



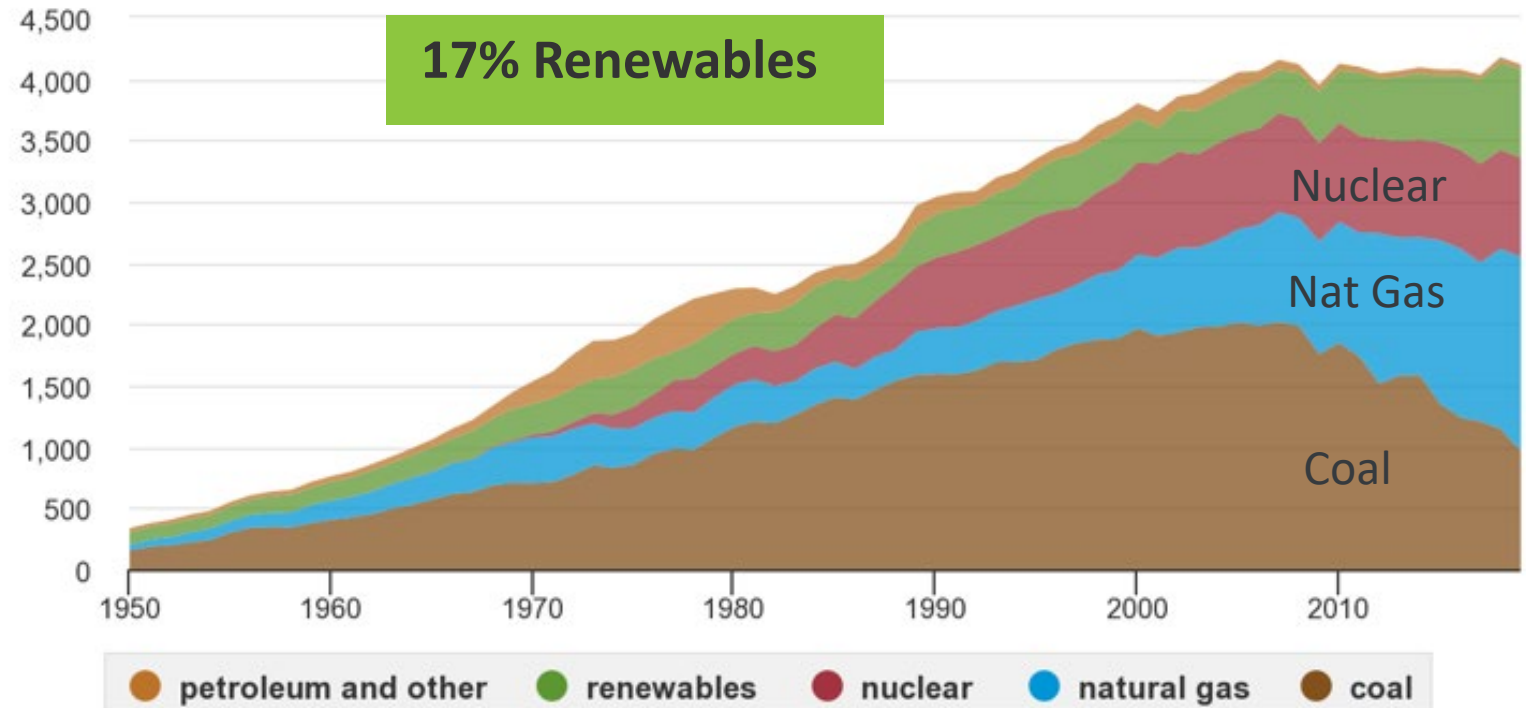
Towards the Energy System of Tomorrow
EESI Panel

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Energy Systems Integration

The US Energy Supply is Shifting

U.S. electricity generation by major energy source, 1950-2019

billion kilowatthours



Note: Electricity generation from utility-scale facilities.



Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 7.2a, March 2020 and *Electric Power Monthly*, February 2020, preliminary data for 2019

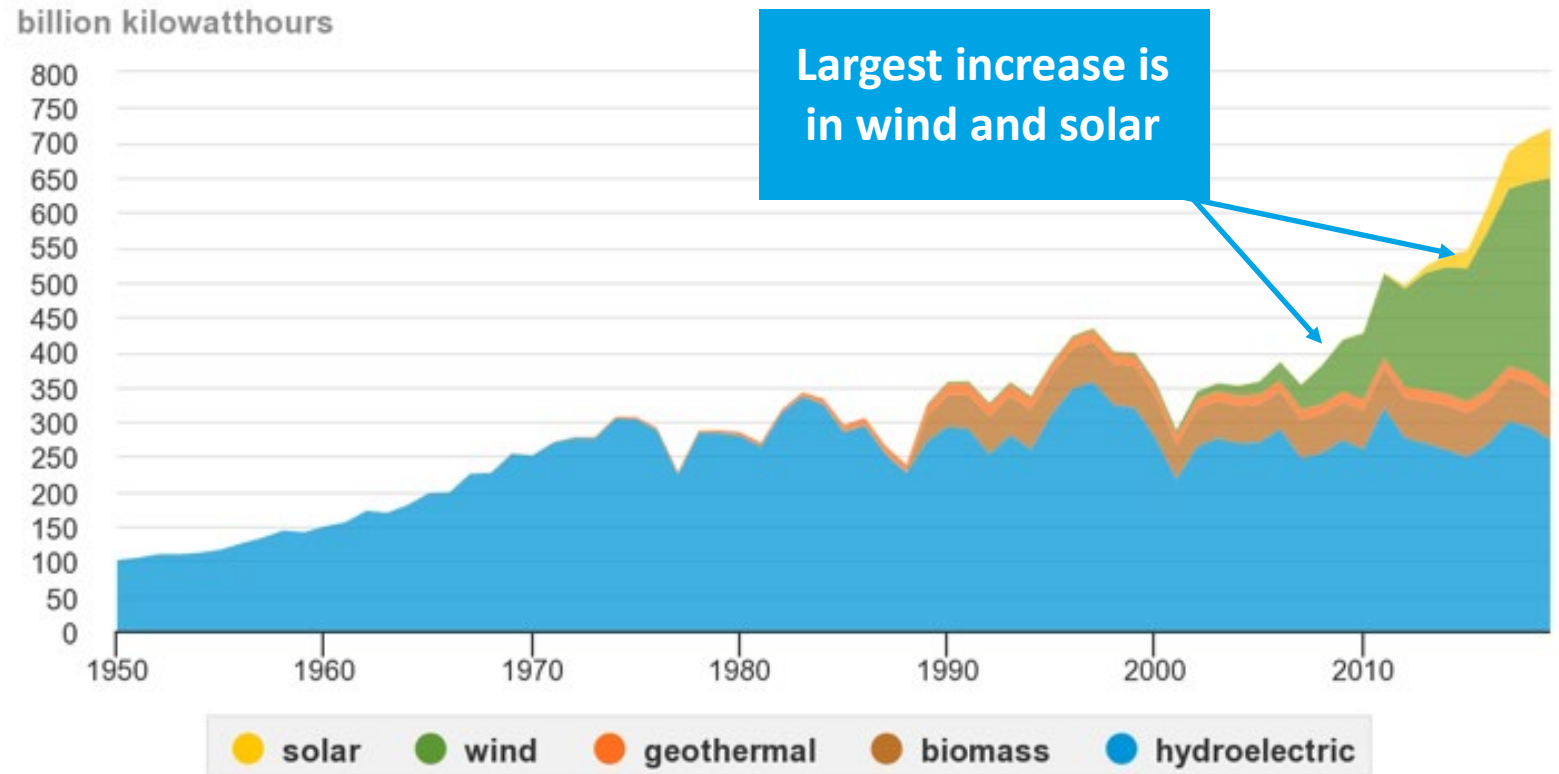
The US Energy Supply is Shifting

Renewable Energy

In 2019, 17% of annual electricity was from renewable sources.

- 7% Wind
- 7% Hydro
- 2% Solar
- 1% Biomass
- 0.5% Geothermal

U.S. electricity generation from renewable energy sources, 1950-2019

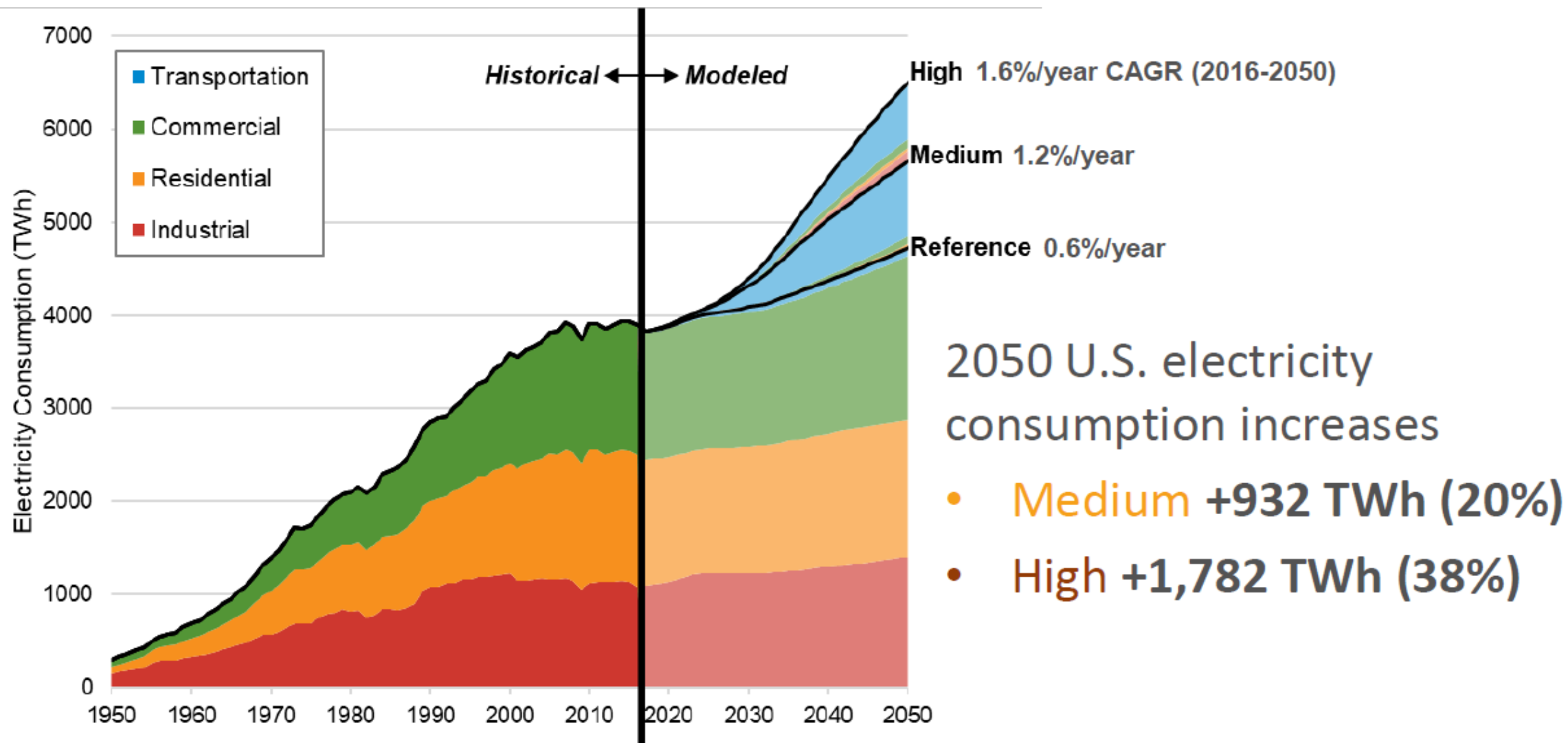


Note: Electricity generation from utility-scale facilities. Hydroelectric is conventional hydropower.

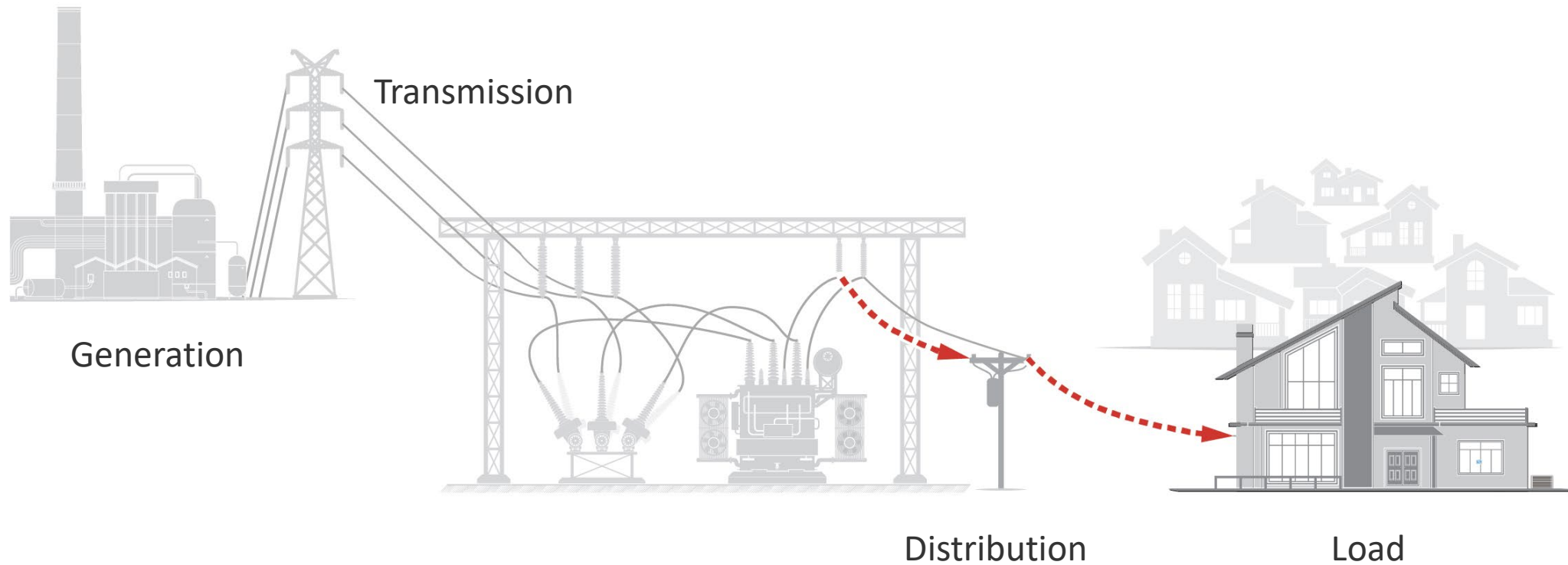


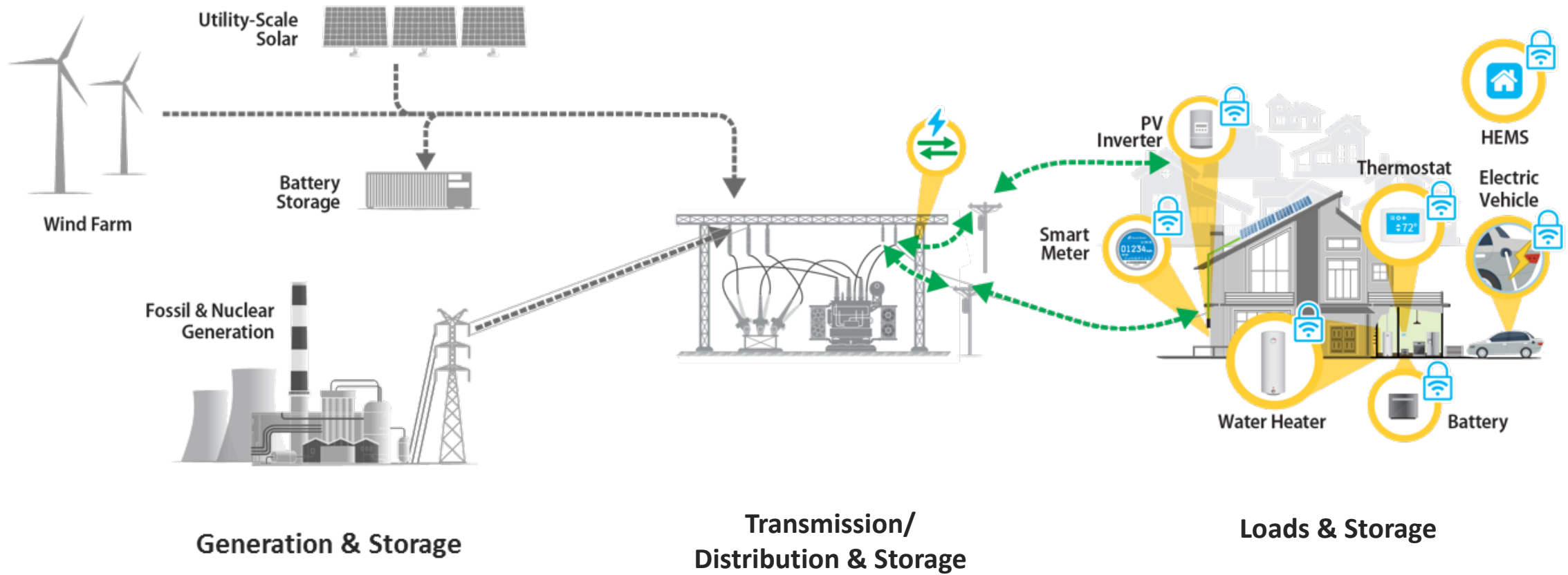
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 7.2a, March 2020 and *Electric Power Monthly*, February 2020, preliminary data for 2019

Vehicle electrification dominates incremental growth in annual consumption



The Grid of the Past





The Grid is Changing

Power Electronics-Based Energy System Operating with Less Inertia

Generation

- Solar PV, wind, microturbines, fuel cells use power electronics (PE) interfaces to connect to the grid
- Over 50% PE generation by 2050
- Other bulk source work synergistically

Storage

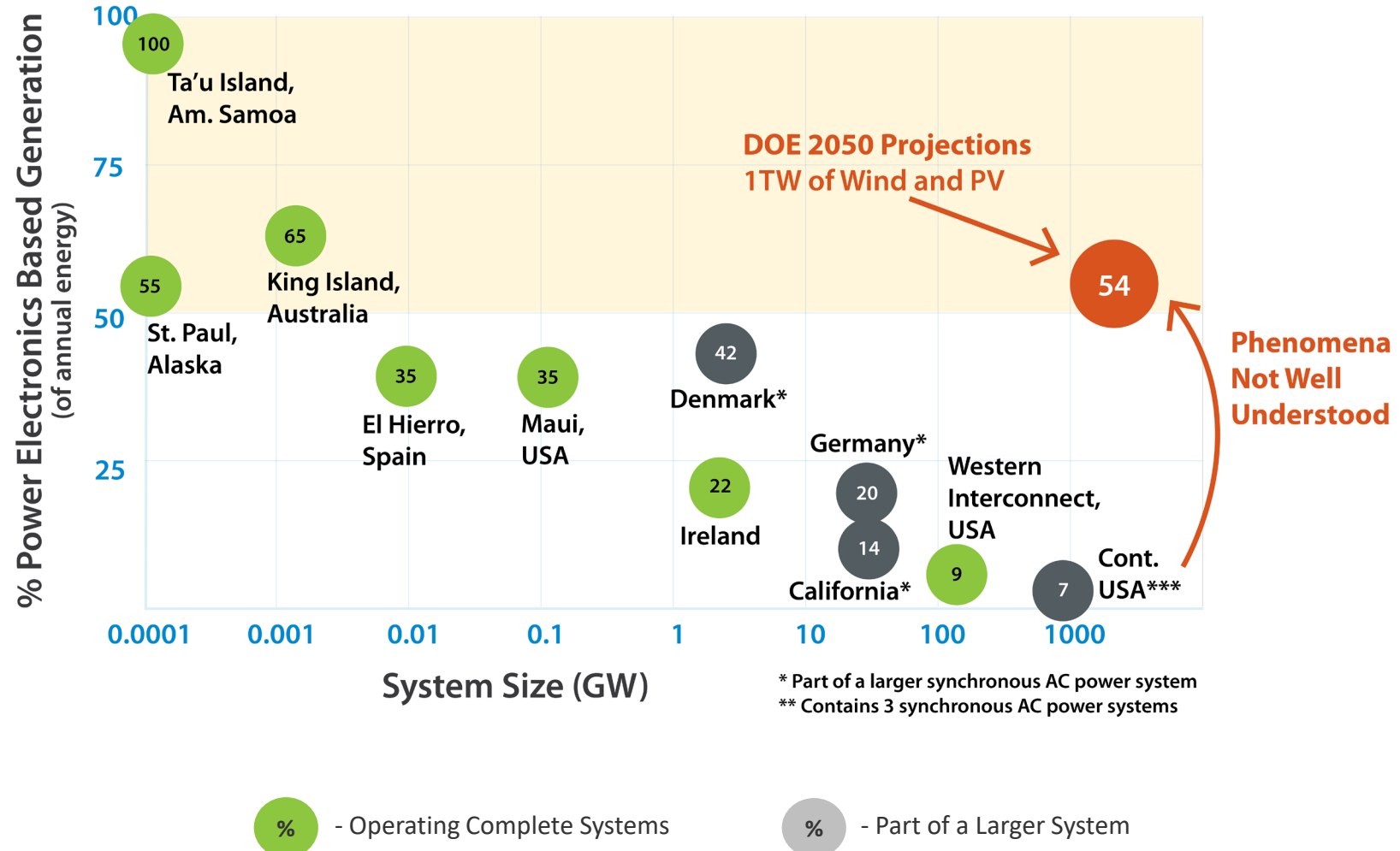
- Batteries use PE interfaces to connect to the grid
- Pumped hydro can add PE to increase controllability and provide grid services

Building Loads

- Over 60% of major home appliances expected to be PE-based by 2021
- Lighting switching to LEDs
- Variable speed drives for motors

Mobility

- EVs – 7 million by 2025
- MD/HD – Electrifying

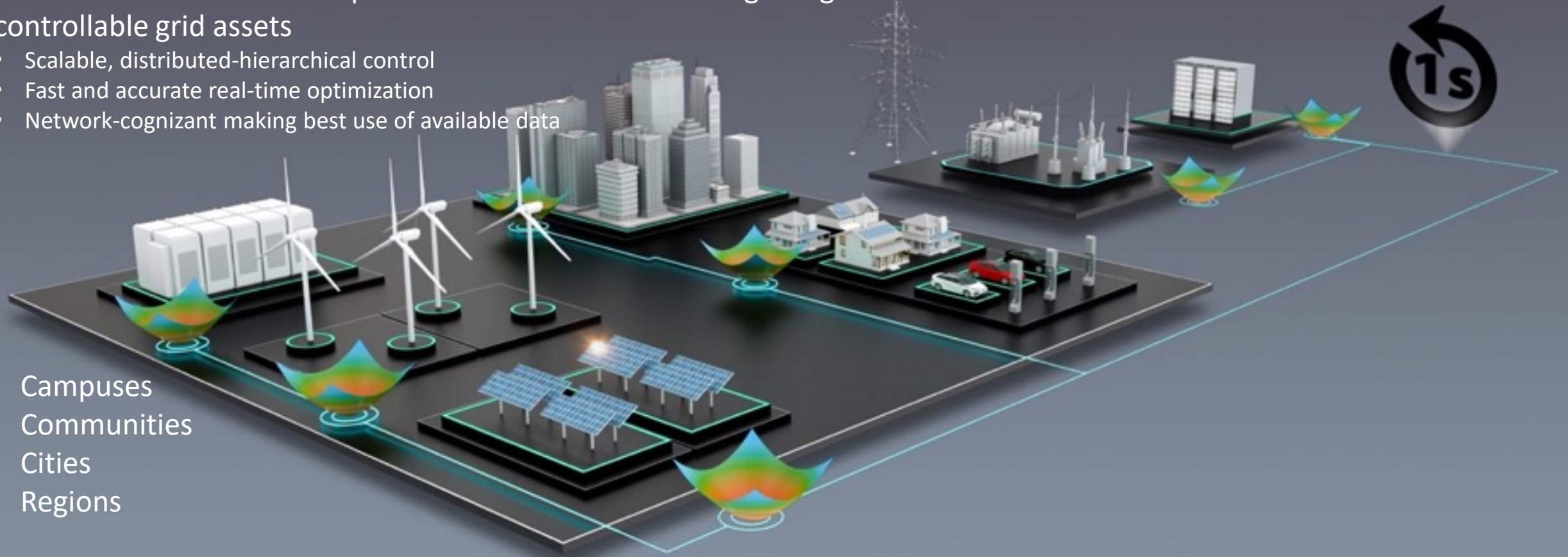


Advancements in AI and Autonomous Energy Systems (AES)

NREL's AES Research developed advanced controls for integrating hundreds of million controllable grid assets

- Scalable, distributed-hierarchical control
- Fast and accurate real-time optimization
- Network-cognizant making best use of available data

- Campuses
- Communities
- Cities
- Regions



Enabling large-scale deployment of distributed energy resources (EVs, Buildings, Generation) through advancements in optimization, control, data analytics, and complex system simulation



LA100

The Los Angeles 100% Renewable Energy Study

Detailed, ultrahigh resolution analysis evaluating a range of future scenarios to equip LA decisionmakers to understand:



What are the **pathways and costs to achieve a 100% renewable electricity supply** while electrifying key end uses and maintaining the current high degree of reliability?



What is the **impact on the environment**?



How might the **economy and rates** respond to such a change?

Sources of Energy System Disruption



Natural Disasters



Space Weather



Physical Threats



Electromagnetic
Pulse



Cyber Threats

Natural Hazards

Human Threats

Thank You

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