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BUILDING INTELLIGENCE

FREEDM Symposium Keynote

Electrical Engineering in the 4th Industrial Revolution

Bill Dean

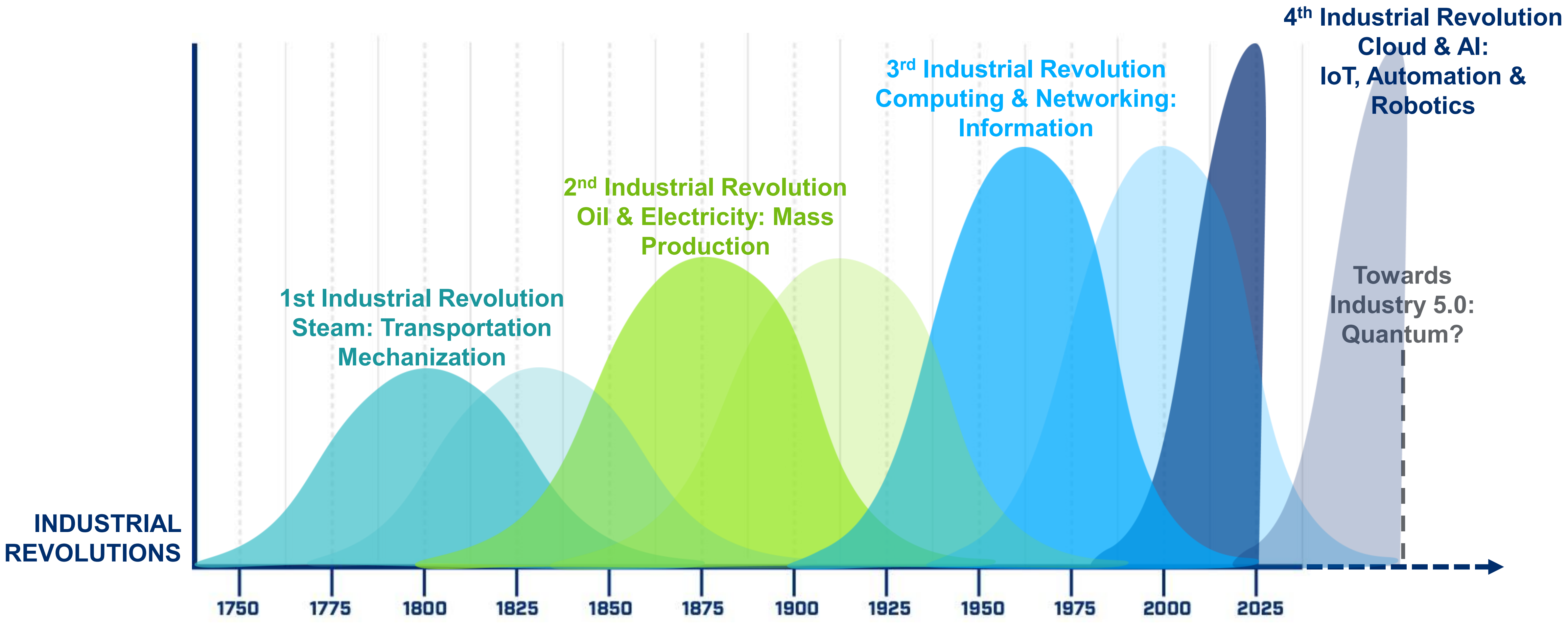
CEO & President | M.C. Dean

M.C. DEAN ENGINEERING HUB AT NC STATE

mcdean.com

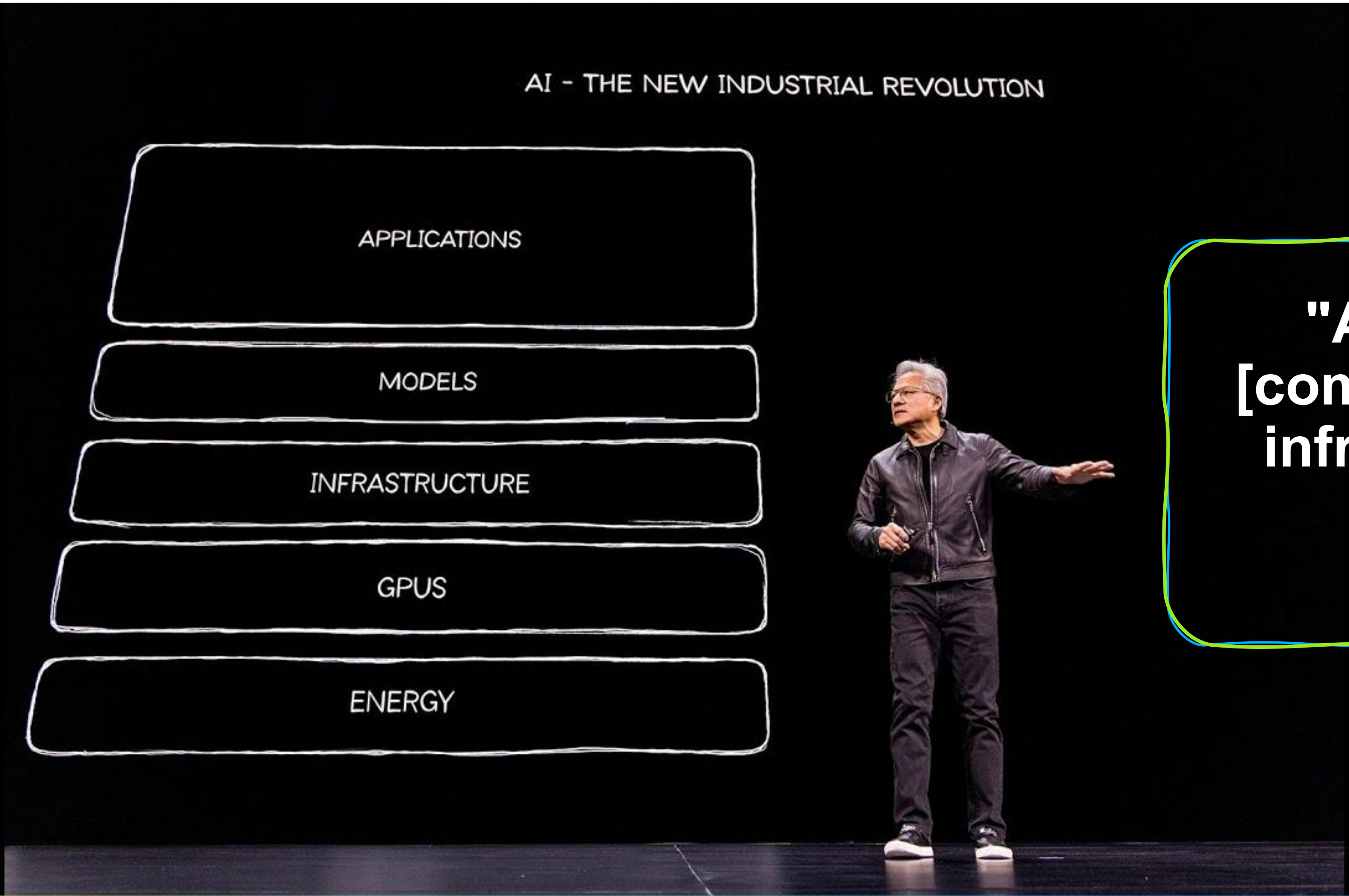
Every Industrial Revolution has been an Energy Revolution at its Core

Requires transformational leaders + Mastery of new technologies + Mastery of new tools + Mastery of new processes



Every Industrial Revolution has been an Energy Revolution at its Core

Energy is at the Foundation of the AI Technology Stack



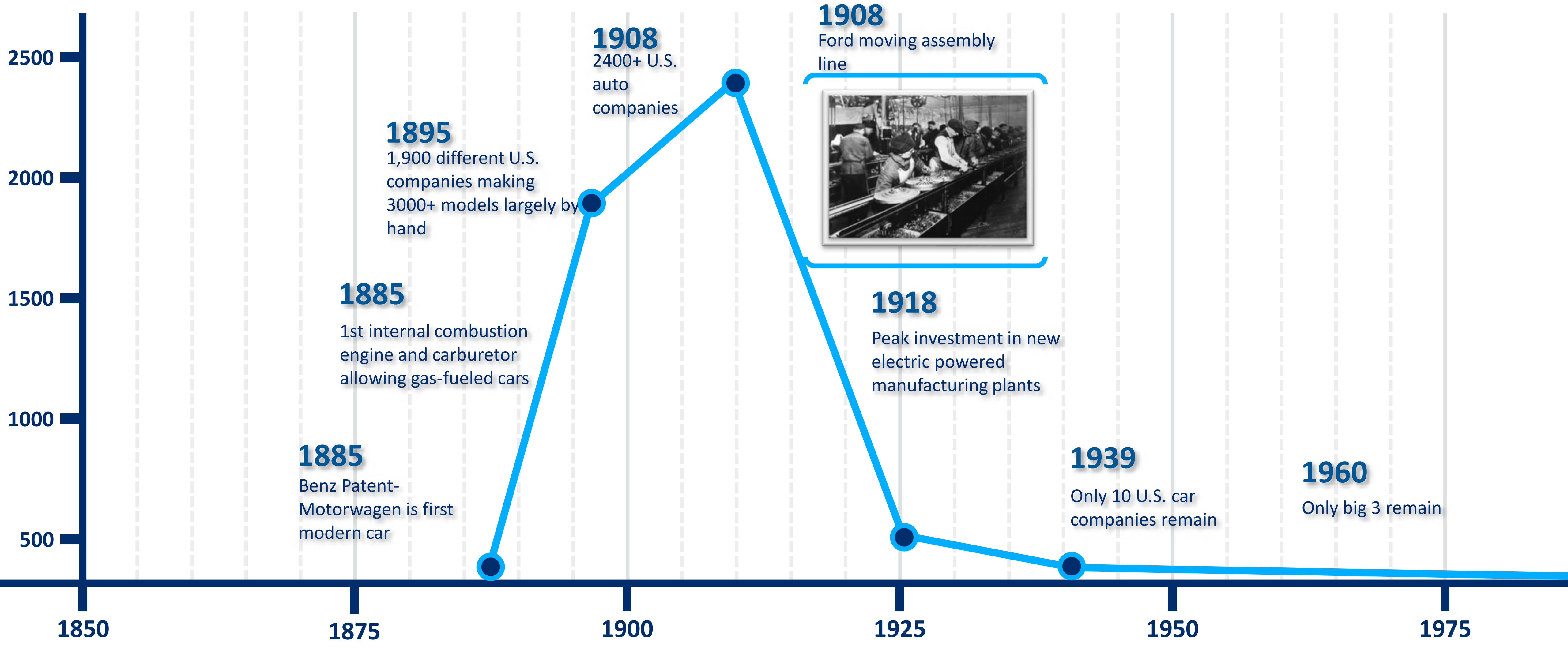
"AI is a five-layer cake... [comprised of] energy, chips, infrastructure, models, and applications."

- Jensen Huang, NVIDIA CEO

First Comes Solving the Problem
(i.e., making the car)

Second Comes Solving the Problem at Scale
(i.e., making 10M cars/yr)

Necessitates Multi-disciplinary Engineering Performance



Automotive Industry in the 2^{nd} Industrial Revolution

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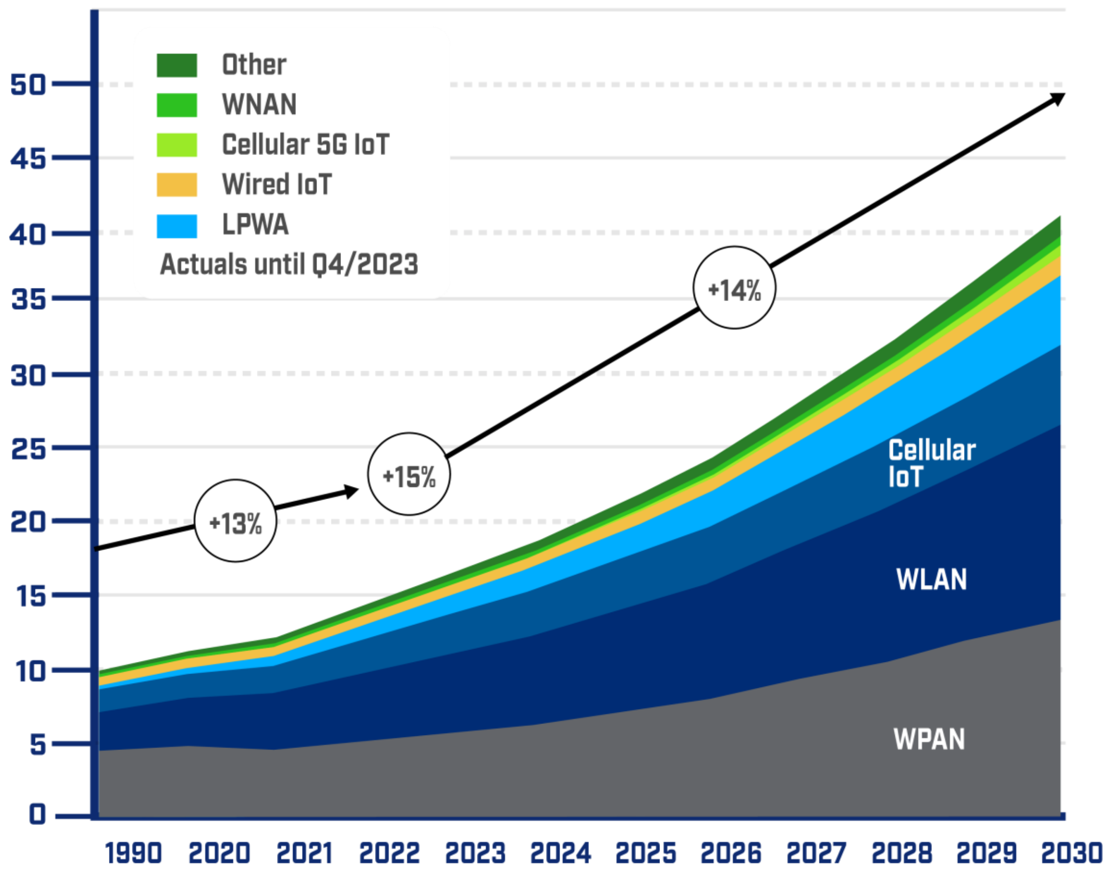
Internet of Things: World of Network-connected Devices

Global IoT Market Forecast

40 Billion IoT Devices by 2030

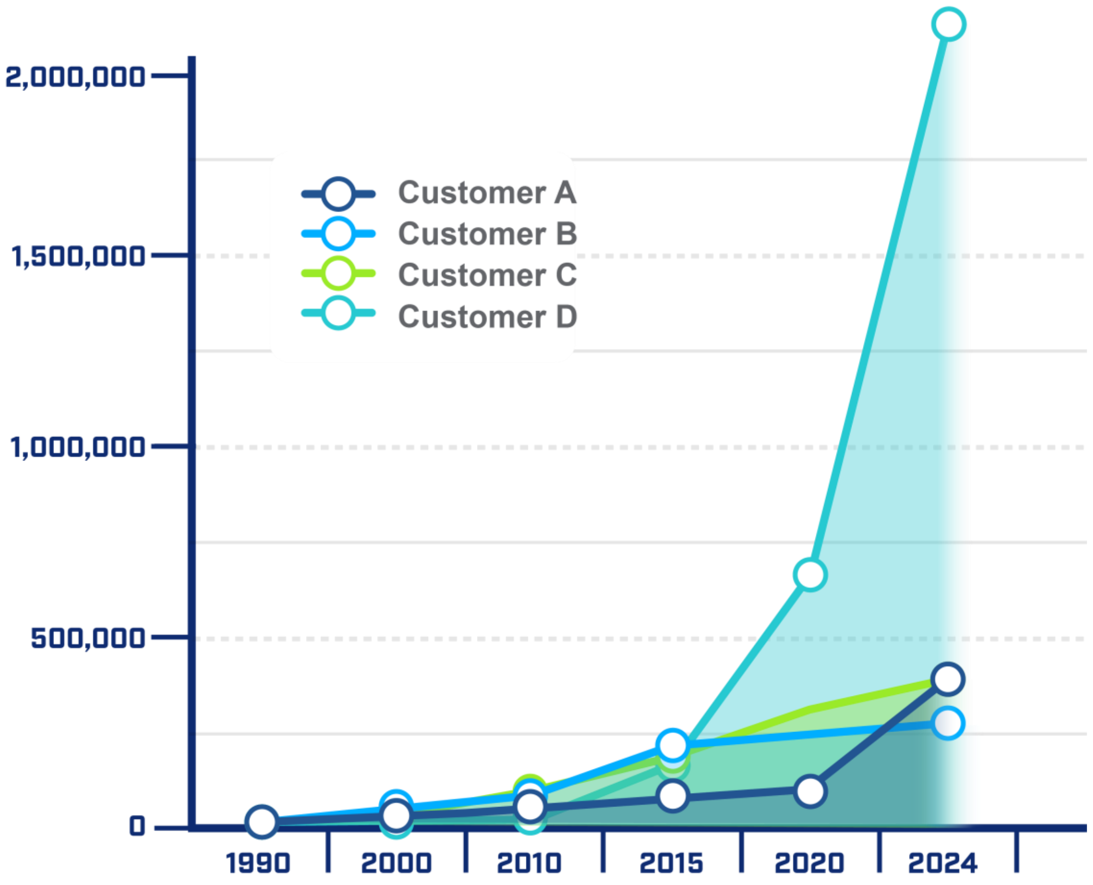


Source: IoT Analytics

Observed in M.C. Dean Customers

Enterprise Connected Devices

(Estimated Device Count)



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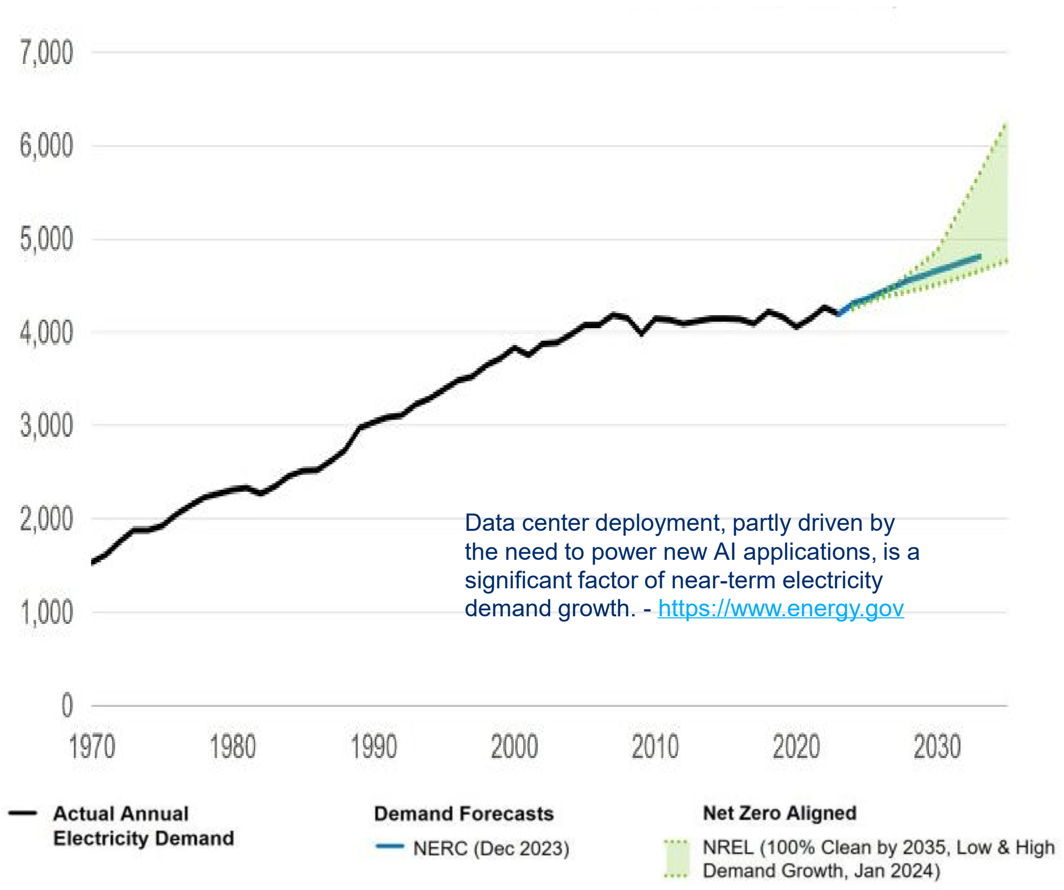
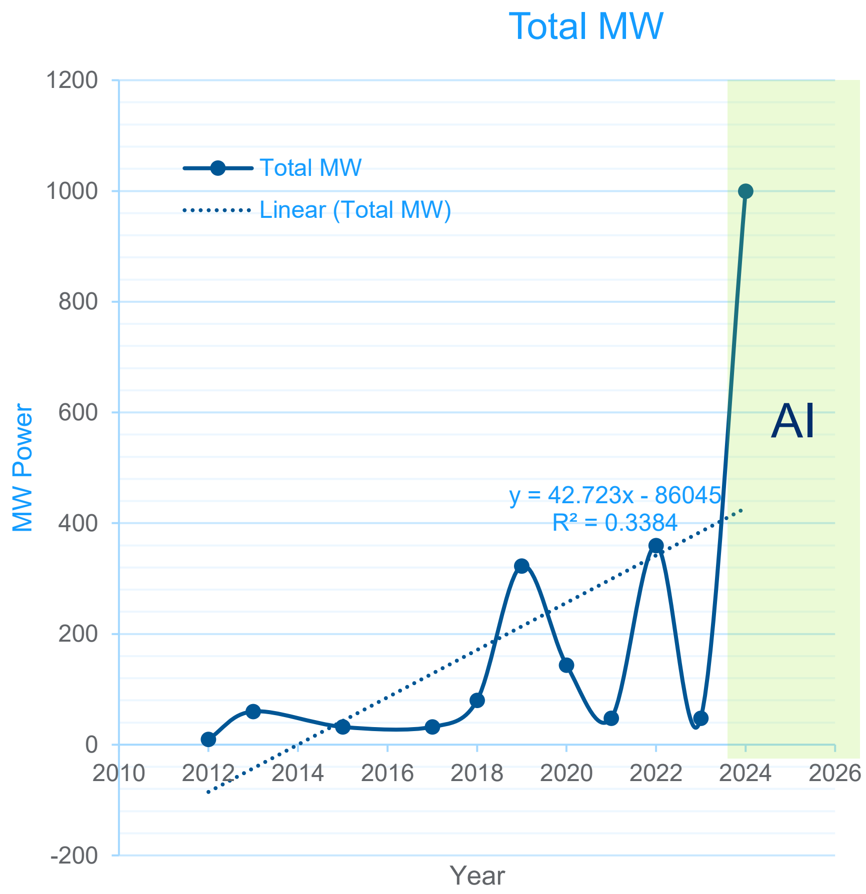
AI/ML → Driving Power Demand

Electricity Demand (TWh)



DC Power Demand Observed



Traditional data centers are designed with 5-10 kW power per **rack**, while AI data centers require 60 or more kW per rack. - https://www.datacenterknowledge.com

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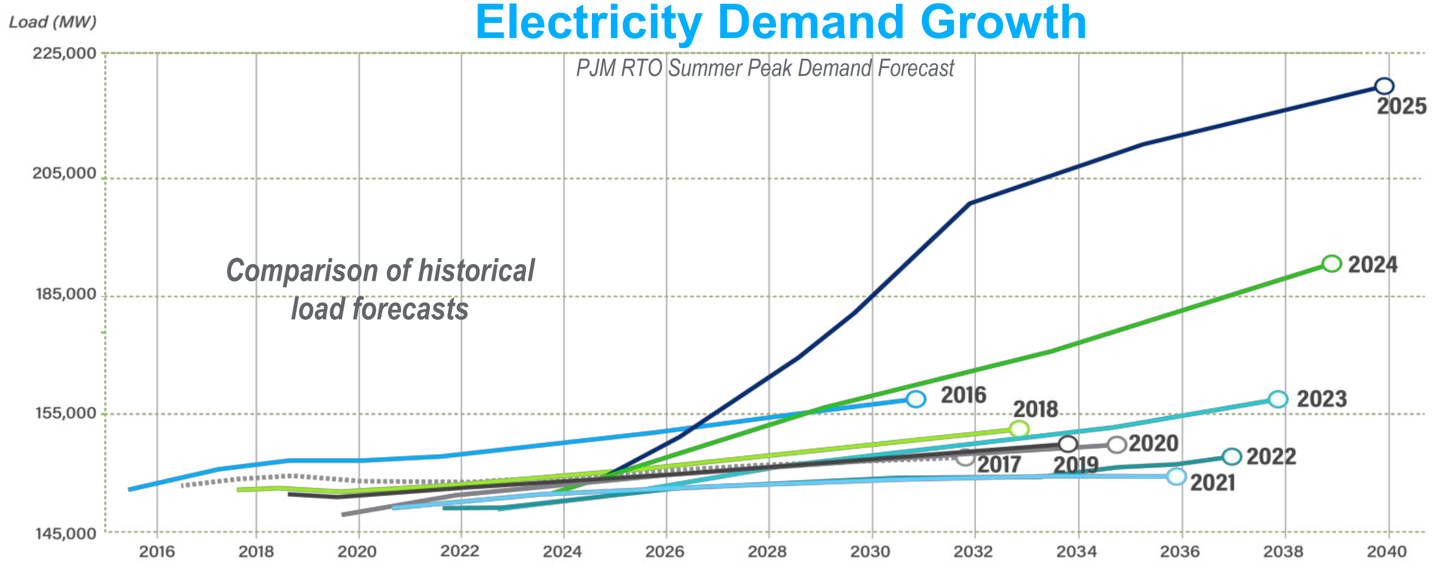
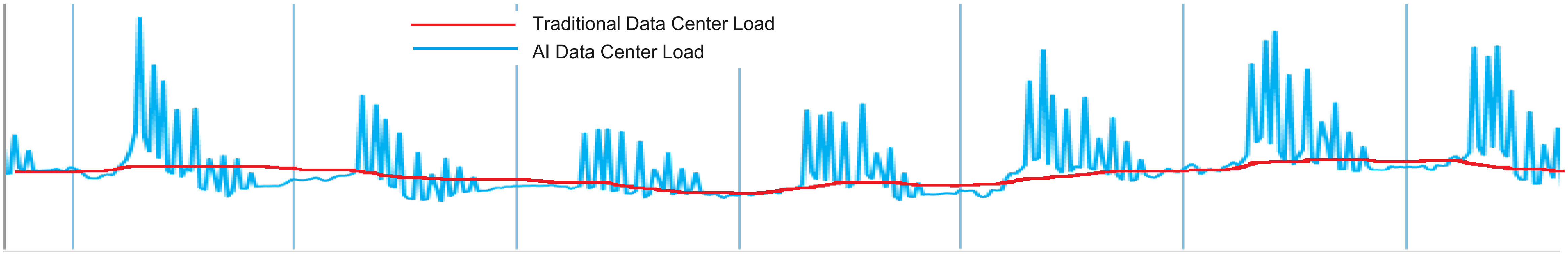
AI/ML → Straining Energy Reliability & Demand

AI FACTORIES

- Load profiles
- Escalating demand

Electricity Demand Growth





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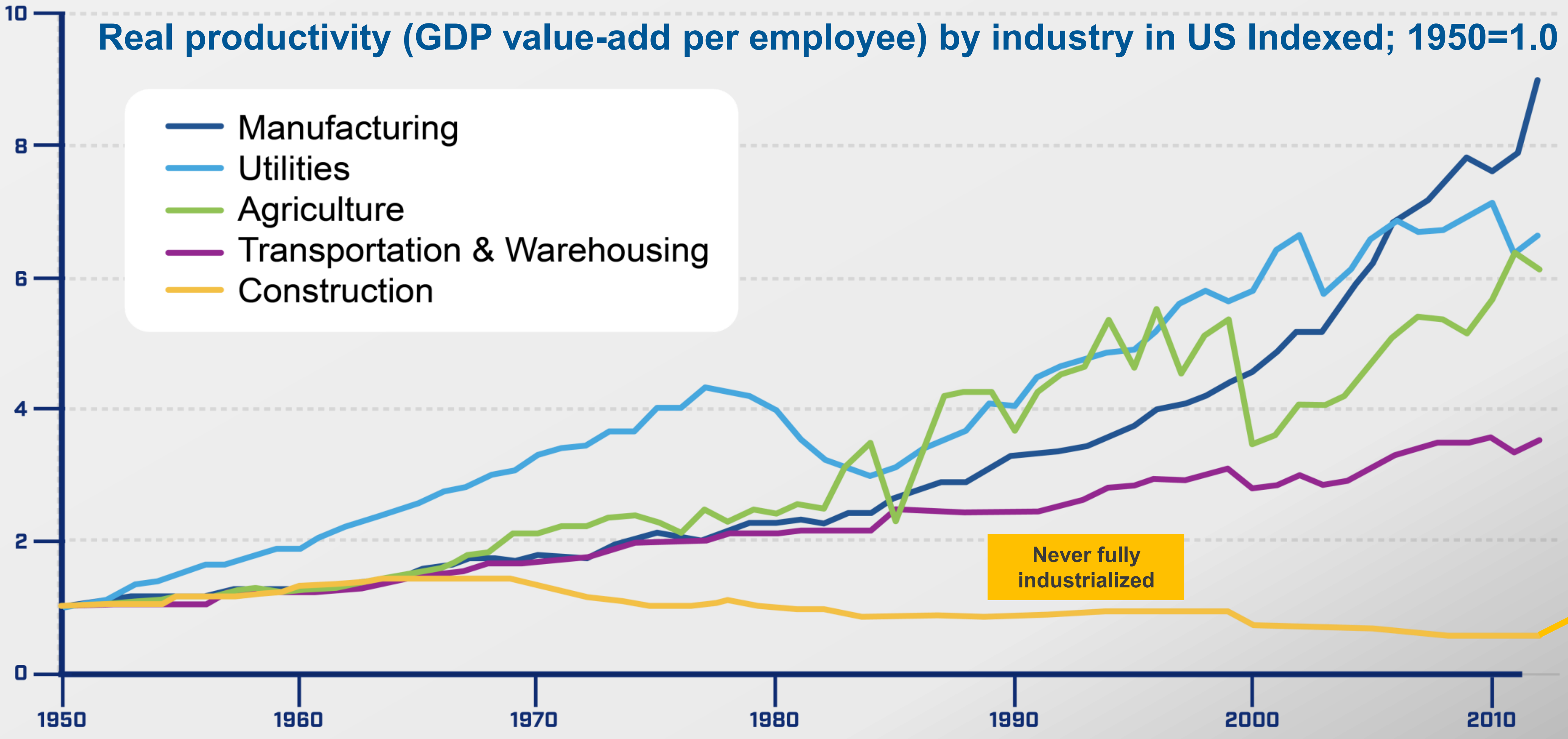
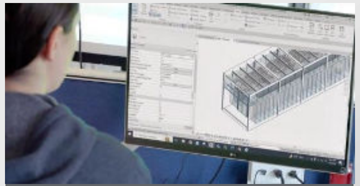
Capital Infrastructure lagged in prior Industrial Revolutions

Mass Customization Eluded Capital Infrastructure – UNTIL NOW





It takes
3-5yrs &
1000x to BUILD
what it costs to
MODEL

UNTIL NOW

SOURCE: Bureau of Economic Analysis (BEA), Hideyuki (2011)

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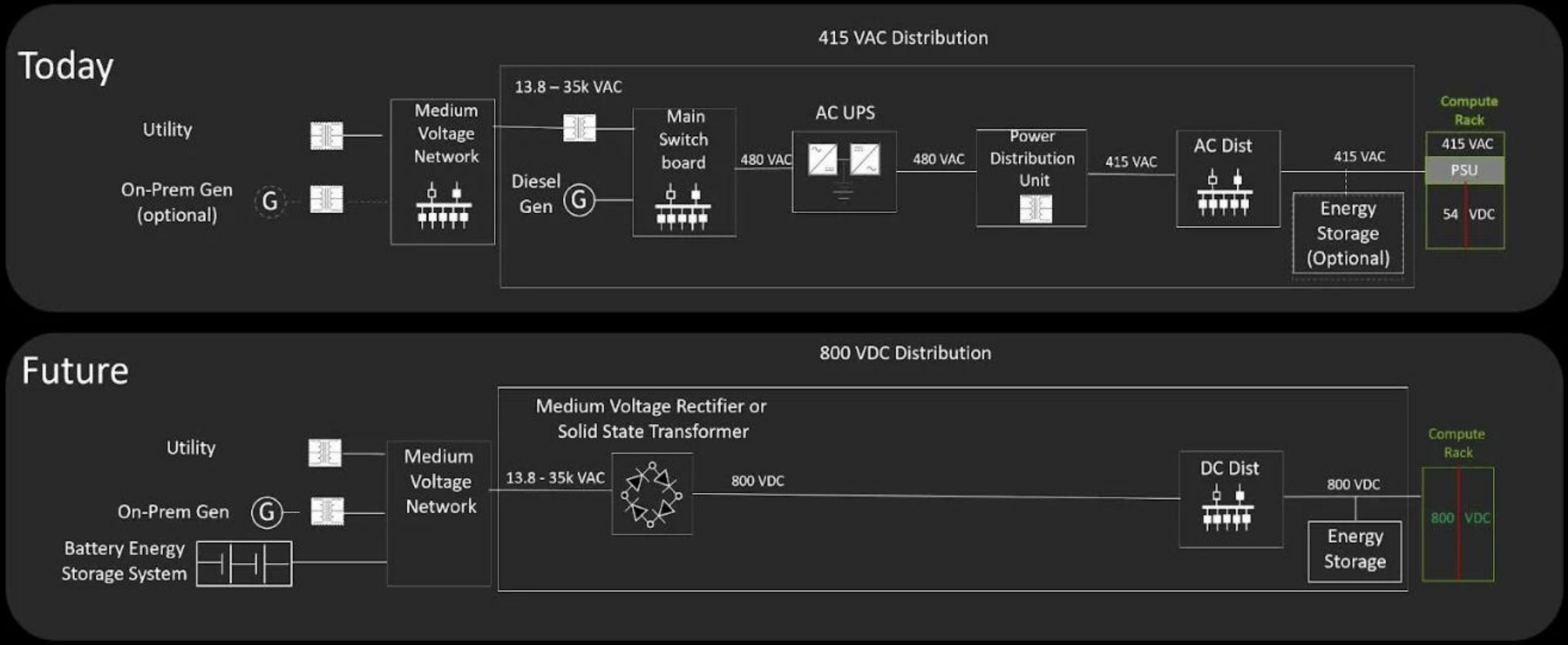
Changing Architectures from AC to HVDC

Electrical & Mechanical Systems are co-evolving with Compute



"*For years, a significant advance in processor technology meant a roughly **20% rise in power consumption**. Today, that predictable curve has been shattered.*"

"*The leap from the NVIDIA Hopper to the NVIDIA Blackwell architecture is a good example. While the individual GPU power consumption **(TDP) increased by 75%**, the growth of the NVLink domain to a 72-GPU system resulted in a **3.4x increase in rack power density**.* – NVIDIA Blog"

Building the 800 VDC Ecosystem for Efficient, Scalable AI Factories | NVIDIA Technical Blog
Powering the AI Era: Innovations in Data Center Power Supply Design and Infrastructure | Data Center Frontier

Emerging AI-enabled Power Systems Modeling

It takes 3-5yrs &1000x to BUILD what it costs to MODEL

CURRENT STATE
SILOED SPECIALIZED SYSTEMS

Functional Design Tools

etap | PSCAD | EasyPower

DIgSILENT POWERFACTORY

Physical Design Tools

Navisworks | Revit | Trimble

BIM | IFC | Bentley

Planning & Operations Tools

Primavera | CMMS | Prologic

FUTURE STATE
AI-DRIVEN • INTEGRATED • REAL-TIME

Unified Digital Twin Platform

NVIDIA Omniverse

AI Surrogate Models

NVIDIA PhysicsNeMo

Real Time Data & Optimization

Data Analytics

Sources: ETAP (etap.com); PSCAD (pscad.com); DIgSILENT PowerFactory (digsilent.de); Autodesk BIM (autodesk.com/bim); Bentley Systems (bentley.com); NVIDIA Omniverse Digital Twins (resources.nvidia.com); NVIDIA PhysicsNeMo (developer.nvidia.com/physicsnemo); NVIDIA DCGM (developer.nvidia.com/dcgm)

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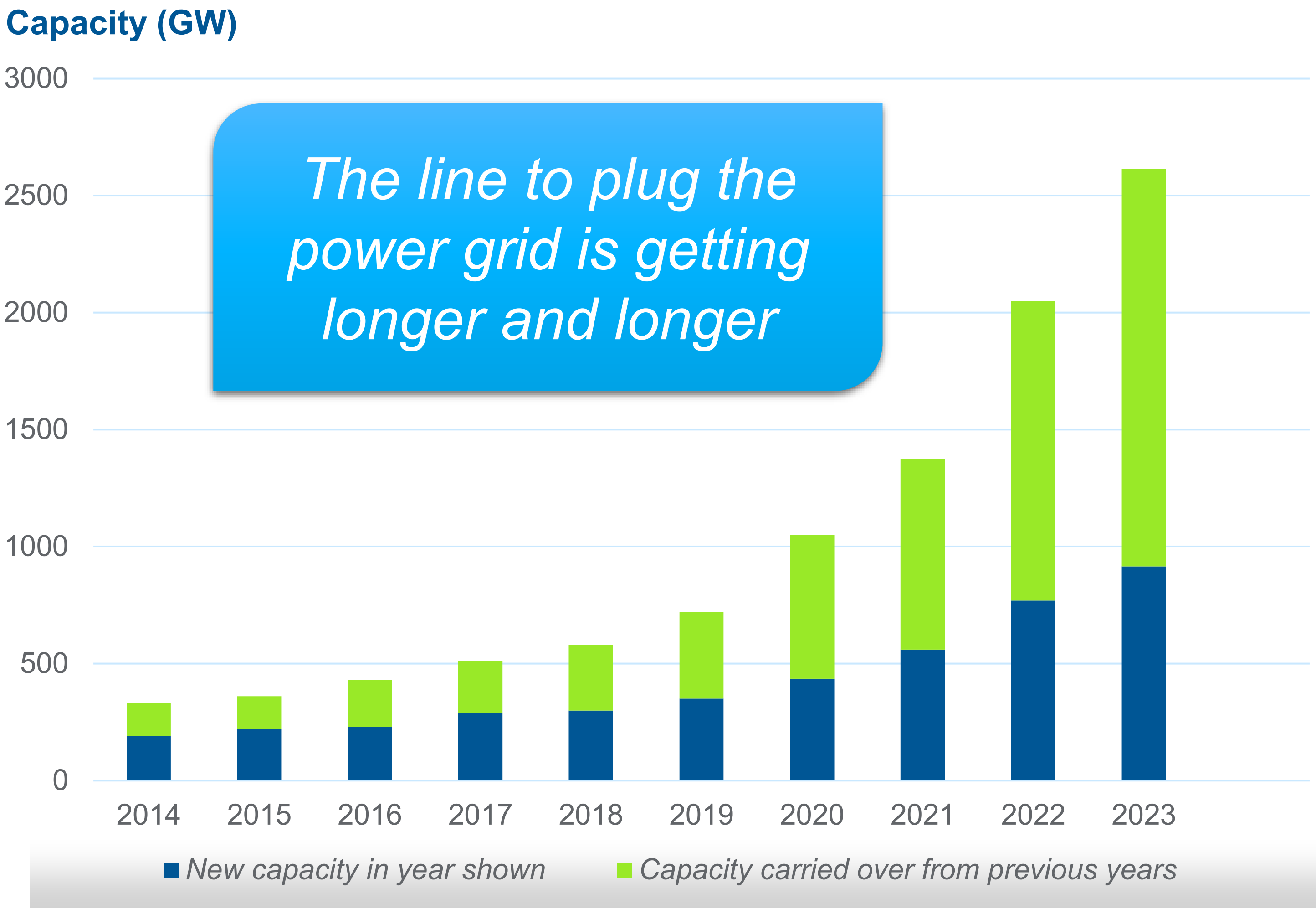
Grid Interconnection Challenges

What's Changing

- **Load growth is faster & highly variable**
- **Interconnection processes built around generators, not massive loads**
  - Utility/ISO Interconnection processes not standardized
  - "Speculative request" cause timing problems
- **Hardware lead times:**
  2+yrs for transformers & switchgear
- **New operating patterns stress the grid differently**



LBNL "Queued Up" (via Canary Media): US interconnection queue size has ballooned

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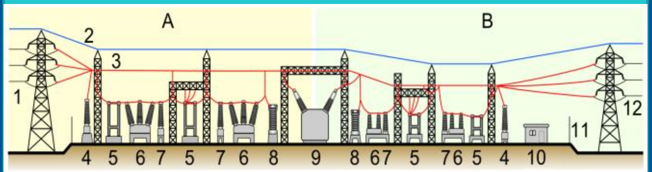
Grid Interconnection Challenges & Emerging Solutions

Interconnection for ~1 GW campuses

Grid & Transmission corridor

- Thermal constraints (N-1)
- Deliverability / congestion
- Stability & system strength



POI substation

- Transformer MVA capacity
- Breaker duty / short-circuit
- Protection, relaying, metering

Campus distribution

- Harmonics / flicker from power electronics
- Reactive power needs
- Ramps during commissioning / failover

New EPC Frameworks Advancing

- FERC Interconnection Final Rule
- Early transformer procurement and spares strategy
- Standardized substation designs & modular builds
- Microgrid / On-site Generation Integration
  - On-site BESS for ramp control and peak shaving
  - Microgrid controller to manage UPS-gen-BESS transitions

Technology Advancements

- STATCOM/SVC for dynamic voltage support
- Synchronous condenser where system strength is weak
- Harmonic filtering + PQ monitoring at the POI
- Protection coordination + validated dynamic/EMT models
- Grid-enhancing techs (DLR, power-flow control, topology optimization)

Operational Shifts

- Phased energization (MW blocks) aligned to upgrades
- Load shifting (training jobs to off-peak) where feasible
- Flexible/conditional service (curtailment rights, ramp limits)

Impacts of Grid Stability on National Security

AI Loads Further Challenge Existing Grid Stability Concerns

Zone A – Mission Core

Represents: Command & Control, Data centers / SCIFs, Operations centers, flight ops, weapons systems, Life-safety and continuous-run facilities

Power characteristics: Highest criticality, Often on dedicated feeders, UPS + backup generation

Vulnerability: Any interruption = mission impact, dependent on external substations unless islanded

Zone B – Immediate Mission Support

Represents: Communications buildings, Maintenance shops, Security systems, Fueling, logistics nodes directly supporting ops

Power characteristics: Shared feeders are common, partial backup coverage

Vulnerability: Failure degrades mission tempo, not just comfort, redundancy thins out

Zone C – Shared Infrastructure / Grid Interface

Represents: Installation substations, Main feeders, Utility interconnect points, Areas most likely to share capacity with commercial loads (including AI data centers)

Power characteristics: Highest exposure to grid instability, Single points of failure

Vulnerability: Where AI data center load growth most directly competes, Cyber-physical attacks or equipment failure cascade inward, highest-risk zone on installations.

Zone D – Installation Support & Community Services

Represents: Housing, Medical clinics (non-trauma), Training facilities, Admin buildings

Power characteristics: Lower criticality, restored later in outages

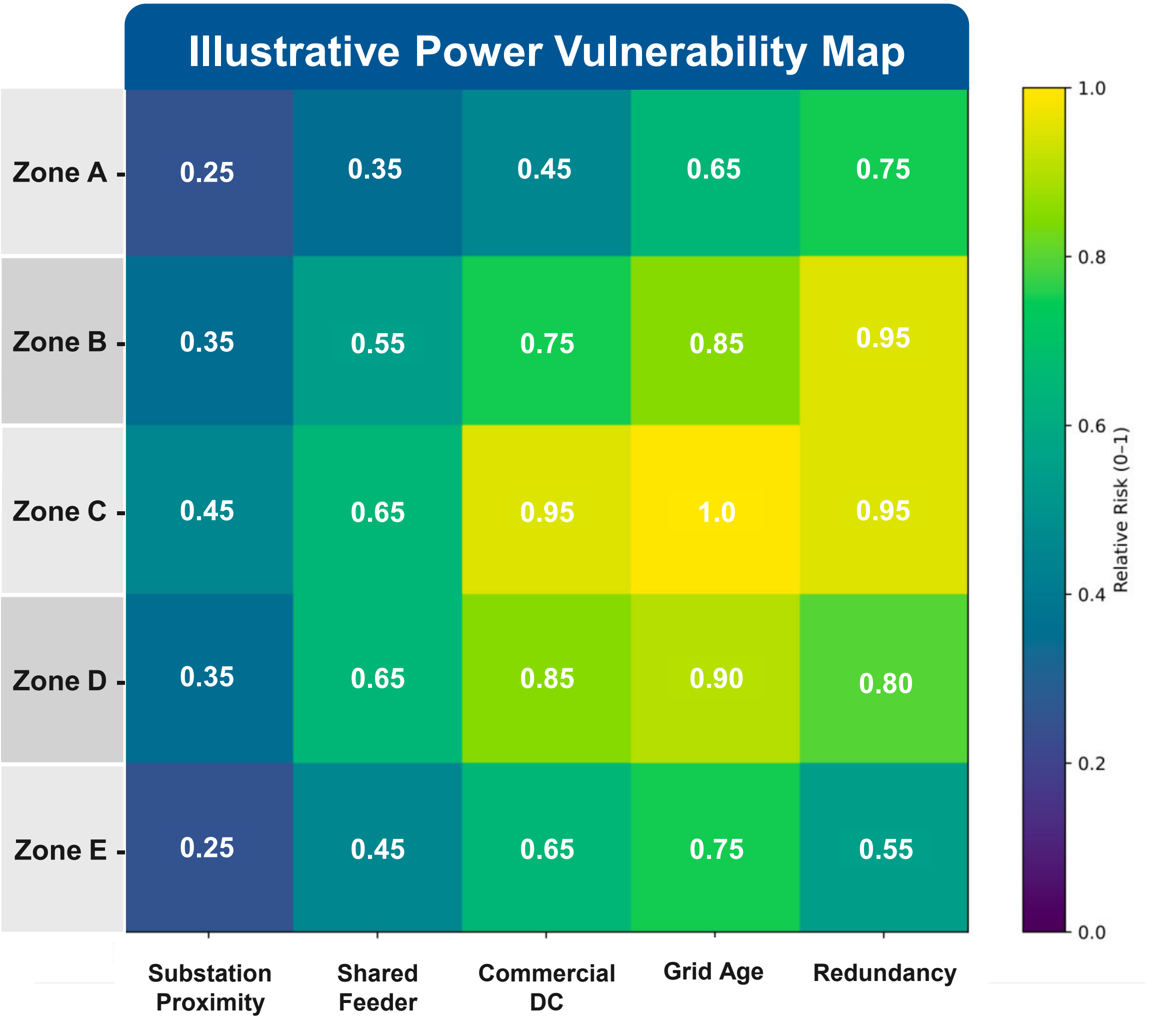
Vulnerability: Indirect mission impact via workforce availability, lowest priority for grid restoration

Zone E – External Dependency & Perimeter

Represents: Off-installation substations, Transmission corridors, Fuel delivery routes, Municipal infrastructure the base depends on

Power characteristics: Outside DoD control, subject to utility congestion, weather, civil demand

Vulnerability: Hardest to harden directly, AI data center clustering increases systemic risk



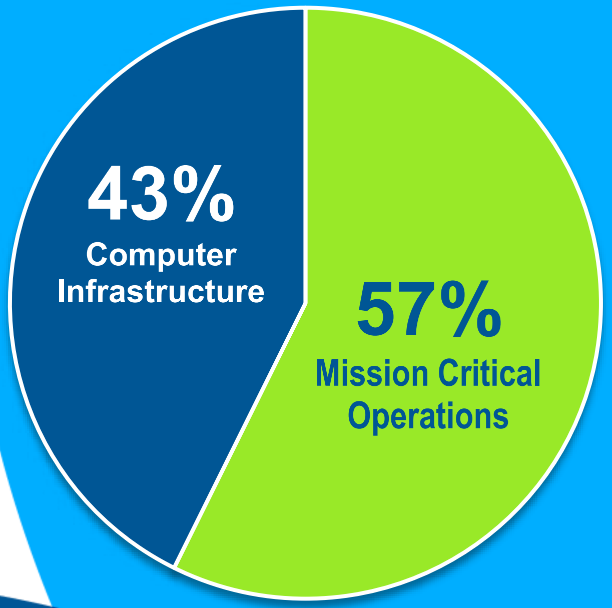
Impacts of Grid Stability on National Security

AI Loads Further Challenge Existing Grid Stability Concerns

CASE STUDY
MAJOR DoD CAMPUS

100% Supporting Mission Critical Expansion

300%↑ Power Capacity in Last Decade

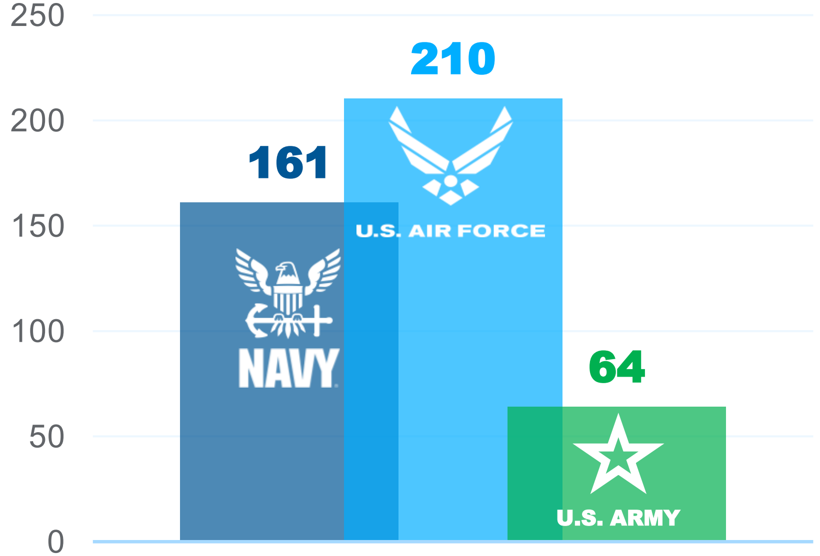


REQUIREMENTS FOR
Defense-reliant Electrical Power

- Mission Assurance & Energy Resilience
- Redundancy & Diversity of Supply
- Capability to operate islanded from civilian grid when needed
- Operational fuel security & logistics
- Cyber-physical security

POWER GRID D+

INFRASTRUCTURE REPORT CARD
ASCE



2018 Outages >8hrs

Source: DoD FY19 Energy Performance, Resilience & Readiness Report

In FY21, 6,000+ outages at DoD installations in the U.S. totaled 3,000+ days of lost power. - *Utility Dive*

Accelerated Delivery of AI Infrastructure Solutions

Advanced Manufacturing of Complex Infrastructure

- Multi-Disciplinary
- Modular

**GW shown in total planned campus capacity

Power-Ready AI / Cloud Infrastructure

Resilient, reliable power solutions

- Onsite Microgrids & Hybrid Power
- Energy Storage Solutions
- Bridging & Peaking Solutions
- Grid & Off Grid Energy Efficiency
- Sustainable Community Impact

DUKE ENERGY PROGRESS **13.8 GW**

GENERATION CAPACITY

*Parent Duke Energy announced $103B capital plan for **14GW by 2031** to meet AI demand.* – *Charlotte Observer*

World's largest AI campus coming to the Texas Panhandle (Fermi)

Leaders of the expected world's largest advanced energy and artificial intelligence campus coming to the Panhandle shed light on upcoming plans. (kfda)

By Paige Stockton
Published: Jul. 2, 2025 at 6:40 PM EDT | Updated: Jul. 2, 2025 at 11:17 PM EDT

abc 7NEWS

Data center Project Jupiter's greenhouse gas emissions could rival NM's largest cities

Advocates say developers exploiting loophole in state air quality regulations

BY: JOSHUA BOWLING - DECEMBER 5, 2025 3:36 PM

Source NM

BorderPlex Digital Assets in August gave lawmakers on the state Legislative Finance Committee a rendering of Project Jupiter. (Courtesy of BorderPlex Digital Assets)

Data Center Construction Boom Continues: 8 Projects to Watch in 2026

AI-driven data center construction continues its rapid growth, keeping some contractors optimistic about this year and beyond.

Ben Thorpe
Feb 6, 2026 | Updated Feb 10, 2026

EQUIPMENT WORLD

OpenAI's Stargate I data center in Abilene, Texas, set to come fully online this year. Source: OpenAI

New Era plans 7GW AI data center in Lea County, New Mexico, powered by gas and nuclear

Signed land option purchase agreement for around 3,500 acres in Lea County, New Mexico

November 07, 2025 By: Zachary Skidmore

DCD **7GW**

New Era Energy & Digital has signed a land option purchase agreement for around 3,500 acres in Lea County, New Mexico, with plans to develop an up to 7GW AI data center campus powered by natural gas and nuclear energy. If realized, the site is expected to support more than 2GW of natural gas generation alongside a planned 5GW plus nuclear installation. Initial power delivery at the site is targeted for 2028.

- Getty Images

COMPANIES ENERGY TRANSITION

Crusoe, Blue Energy to Build First-Ever Gas-to-Nuclear Powered Data Center Project

Mark Segal | November 3, 2025

POWER

DATA CENTERS

Utah Groups Look at Nuclear Options to Power World's Largest Data Center Site

Darrell Proctor

Friday, December 12, 2025 SHARE:

An energy company focused on supporting artificial intelligence (AI) through infrastructure has signed a memorandum of understanding (MOU) with a Utah-based nuclear power services company, as the groups evaluate ways to provide electricity for a massive data center campus in that

DataCenterNews

By Sean Mitchell, Publisher

Permian Basin launches 150MW off-grid power for AI data centres

Sat, 16th Aug 2025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AT NC STATE
ADVANCED MANUFACTURING:
Reliable, complex infrastructure at scale.
GRID INNOVATION: Islanding, hybrid mode operation, and next-generation microgrid management.
Microgrids for Grid Autonomy & Energy Resiliency
WORKFORCE DEVELOPMENT:
Supporting Ph.D., M.S., and undergraduate students through funded fellowships and project-based learning.
ENERGY STORAGE, CONTROLS, AND DEMAND-SIDE MANAGEMENT:
With a focus on resiliency, reliability, and emergency response.
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