

# Building the Grid for the Future: Climate Resilience, Affordability, and Growth



Image: Gray Line

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# The Scott Institute for Energy Innovation is Carnegie Mellon's campus-wide energy research institute

- We have over **180 faculty affiliates** and **15 Energy Fellows**
- Our mission: **We seek to encourage the development of technologies, systems, and policies that will accelerate the transition to a sustainable, net-zero emissions future.**



# How Policymakers Use Energy and Climate Research

- **Diplomatic:** Overall commitment setting and foreign policy
- **Policy:** Support for domestic legislative or executive policy
- **Regulatory:** Assessing benefits and costs of proposed regulations
- **Budget:** Allocating deployment and R&D investments and directions
- **Distributive:** Assessing equity impacts
- **Societal:** Projected benefits and positive impacts relative to a baseline

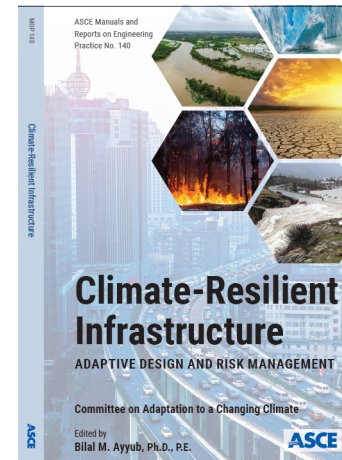
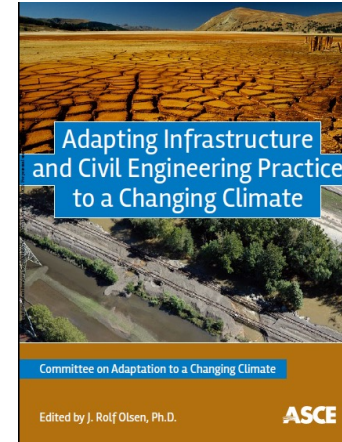


# Deep uncertainties and systems impacts associated with the decisions to address physical and transition risks

- Some uncertainties involve **data**
  - What precipitation or temperature extremes should a utility plan for? How much will SMRs cost?
- Some involve **technologies**
  - How will vehicle automation and AI affect emissions trajectories or peak power demand?
- Some of involve **social systems**
  - How will climate change and technology adoption rates change, who pays, and who benefits?

# Energy and Supply Chain Infrastructure Has Exposure and Vulnerabilities to Multiple Climate Threats

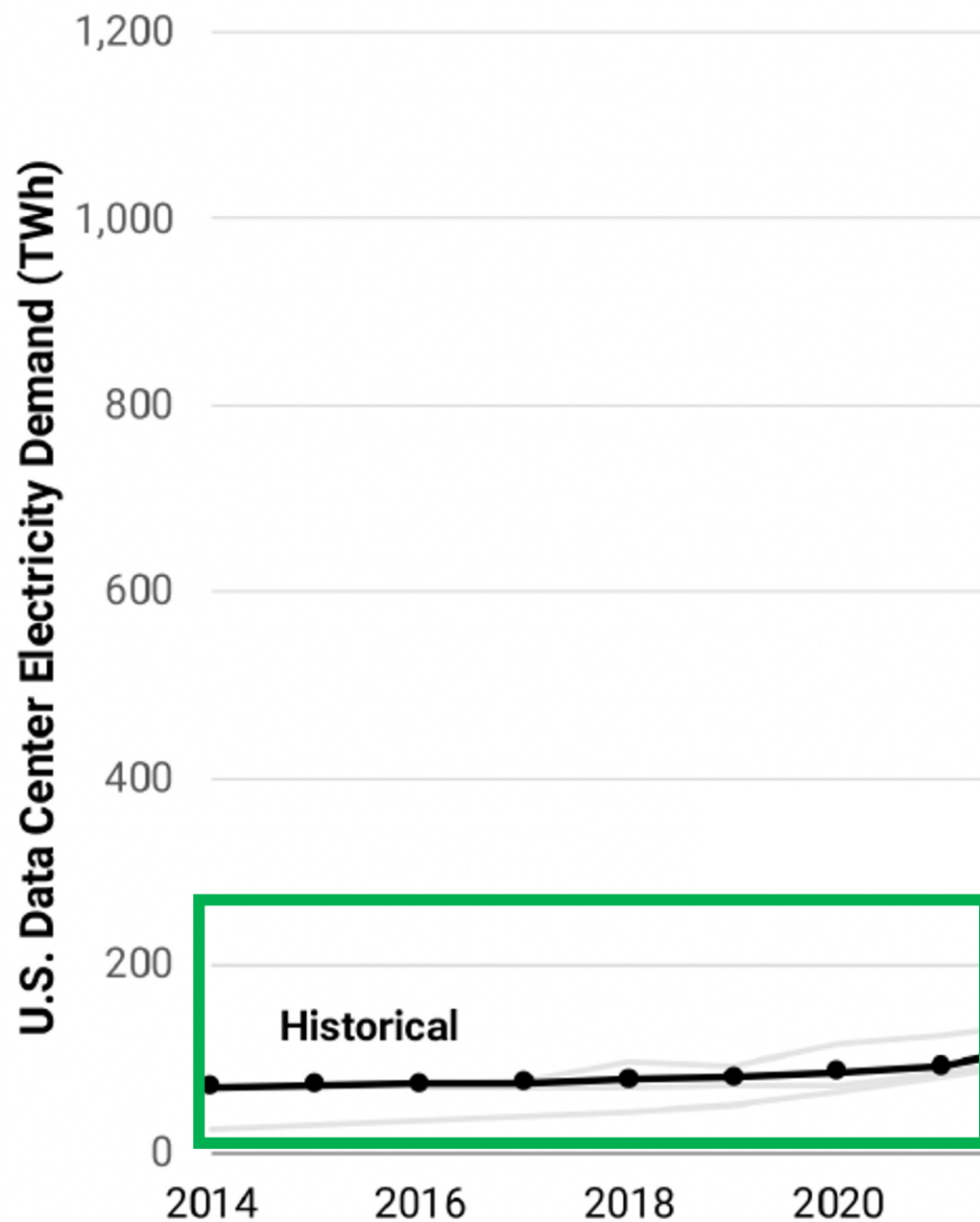
**Increases in extreme heat**  
**Heat waves**  
**Changes in arctic temperatures**  
**Rising sea levels**  
**Storm surge**  
**Extreme precipitation events**  
**High winds**  
**Drought**  
**Wildfires**  
**Earlier snowmelt**  
**Reduced snowpack**



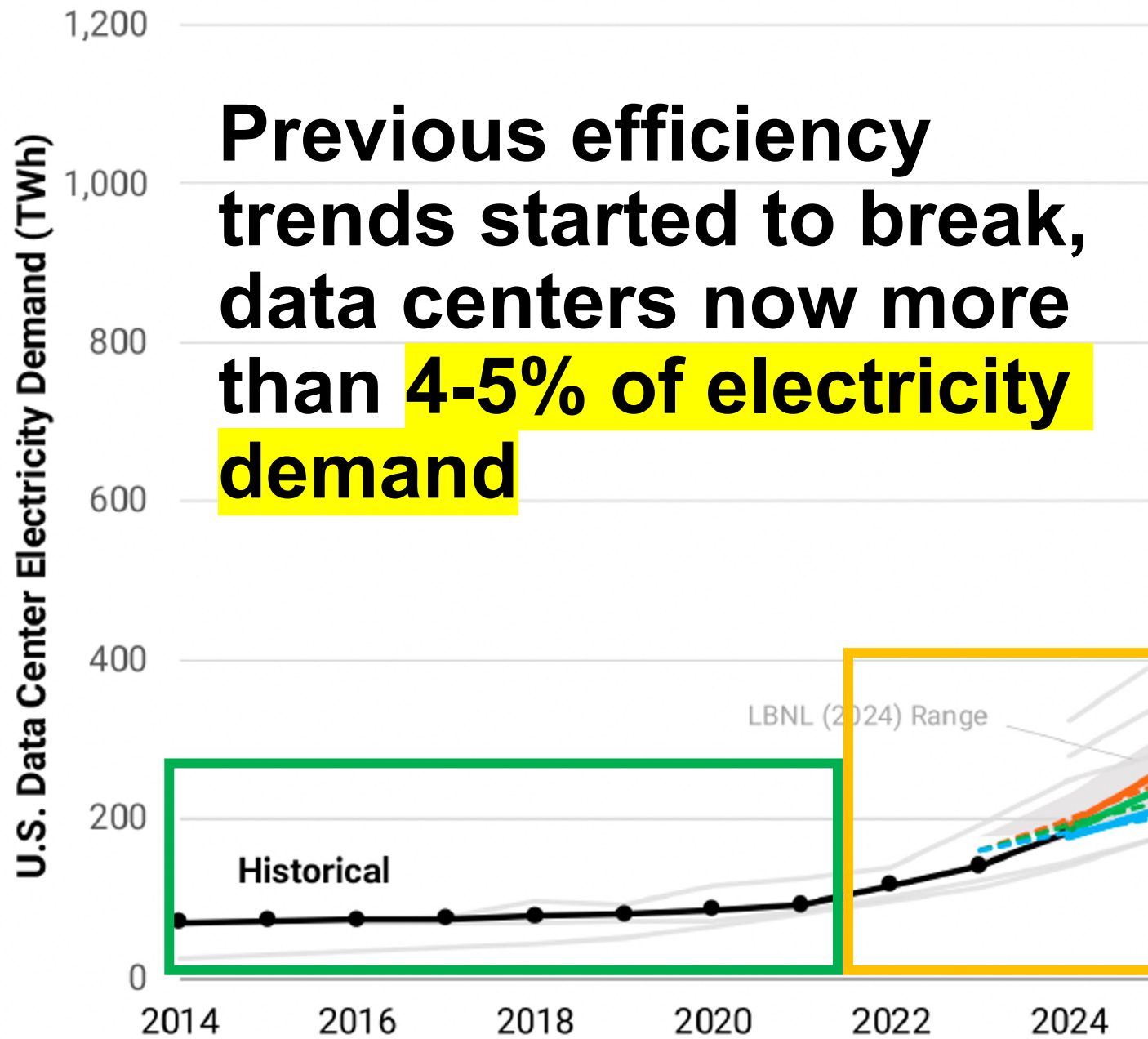
**Do Now What  
We Would Not  
Regret Later**

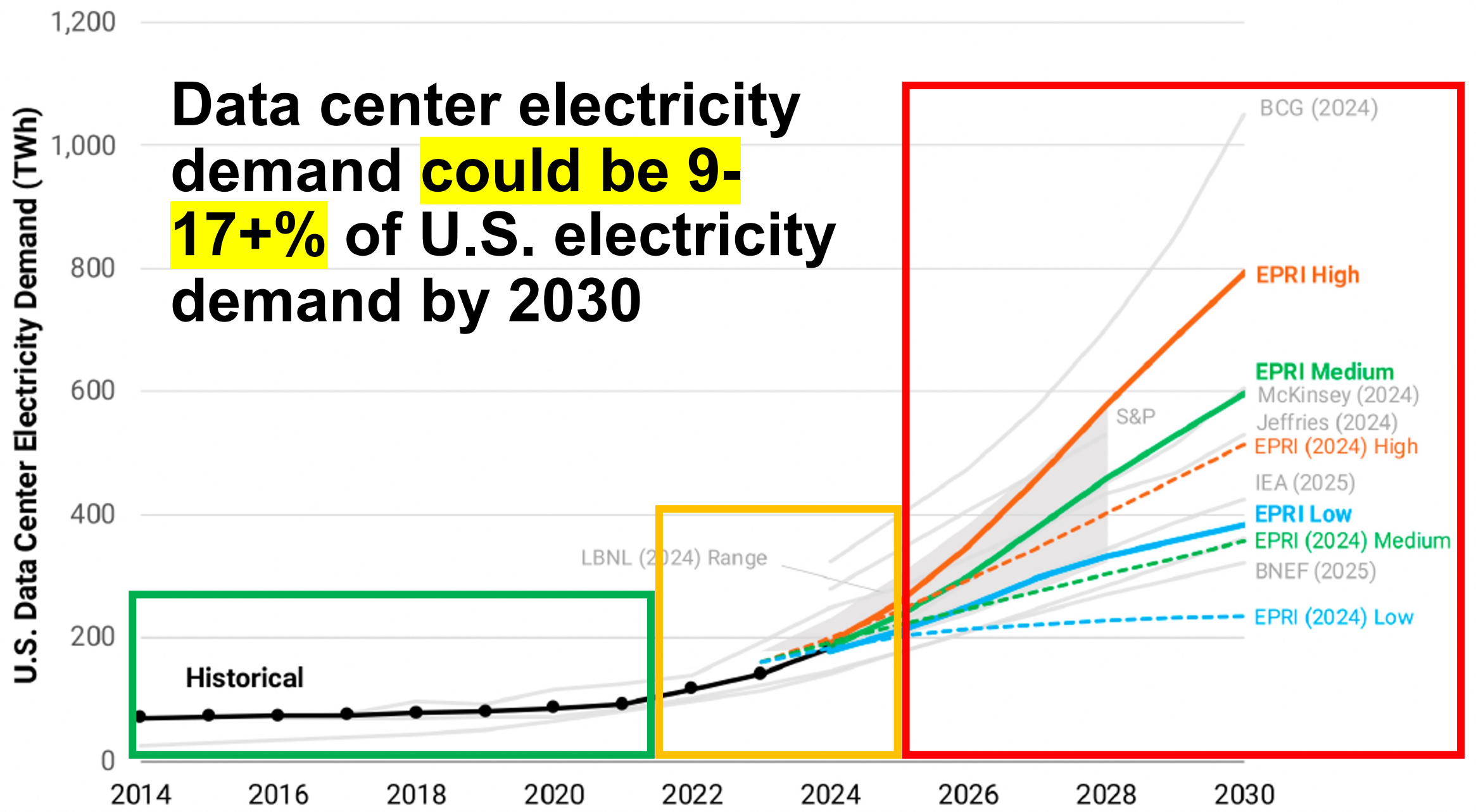
# AI and Infrastructure Choices Determine Next Two Decades of Energy, Economic, Resilience, and Environmental Outcomes <sup>7</sup>

- Electricity is the security infrastructure of this century, but the grid is vulnerable and residential electricity prices are **growing faster than inflation**.
- AI data centers are driving near-term electricity growth, but **electric infrastructure buildout will influence capabilities and feasibility of electrification**.
- AI **has the potential to improve energy, climate, and affordability outcomes** but requires focused policy and public-private partnerships.



From 2010-2020, global internet traffic increased 17-fold but data center energy use only increased 10%



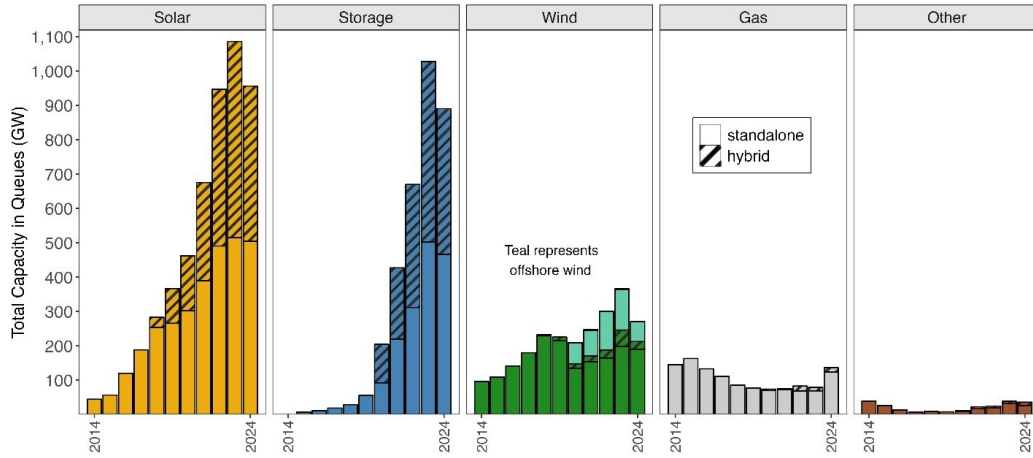


# Fossil-Fired Backup Generation Raises Local Pollution, and Water Consumption Creating Challenges In Some Areas

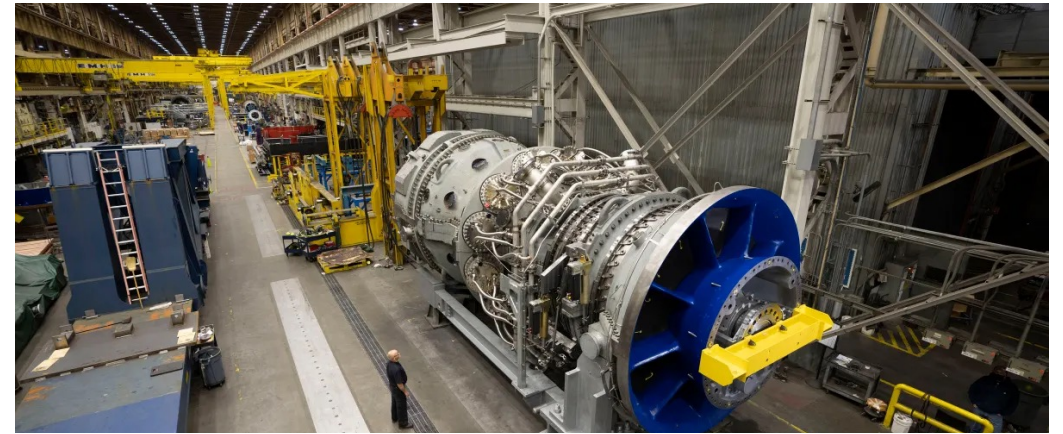


# AI Model Training Can Require Months of Continuous Operations, AI Buildout is Straining Energy System Supply

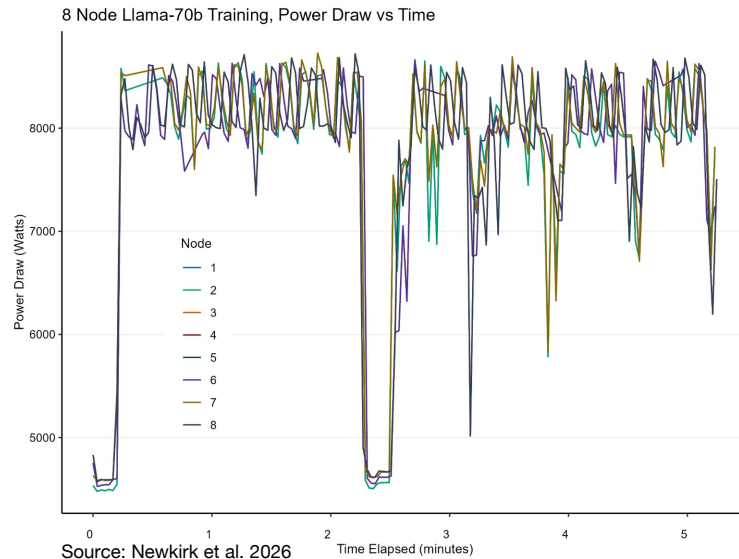
## Interconnection Queue (LBNL, 2025)



## Natural Gas Turbine Backlog (Anderson, 2025)



## Transient and Power Fluctuations (Newkirk et al., 2025)

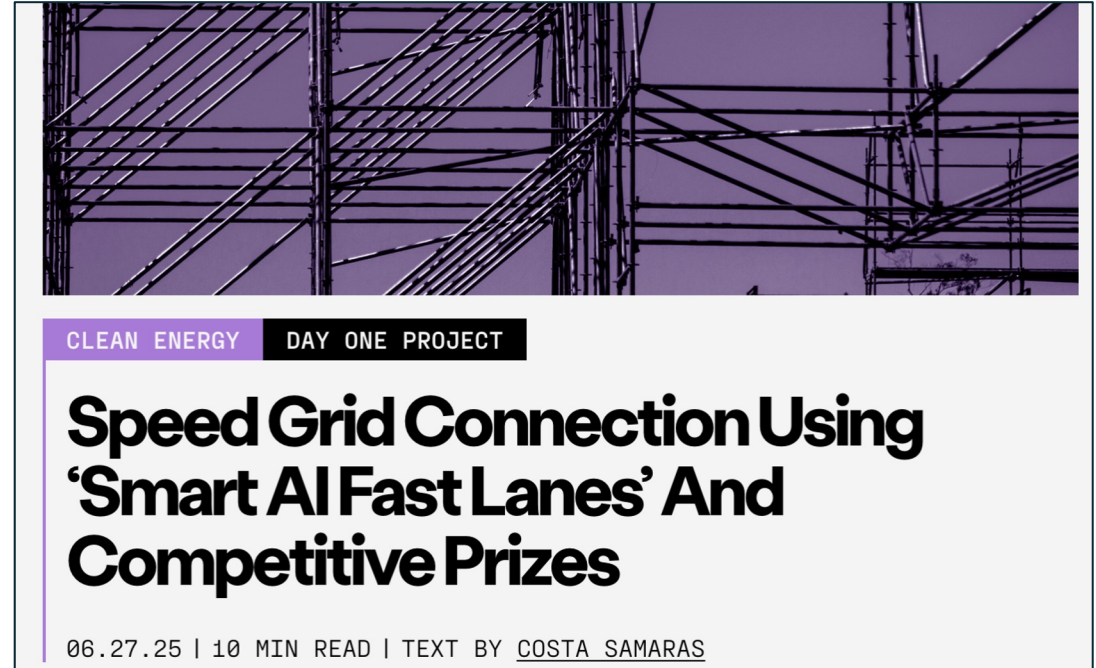


## DC Power Systems Advantage (Emerge Alliance 2013)



# Need Clean Supply, “MPG efficiencies”, Resilient Infrastructure, & Flexibility

- Grid stability is at risk
- Communities face risks from prices, emissions, and water use
- Need demonstrated use cases of positive outcomes
- AI has the potential to drive better climate and security outcomes but will not happen on its own

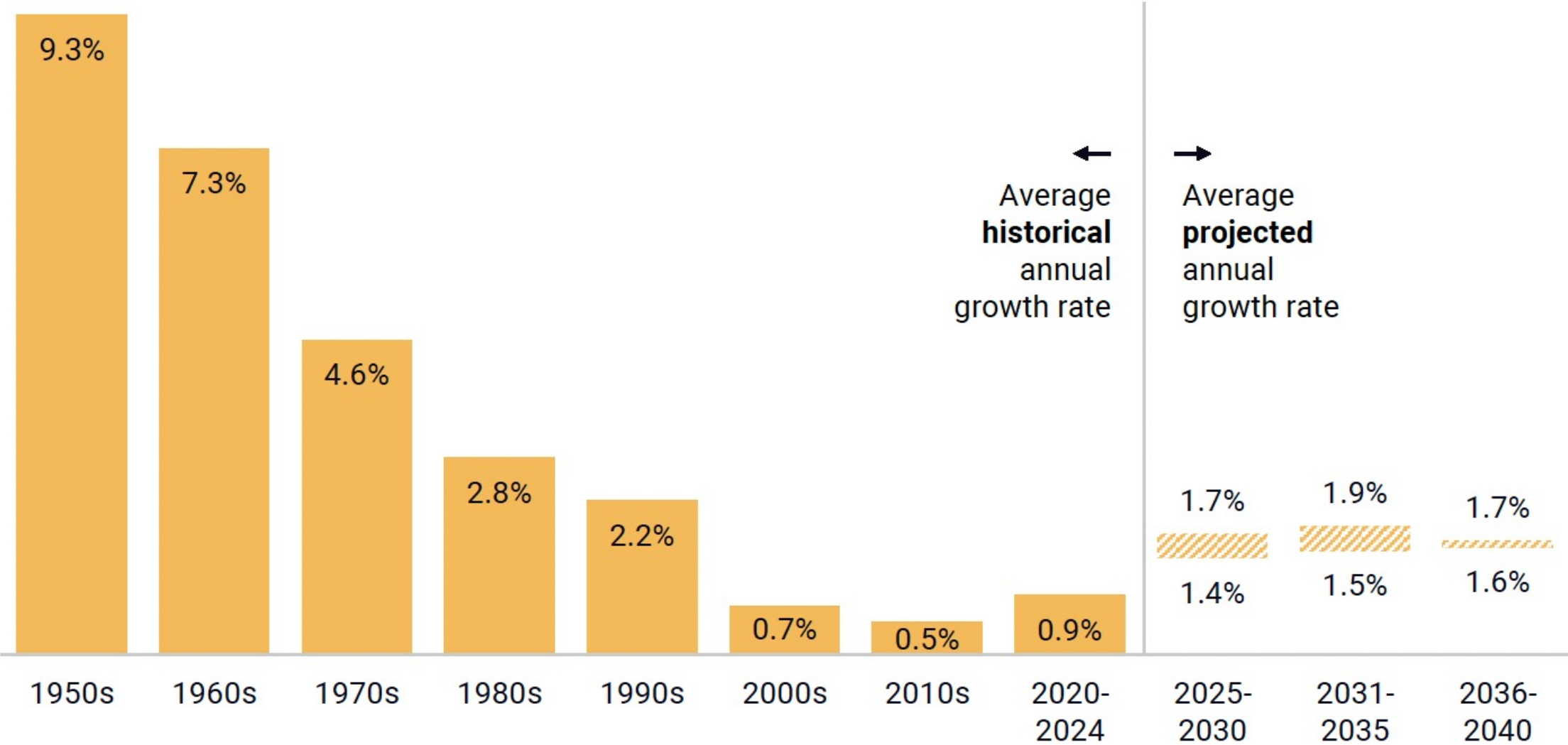


<https://fas.org/publication/speed-grid-connection-smart-ai-fast-lanes/>

# Data Centers and AI **Are Only Part** of Future Anticipated Electricity Growth



# Return to Electricity Demand Growth Requires Policies for Affordability and Reliability



# Recommendation 1: Use a “Smart AI Fast Lane” Connection Fee to Quickly Connect to the Grid with “Bring Your Own Clean Power” Funding

- Foundation for Energy Security and Innovation (FESI)
- **Fee to connect** to the grid without lengthy studies.
- Public-private grid fund to **manage infrastructure costs** incurred by regional grids
- Bring Your Own Power funding



Image: Department of Energy

## Recommendation 2: Create an "MPG" for AI

- Award **prizes for meeting efficiency targets** of how much AI work we get for the amount of energy and water used
- Require data centers to report standardized water use, electricity use, and on-site fuel consumption and emissions annually.
- Allow faster permitting for data centers that meet best practices



Image: Newkirk et. Al 2025

# Recommendation 3: Maximize Transmission Throughput<sup>18</sup> and Upgrade Grid Infrastructure

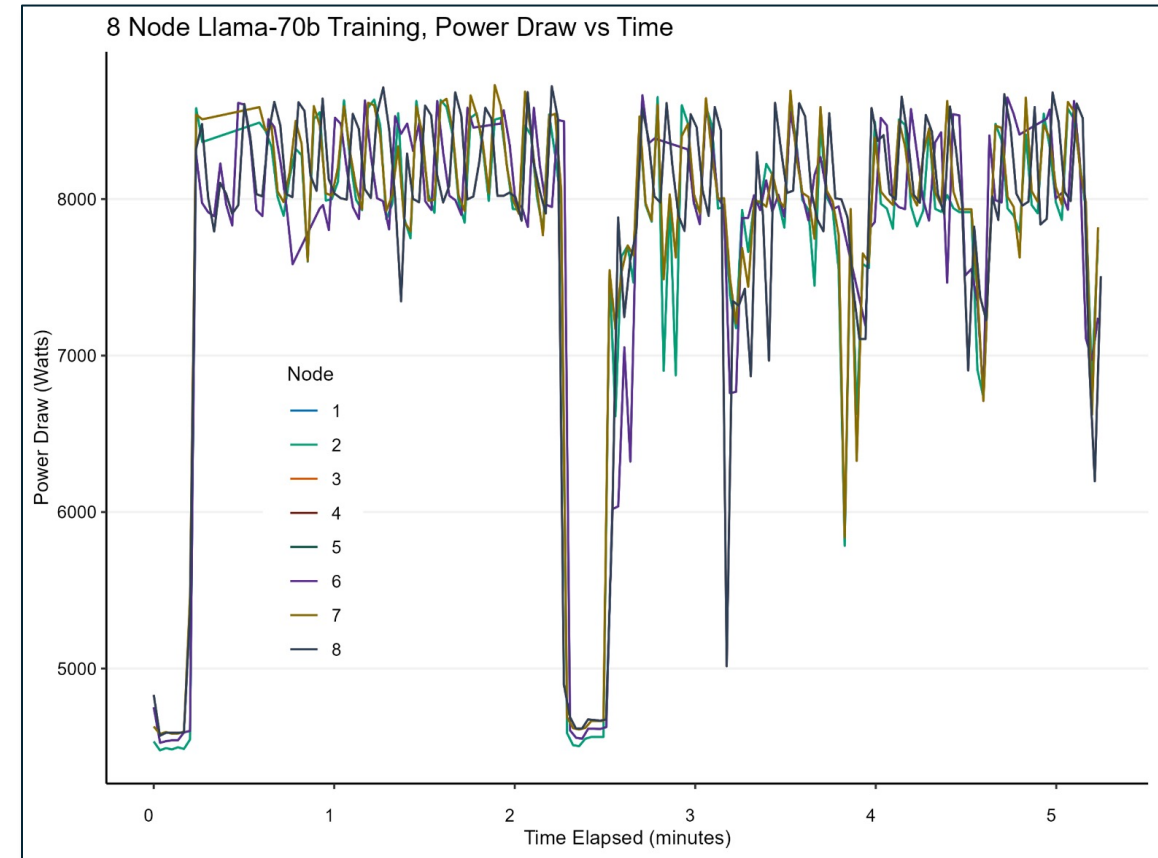
- Shared investment for **deployment of reconductoring, transmission, or grid enhancing technologies** to increase capacity
- Shared investment to **build resilience distribution infrastructure beyond the needs for the project** to reduce future electricity rate cases, which will keep electricity costs affordable



Image: Department of Energy

# Recommendation 4: Reward Flexibility and End-Use Efficiency Investments

- Incentives to **demonstrate flexibility** through smart controls and operations
- Shared investment in areas hosting data centers that **reduce summer and winter peak loads** in the local service territory
- Partnerships to meet home weatherization targets and **deploy virtual power plants.**



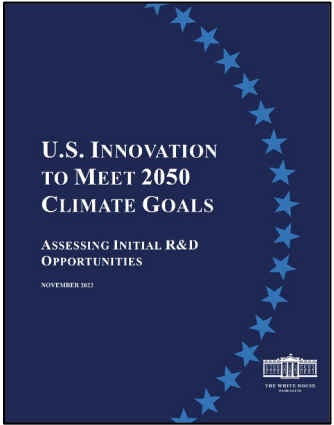
Source: LBNL, 2024

# Assessing Climate and Clean Energy Innovation Needs

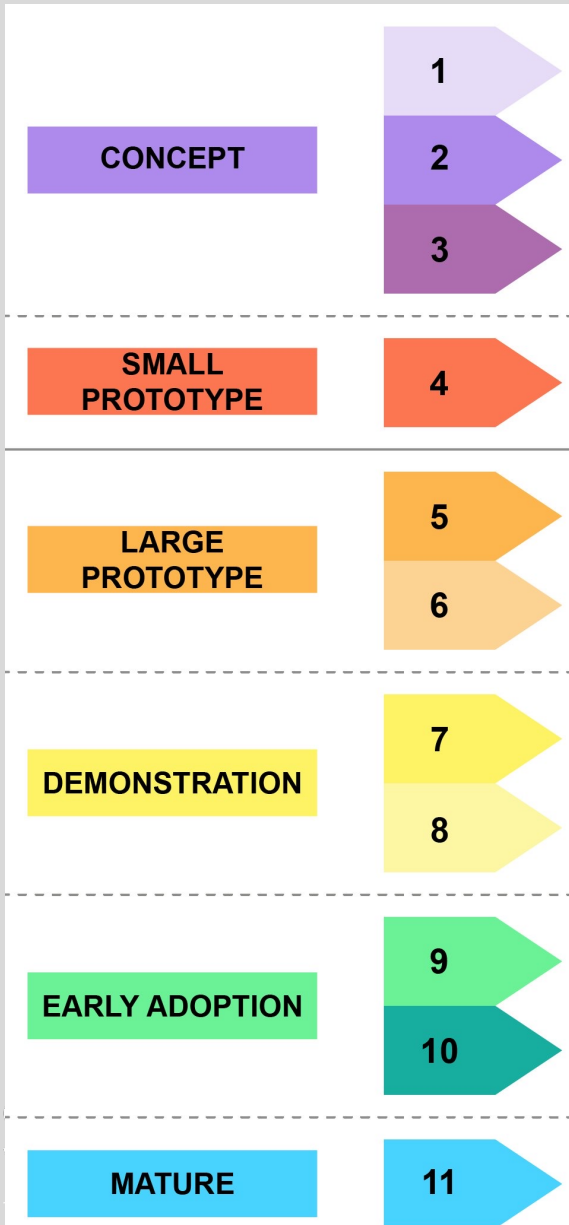
	Transportation Technology	Electricity Generation	Industrial Processes	Buildings & Infrastructure	Agriculture & Methane Reduction	Carbon Removal
	Advanced Batteries Connected & Automated Vehicles Electric & Hybrid Aircraft High-Speed & Electrified Rail Low-CO <sub>2</sub> Heavy-Duty Vehicles Low-CO <sub>2</sub> Shipping Low-Cost Away-From-Home Charging Mobility on Demand	Advanced Nuclear Fission Advanced Solar Advanced Wind Enhanced Geothermal Fusion Energy	Low-CO <sub>2</sub> Aluminum Low-CO <sub>2</sub> Chemicals Low-CO <sub>2</sub> Concrete Low-CO <sub>2</sub> Industrial Heat & Clean Water Low-CO <sub>2</sub> Steel	Low-CO <sub>2</sub> Building Construction & Operation Low-CO <sub>2</sub> Infrastructure Construction Low-GHG HVAC & Refrigerants	GHG-Reducing Cropping Practices Low-CO <sub>2</sub> Greenhouses & Livestock Facilities Non-Agricultural Methane Reduction Reduced Livestock GHGs	Engineered CO <sub>2</sub> Removal Nature-Based CO <sub>2</sub> Removal
Electricity System	Net-Zero Power Grid: Advanced Transmission Planning & Operation				Long Duration Energy Storage	
	Advanced Distribution Systems: Data, Optimization, & Controls			Repurposing Transportation Rights-of-Way		
Carbon-Neutral Fuels	Efficient & Alternative Biofuel Production		Net-Zero Electrofuels		Net-Zero Hydrogen & Ammonia	
	Repurposing Pipelines for CO <sub>2</sub> & H <sub>2</sub> Transport					
Other	Carbon Capture, Utilization, & Storage					
	Circular Economy & Secure Supply Chains					

Sectoral Innovation

Cross-Cutting Innovation



# Innovation is a Good Investment



33% of the technologies that can contribute to net-zero emissions goals are not yet at the demonstration phase

**PUBLIC/PRIVATE PARTERSHIPS**

**PULL TO MARKET**

**DEPLOY**



Sources: CMU, Wikimedia, IEA (2025)

# AI and Infrastructure Choices Determine Next Two Decades of Energy, Economic, Resilience, and Environmental Outcomes

