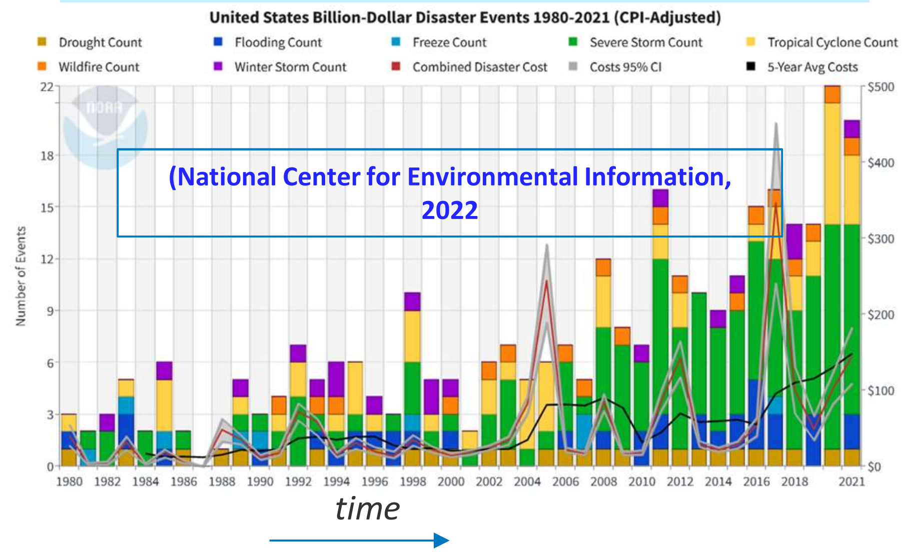

NREL
Transforming ENERGY
Pathways to NetZero:
questions and challenges
Peter F. Green, Deputy Laboratory Director, Science and Technology, Chief Research Officer
September 14, 2023

Achieving NetZero: solutions extend beyond power production from fossil sources

Billion-dollar disaster events in the US

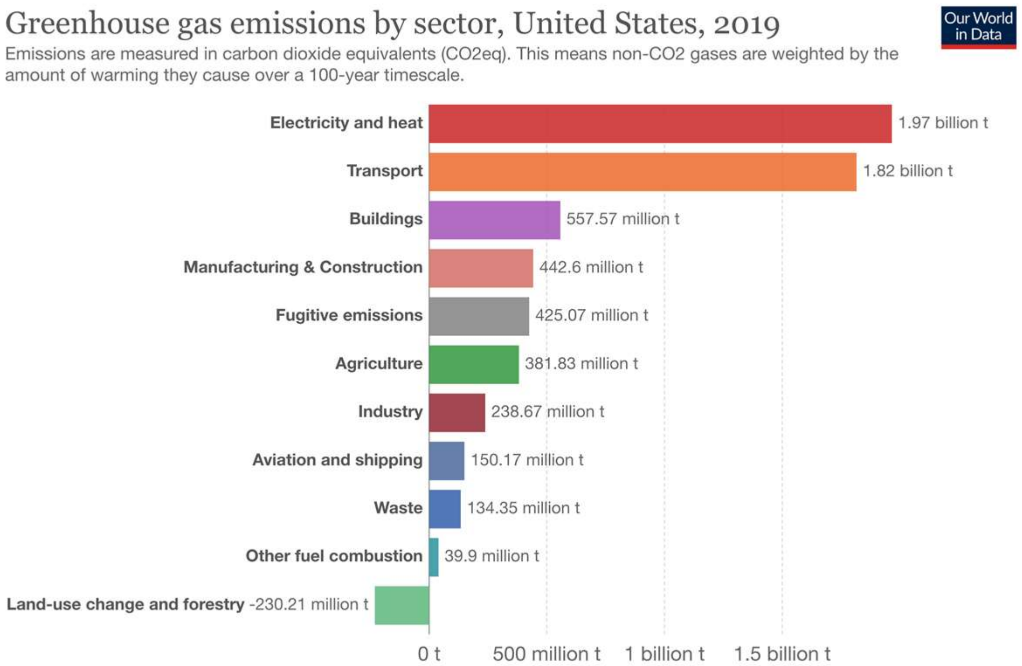


Waste: materials for different applications

Economist, March 2018

The transition toward net zero emissions will include S&T advances, addressing market challenges, as well as economic, social, and cultural considerations

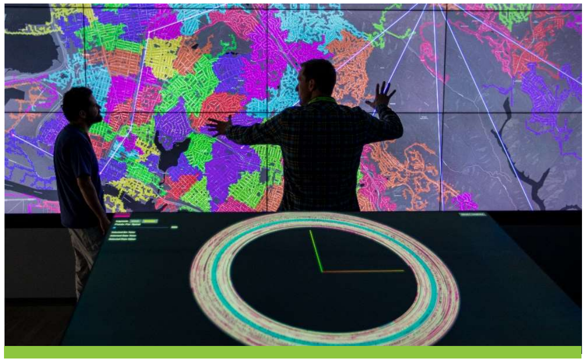
Identifying major sources emissions provide insights into potential solution pathways



Processes Chemicals/materials:

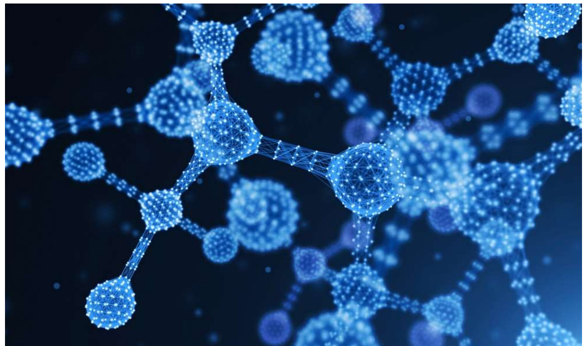
Cement
Steel
Chemicals
Plastics (including disposal)
Cosmetics
Asphalt
Fertilizer
Batteries (incl. supply chain)

Integrated Energy Pathways



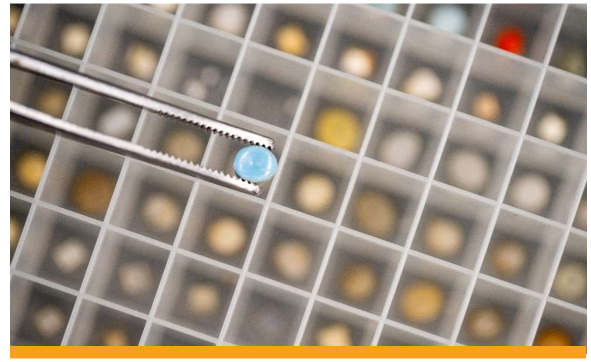
Develop the foundational knowledge and technologies to **optimize the integration of renewables, buildings, industry, energy storage, and transportation**—modernizing our energy systems and ensuring a secure and resilient grid.

Electrons to Molecules



The **conversion of electricity and small waste gases** (e.g., CO_2, H_2O, N_2) into chemical bonds for the purposes of chemical, material, or fuel synthesis and/or energy storage.

Circular Economy for Energy Materials



Establishing the **foundational knowledge/technology** for design, recycle, reuse, remanufacture, and reliability for **energy-relevant** materials and processes.

NREL's Three Critical Objectives…Strategic directions

A collaborative engagement

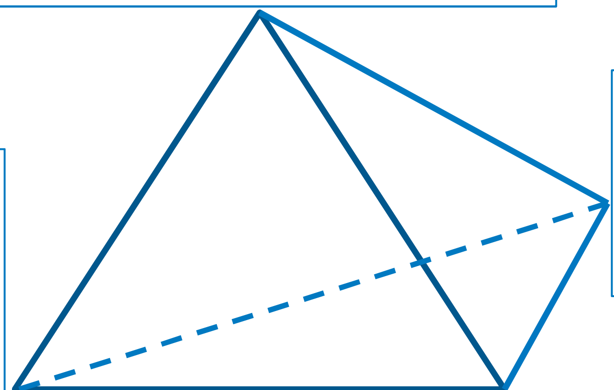
Science and Technology

1. Future energy system
2. Conversion of electrical to chemical energy
3. waste/emissions

Integrated Energy Pathways

Electrons to Molecules

Circular Economy for Energy Materials



Investments

a. Government: *BIL/IRA, DOE Offices*

b. Partnerships

c. **LDRD**

Implementation/Adoption:

Communities to clean energy

LA100, PR100

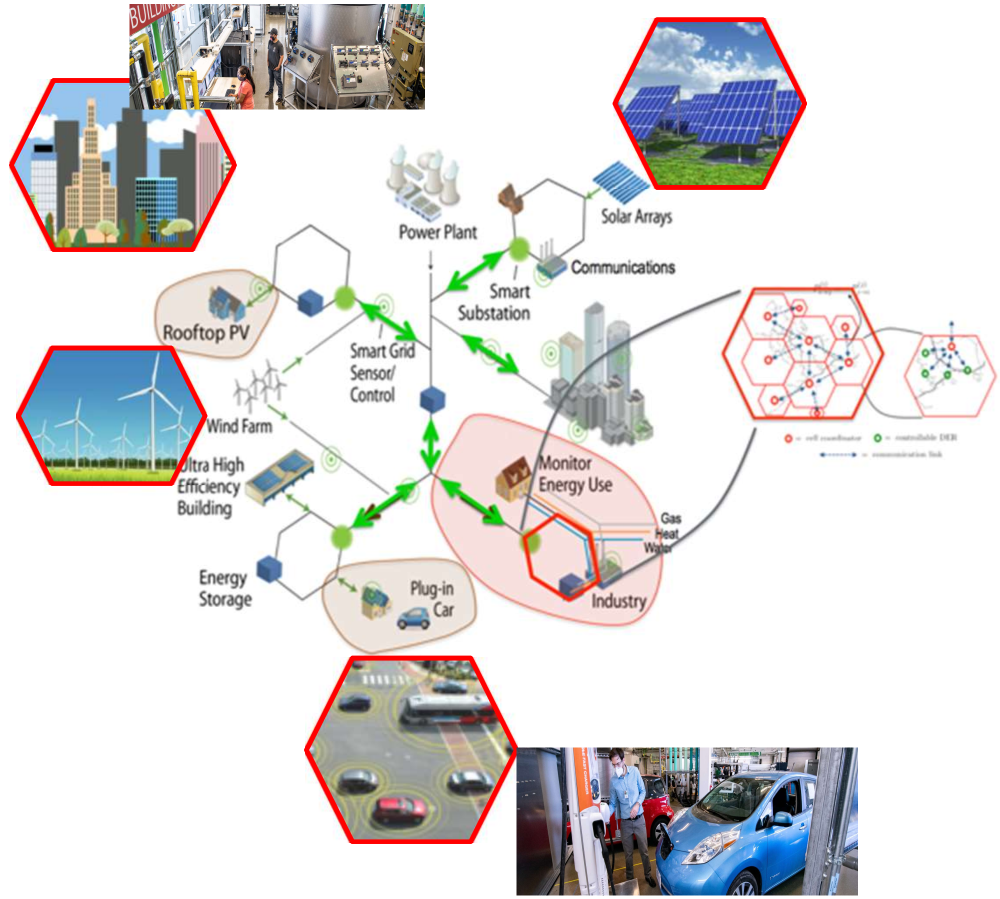
a. Consumer preferences
b. Environmental Justice
c. Economics/Markets
d. Health/environmental

Policy (IRA –tax credits etc.**)**

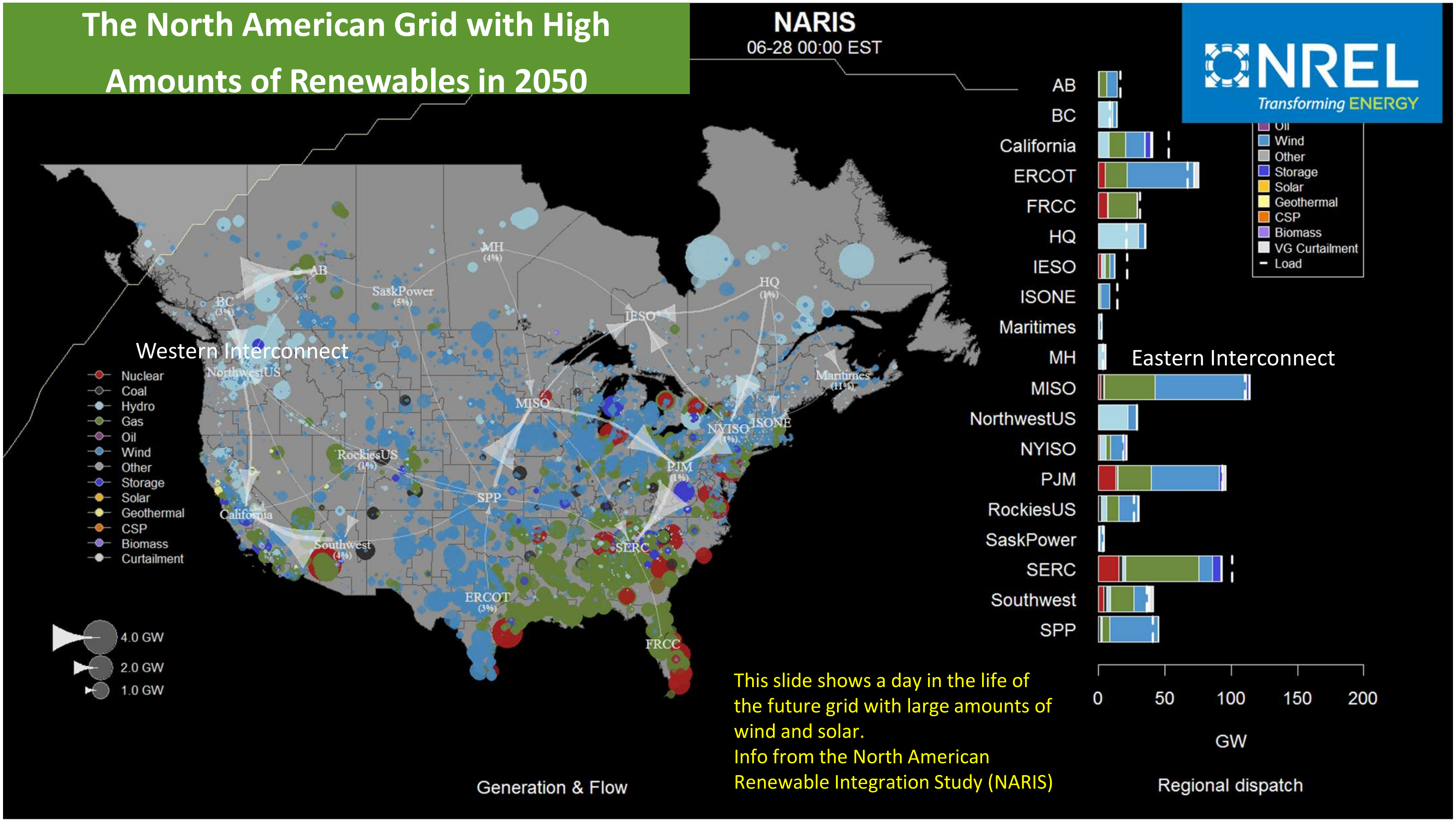
Ordinances (challenge)

Energy system of the future -Decarbonization

- Diverse power generation sources (inverter-based grid) -*High penetrations of wind and solar*
- Electrification –transportation, industry
  - Grid interactive buildings/communities
  - Different Storage technologies (*time scales)*
  - *Mobility…connectivity*
- Autonomous control of millions of devices
  - storage, distributed energy resources, smart appliances, EVs…
- Cyber and physical security, reliability, resilience
- **Low carbon fuels**: marine, rail, air
  - **Hydrogen infrastructure**
  - Carbon Capture, Storage
  - CO_2 conversion: Chemicals, materials, **fuels**



The North American Grid with High Amounts of Renewables in 2050



This slide shows a day in the life of the future grid with large amounts of wind and solar.
Info from the North American Renewable Integration Study (NARIS)

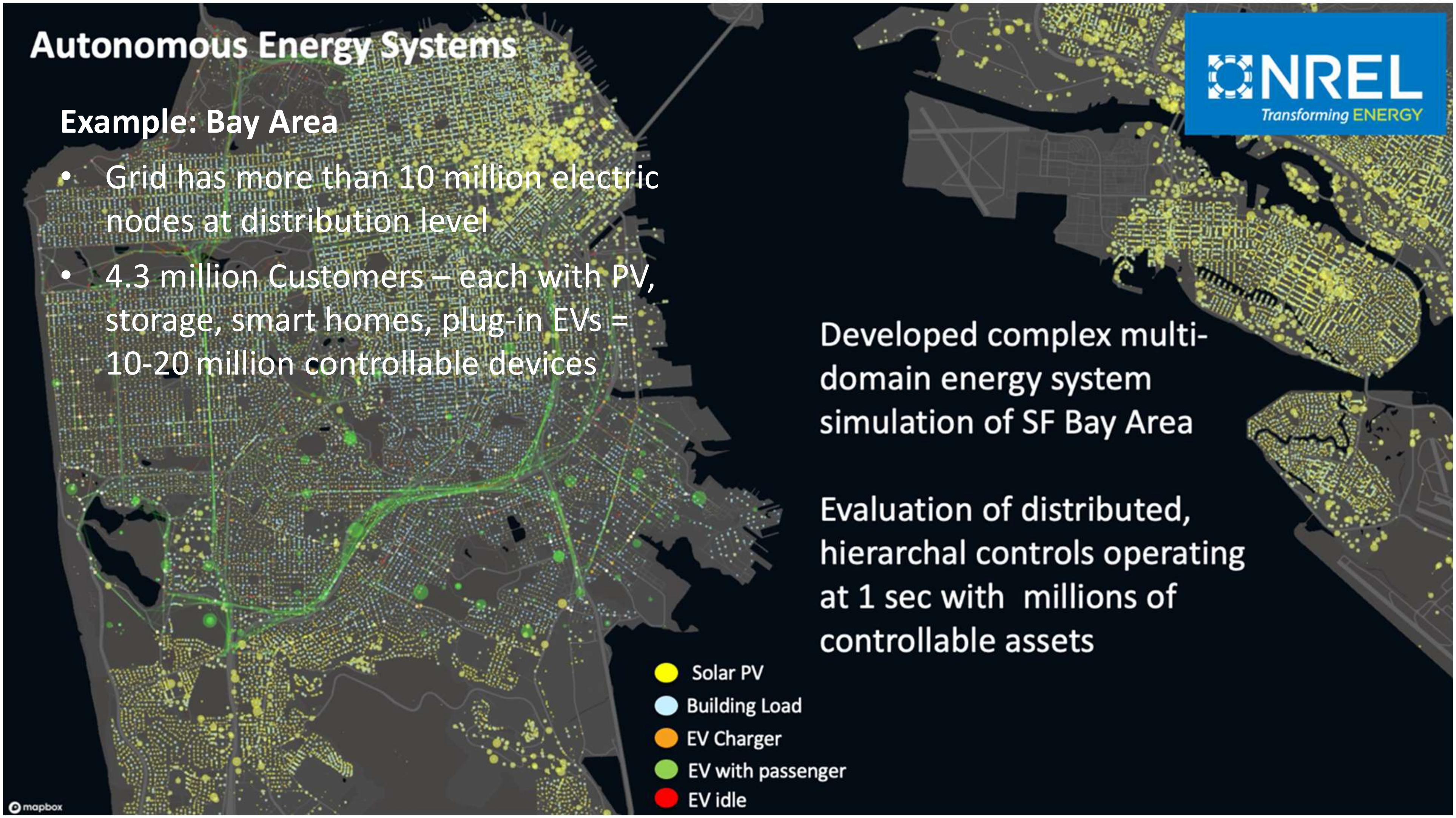
Autonomous Energy Systems

Example: Bay Area

- Grid has more than 10 million electric nodes at distribution level
- 4.3 million Customers – each with PV, storage, smart homes, plug-in EVs = 10-20 million controllable devices

Developed complex multi-domain energy system simulation of SF Bay Area

Evaluation of distributed, hierarchal controls operating at 1 sec with millions of controllable assets



NREL Transforming ENERGY

NREL Brings Distinct Capabilities

Foundational Science | Accelerated Technology Scale-Up | Systems | Markets

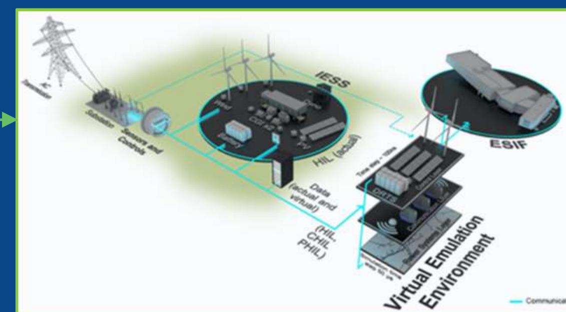
Bench-scale- discovery → Scaling R&D and Process Engineering → R&D with Industry Partners

Solar Energy Research Facility
Science and Technology Facility
Field Test Laboratory Building

Energy Materials and Processing at Scale (EMAPS)

Energy Systems Integration Facility

- Carbon-free H_2
- Products from electrochemical processes and CO_2
- Advanced Batteries
- PV, Wind, Water Power, Geothermal
- New Buildings and Industrial Materials, Manufacturing and Systems
- Grid and security tech



Advanced Research on Integrated Energy Systems

High Performance Computing, Simulation, and Visualization

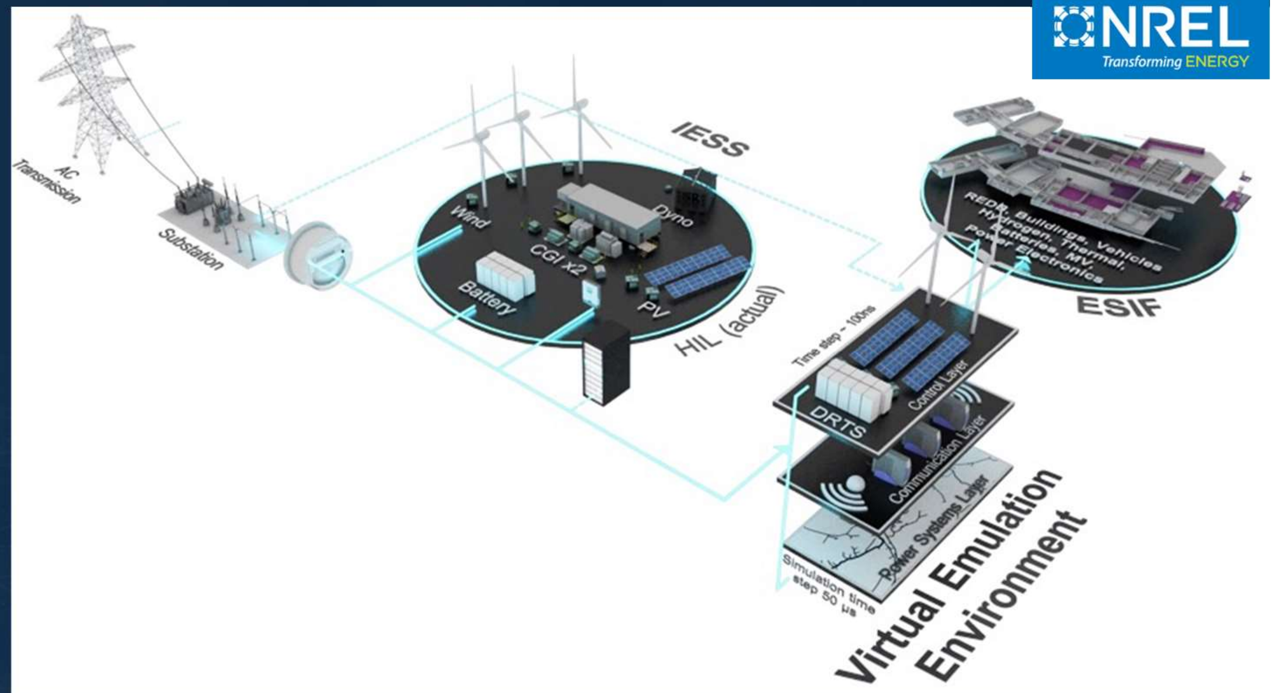
ARIES

Advanced Research on Integrated Energy Systems

ARIES is a research platform developed by the National Renewable Energy Laboratory and DOE's Office of Energy Efficiency and Renewable Energy.

A research platform that can support the nation's transition to a decarbonized energy system.

Mitigating risk, vulnerability, and expense to the electric grid and customers.



TRANSITIONING FROM COAL TO CLEAN ENERGY

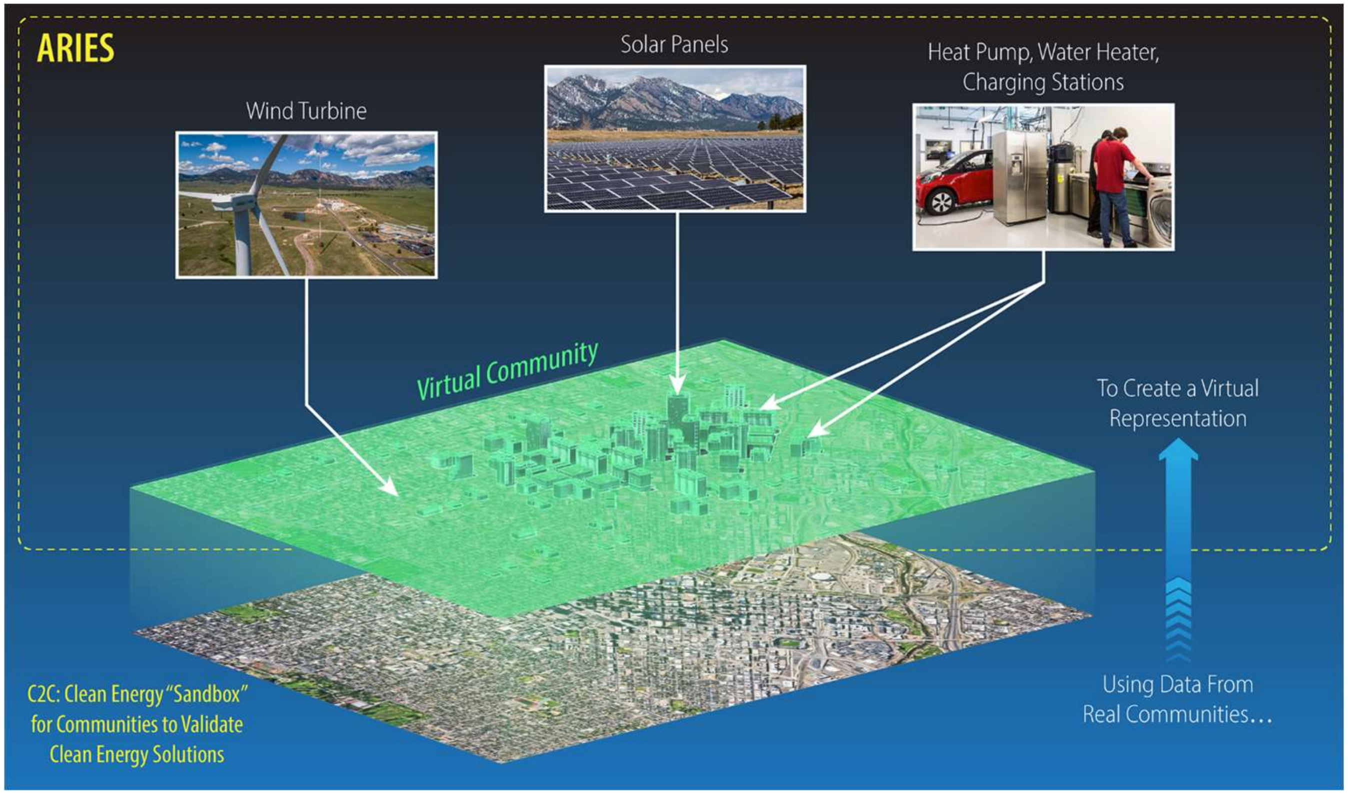
2023
R&D 100
AWARD
WINNER

"Simulation and Emulation for Advanced Systems (SEAS): Bridging the Gap Between Energy Transition Planning and Implementation."

Harsh winter conditions in Alaska affect energy reliance and cost. *Photo from Golden Valley Electric Association*

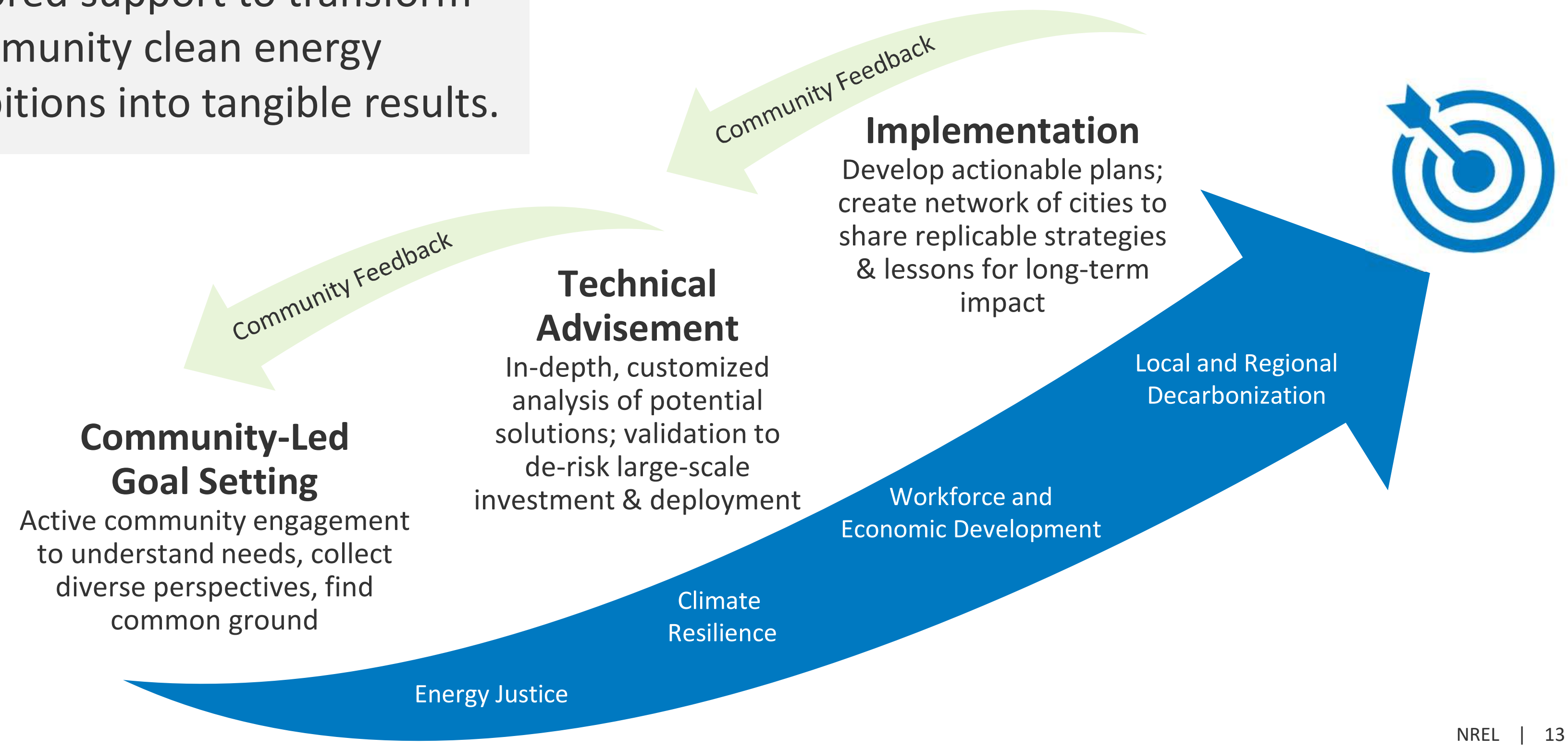
Led by NREL Research Engineer **Jennifer King (MTES)**

AN APPLICATION OF ARIES!

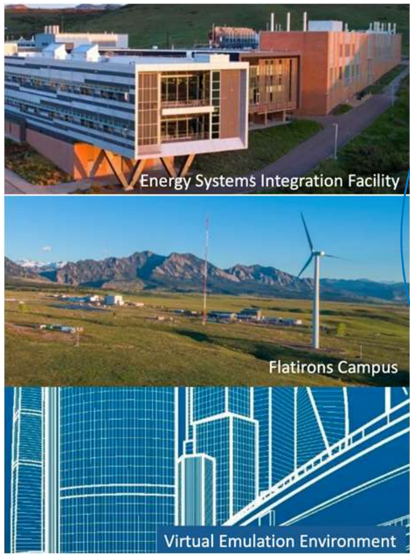


C2C: Clean Energy to Communities

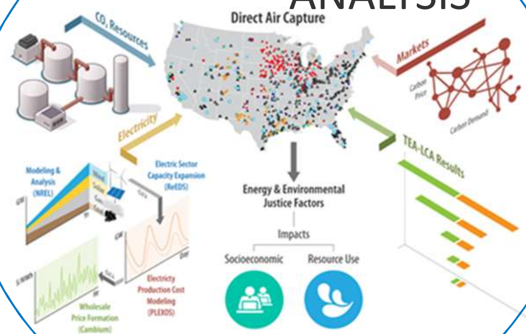
Tailored support to transform community clean energy ambitions into tangible results.



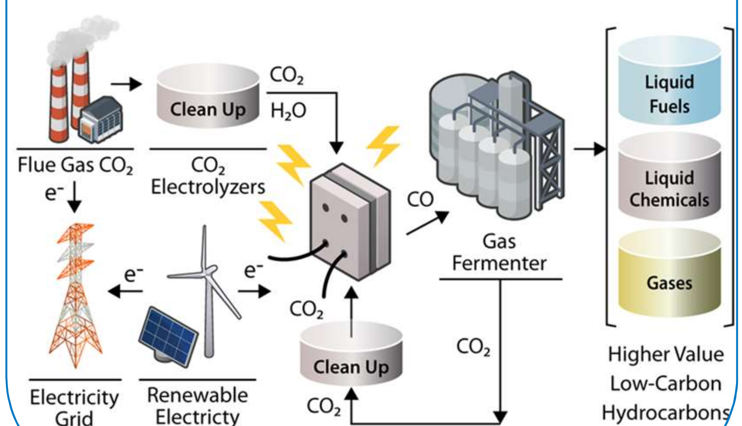
PROCESS INTEGRATION AT SCALE



ANALYSIS



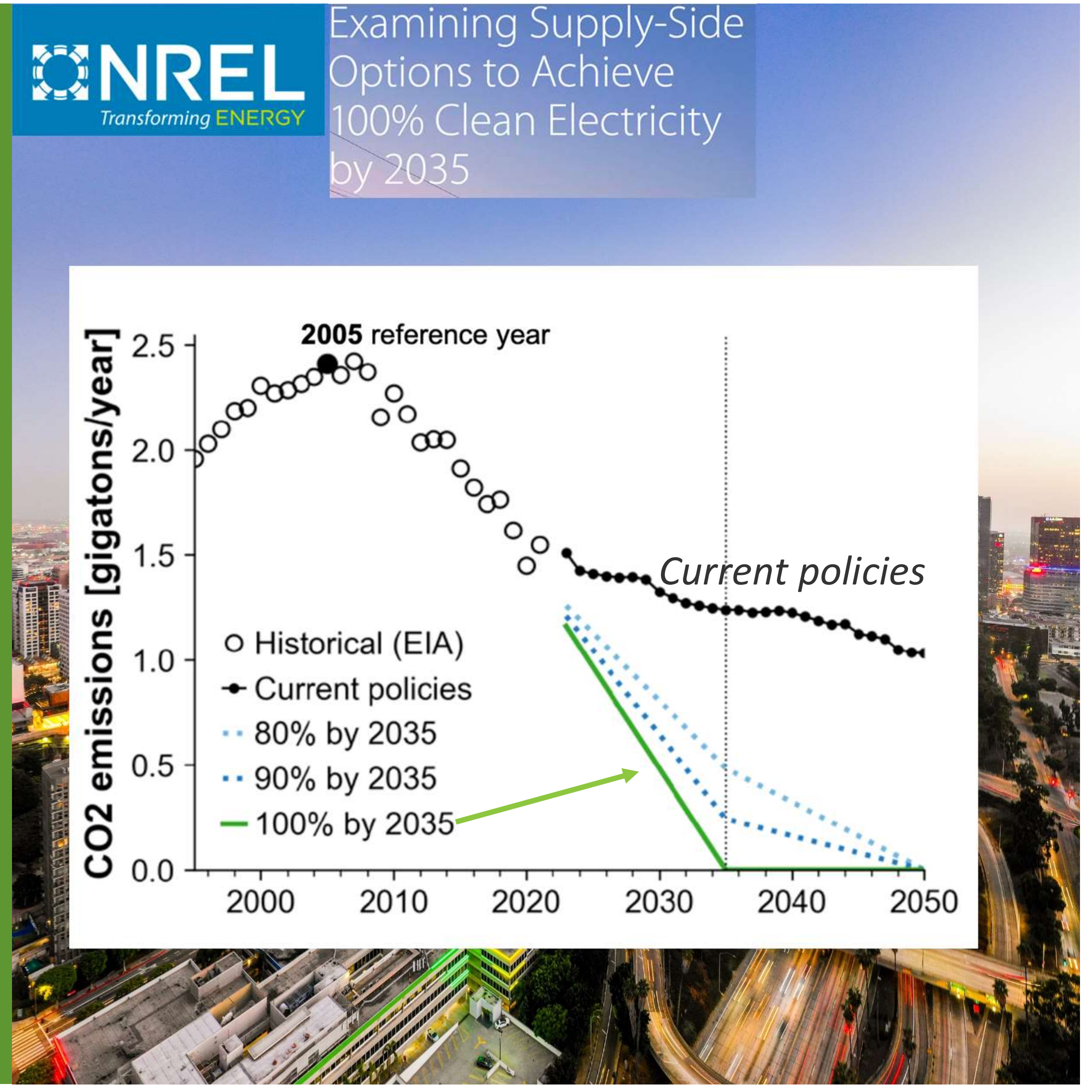
PROCESS INTEGRATION



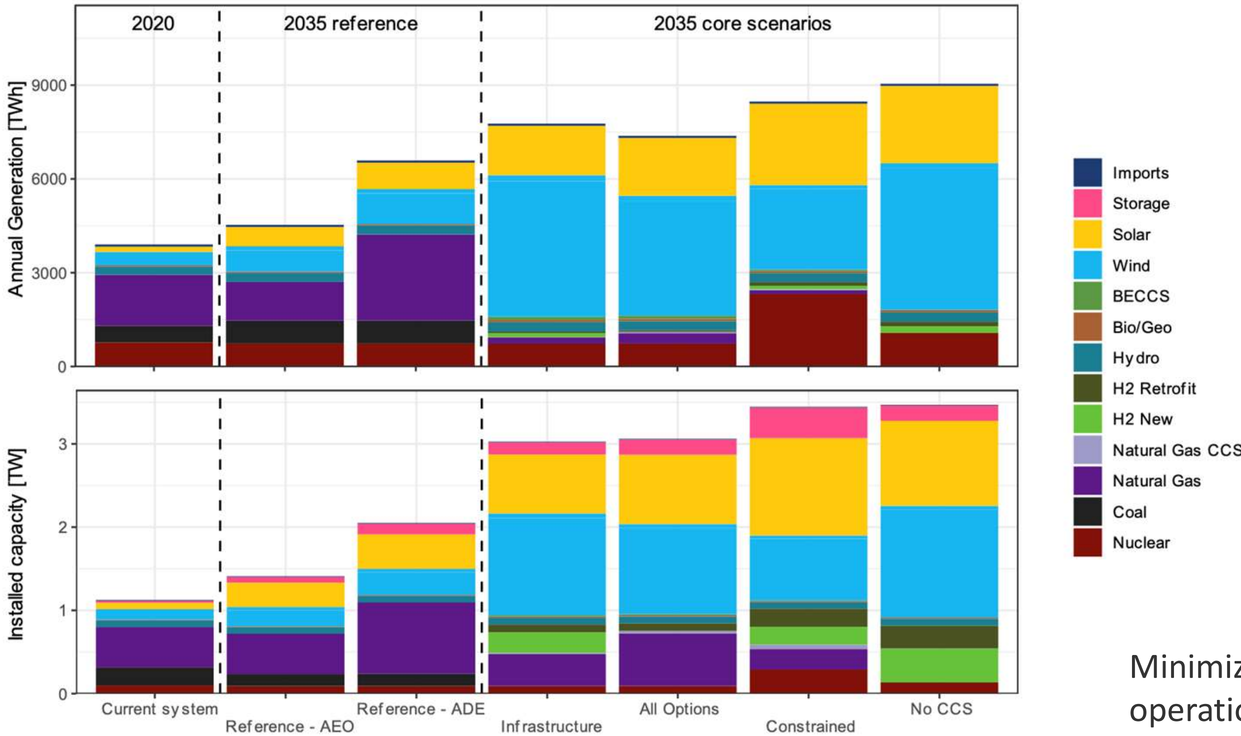
Potential Pathways

1. Electrify end-use technologies
2. Decarbonize the electric sector
3. Energy efficiency
4. Carbon capture, synthetic fuels

Regional energy deployment system (ReEDS)

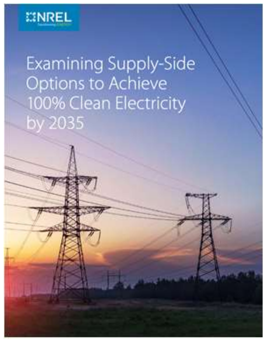


Technology Mix: Wind and Solar are most important in all scenarios (least cost scenarios)



2 TW of wind and solar will be required to meet the goals

Minimizes capital and operational costs



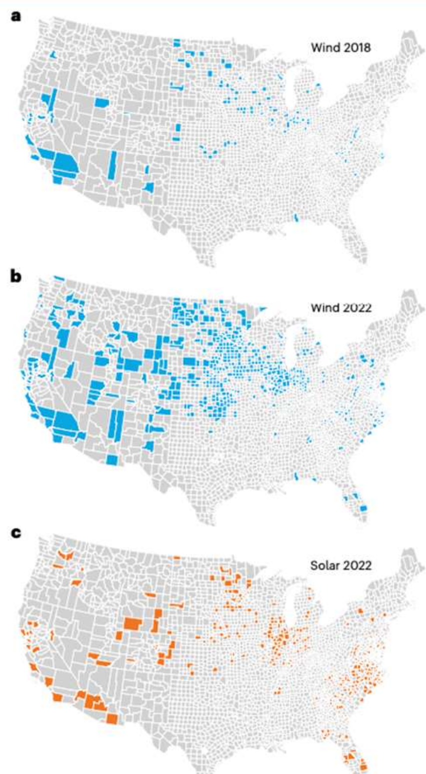
Siting ordinances, in every state, will limit the amount of available wind and solar

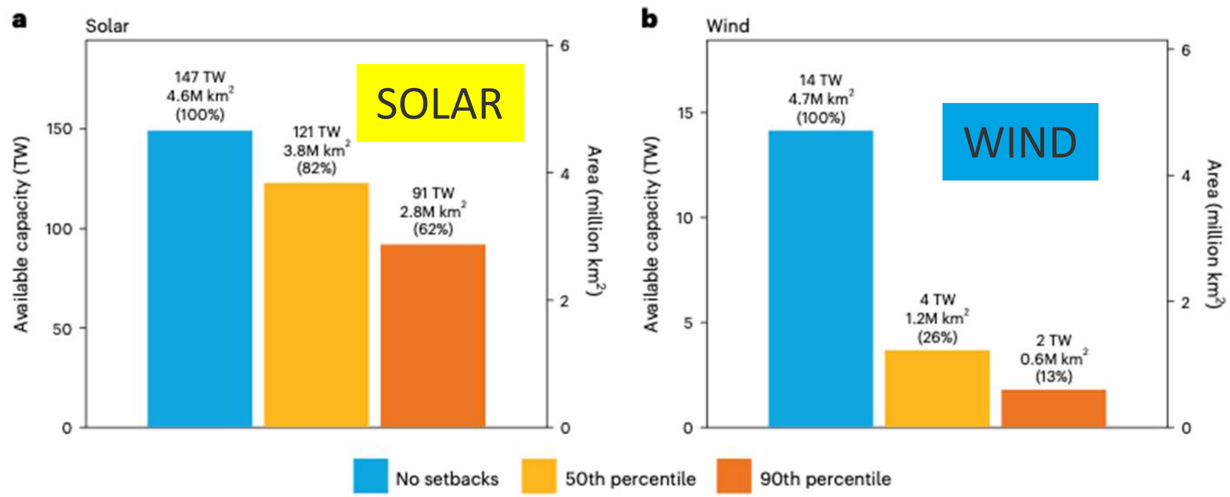
nature energy

Analysis

https://doi.org/10.1038/s41560-023-01319-3

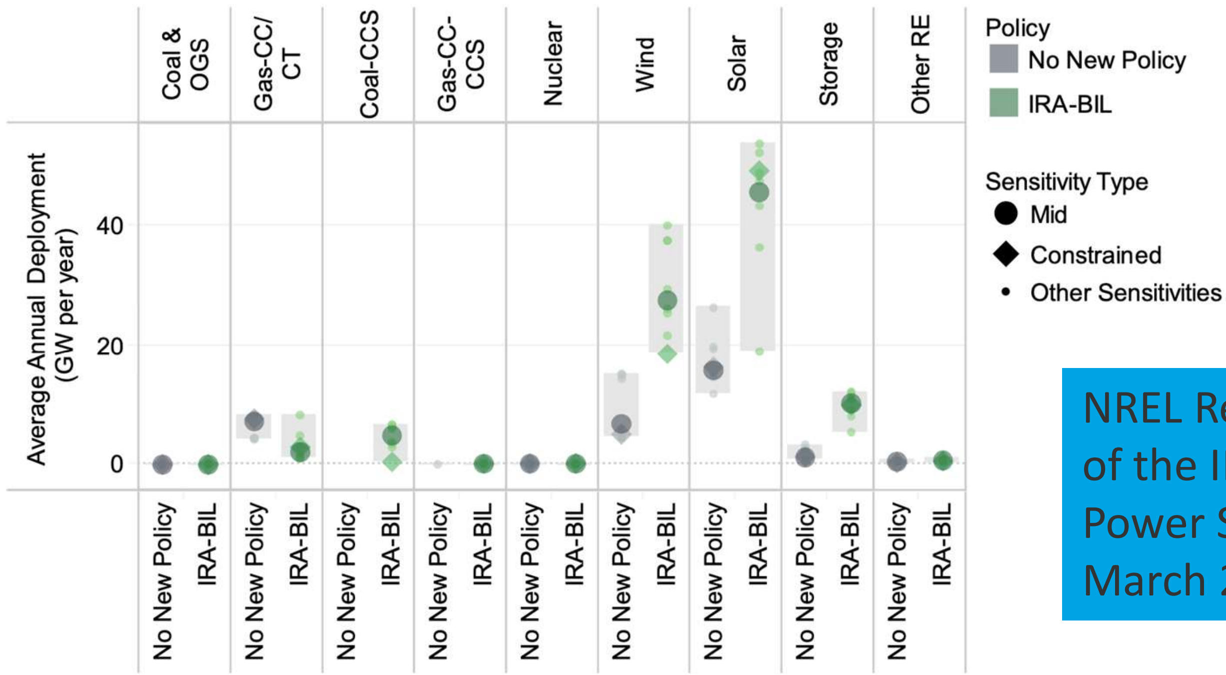
Impact of siting ordinances on land availability for wind and solar development





Restrictions on wind have increased from 2018 to 2022

Clean Electricity Generation Across IRA Analysis Scenarios



NREL Report: Evaluating Impacts of the IRA and BIL on the US Power System, Steinberg et al. March 2023

The inclusion of IRA drives clean electricity to capture 71%-90% of total generation by 2030, where the range reflects the different sensitivities explored

See also

POLICY FORUM

ENERGY AND CLIMATE POLICY

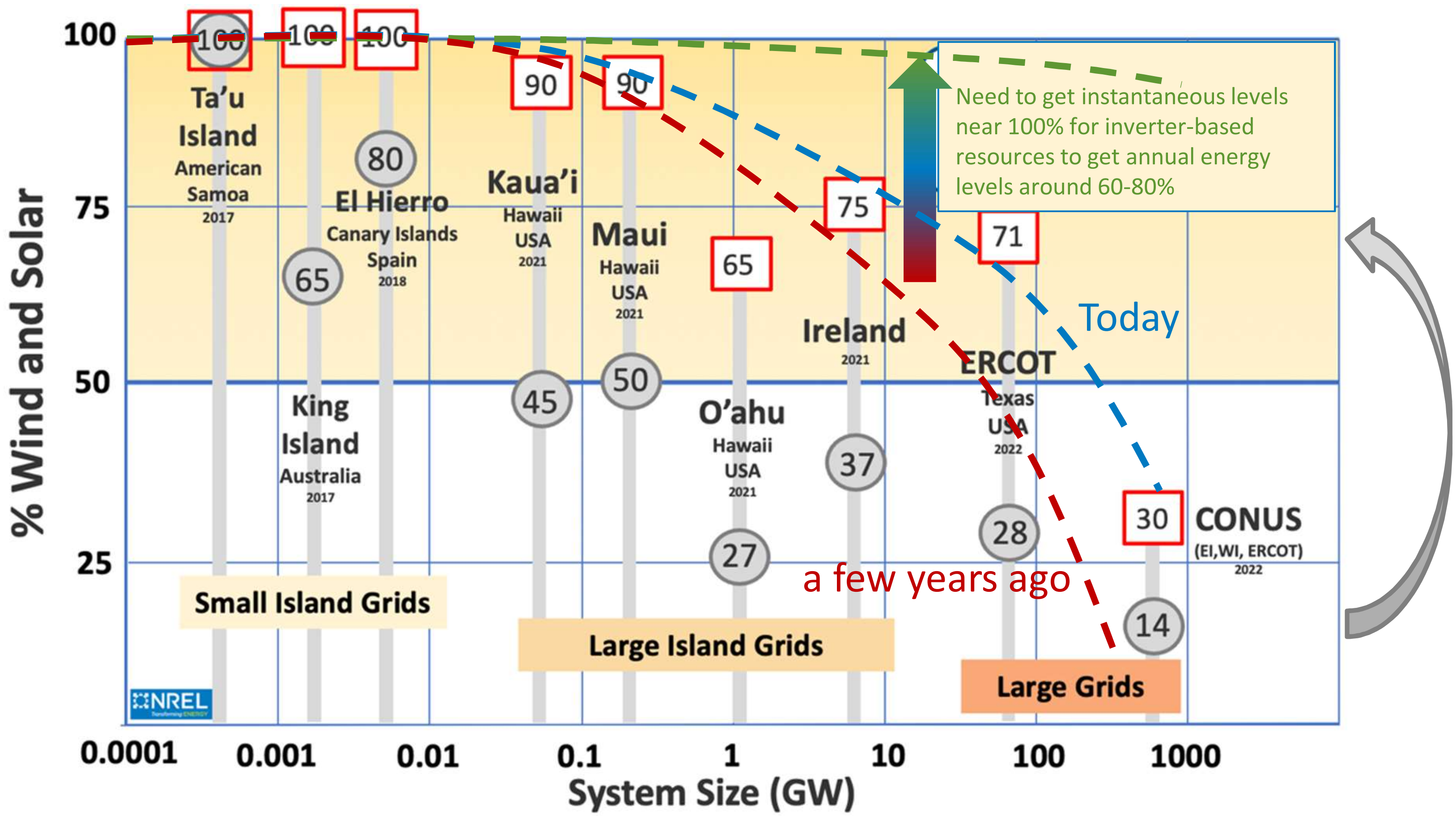
Emissions and energy impacts of the Inflation Reduction Act

Economy-wide emissions drop 43 to 48% below 2005 levels by 2035 with accelerated clean energy deployment

Science

30 JUNE 2023 • VOL 380 ISSUE 6652

What we know about integrating wind and solar



Challenges for Increasing variable renewables on the grid

Techno-Economic

- **Availability**: Renewable resources local and global
- Raw material resources for technologies

Supply vs. Demand Balance

Variability and Uncertainty of Generation
- Operating Reserves
- Unit Commitment and Dispatch

- Cyber and Physical Threats

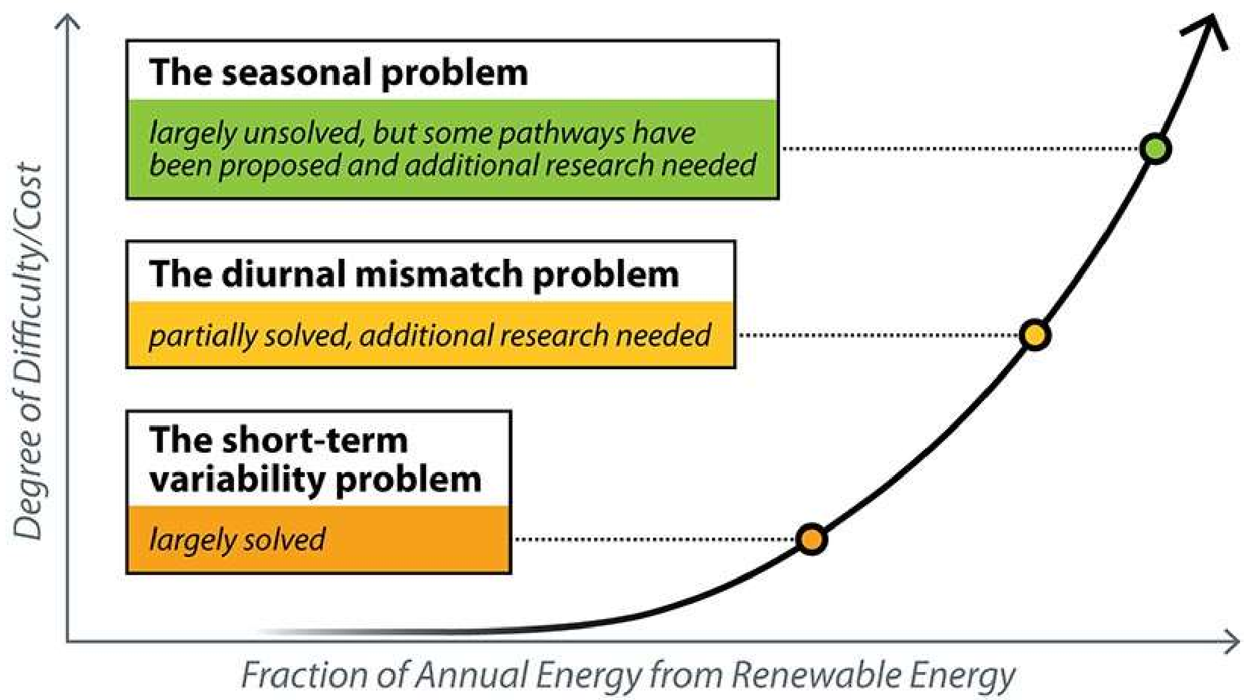
Engineering

Grid Stability

Other Grid Considerations
- Blackstart capability

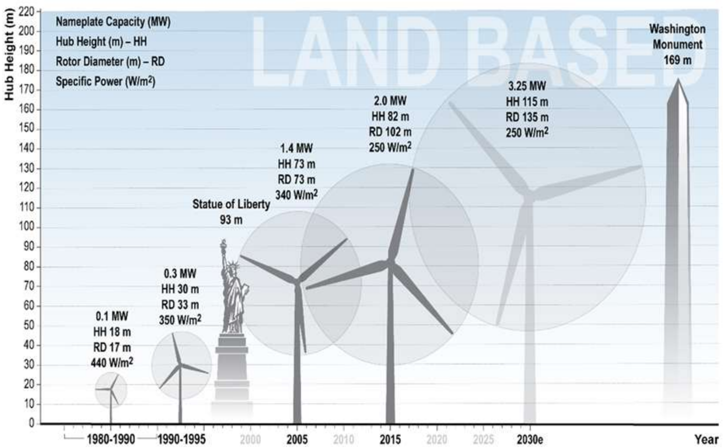
The S&T community has developed strategies to address the technical challenges

Three Timescales of the Balance Challenge




NREL
Transforming ENERGY
Thank you

In the future wind blades will be made of thermoplastic polymers



Circular Economy solutions

Renewable Energy 131 (2019) 111–119

Blades in a landfill

Thermoplastic Blade
Readily recycled

Hydrogen production using offshore wind