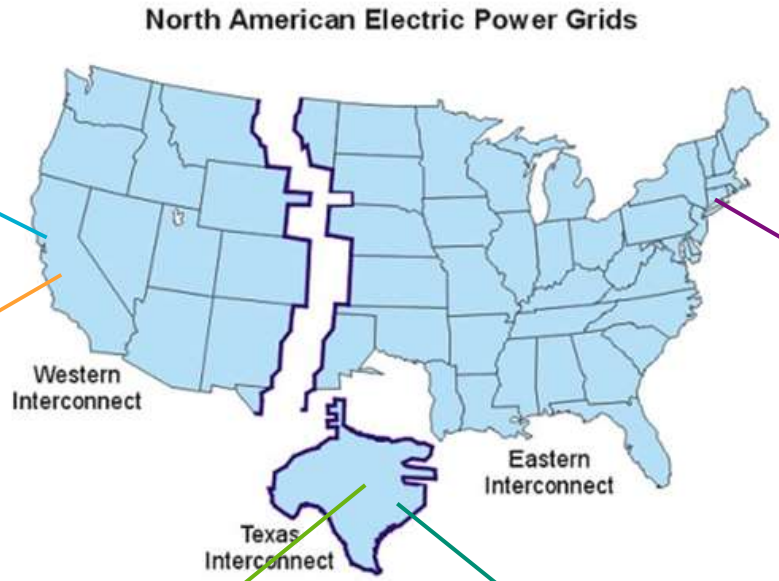
U.S. DEPARTMENT OF ENERGY

NNSA

Challenges to Our Current Grid



"Bay Area power outages: Thousands without power"

"California Declares Grid Emergency, Warning of Blackouts"

"US East Coast begins 2022 with winter storm, almost 1M outages"

"Data analysis estimates 700 deaths in Texas from Winter Strom Uri"

"Almost 70% of ERCOT customers lost power during winter storm, study finds"

Graphic courtesy of epa.gov

Needs for the Grid of the Future

COST

Grid-scale batteries are costly

STORAGE

Current system falls short of new energy storage requirements

TRANSMISSION

New transmission lines are needed to support areas in need

POWER ELECTRONICS

Manage flow of electricity between renewables and the grid

TRANSPORT SYSTEM

Electrification of transportation increases demand on the grid

Transitioning to the Next-Generation Electric Grid

"…conduct long-term regional transmission planning on a sufficiently forward-looking basis to meet transmission needs driven by changes in the resource mix and demand."

The Grid Deployment Office will invest $17 billion in programs and projects to identify and address national transmission, distribution, and clean generation needs

U.S. DEPARTMENT OF ENERGY
Building a Better Grid

U.S. DEPARTMENT OF ENERGY
OFFICE OF ELECTRICITY

ENERGY earthshots
U.S. DEPARTMENT OF ENERGY

U.S. DEPARTMENT OF ENERGY
Office of Cybersecurity, Energy Security, and Emergency Response

ENERGY STORAGE GRAND CHALLENGE
U.S. DEPARTMENT OF ENERGY

Amy Halloran, P.E. arhallo@sandia.gov (505) 844-4904

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