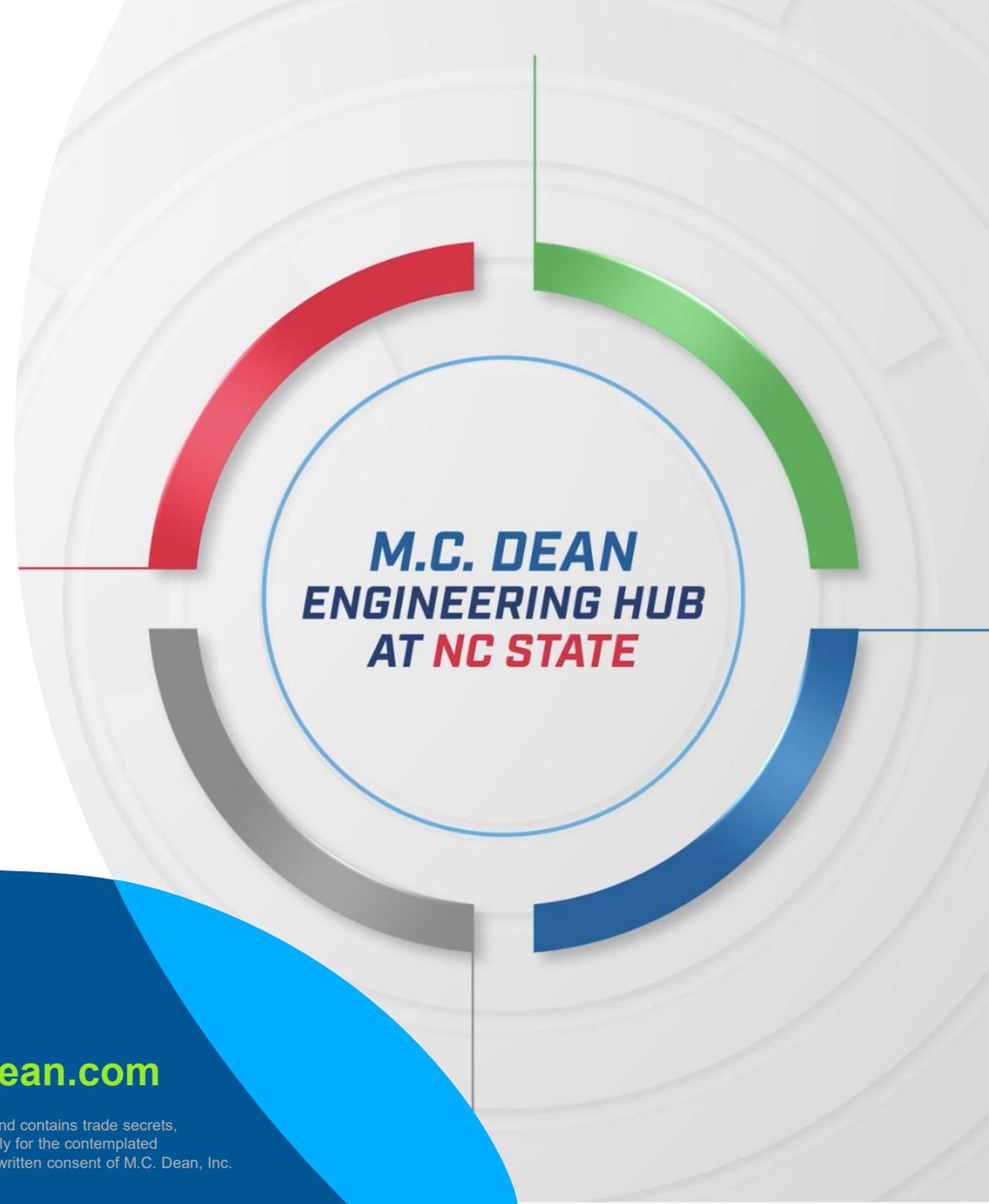




FREEDM Symposium Keynote
**Electrical Engineering in
the 4th Industrial Revolution**

Bill Dean

CEO & President | M.C. Dean

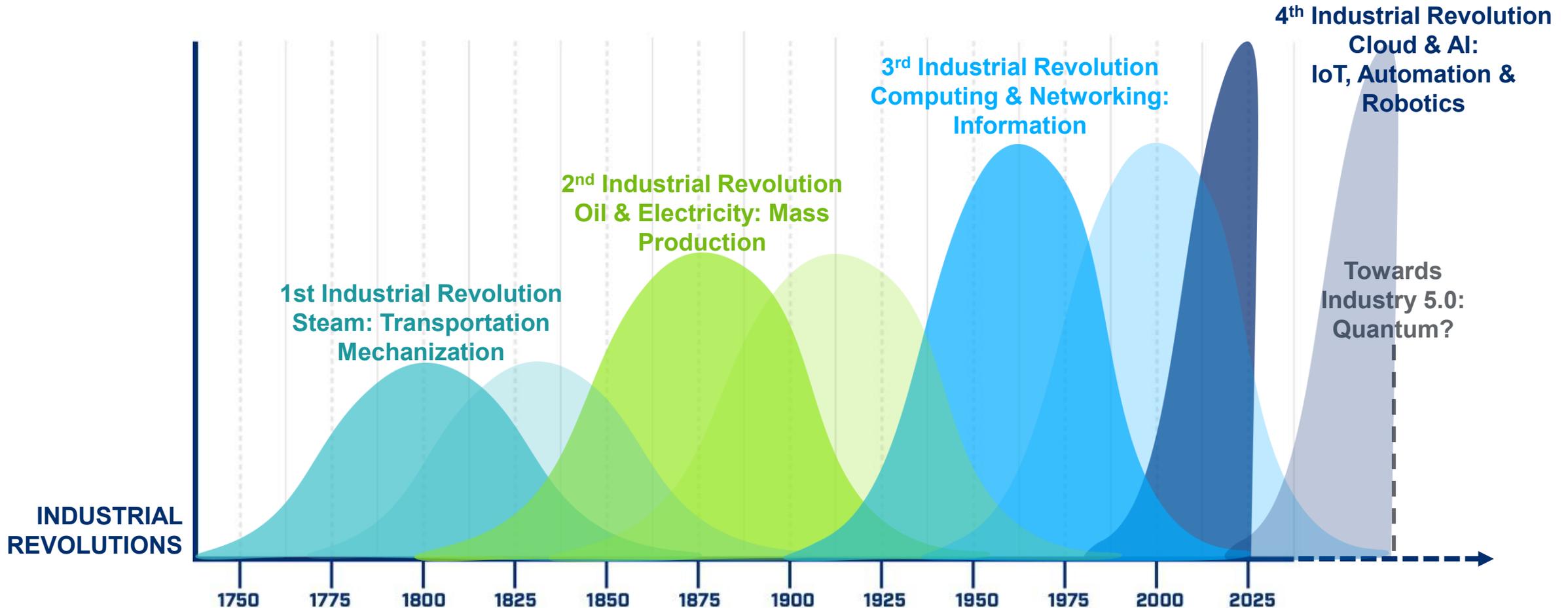


mcdean.com

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Every Industrial Revolution has been an Energy Revolution at its Core

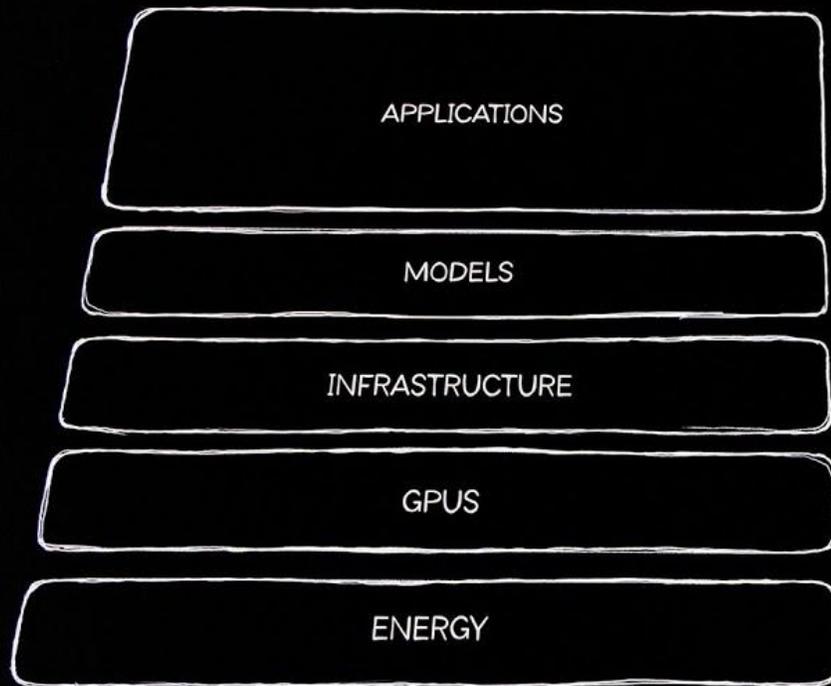
Requires transformational leaders + Mastery of new technologies + Mastery of new tools + Mastery of new processes



Every Industrial Revolution has been an Energy Revolution at its Core

Energy is at the Foundation of the AI Technology Stack

AI - THE NEW INDUSTRIAL REVOLUTION



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

- Jensen Huang, NVIDIA CEO

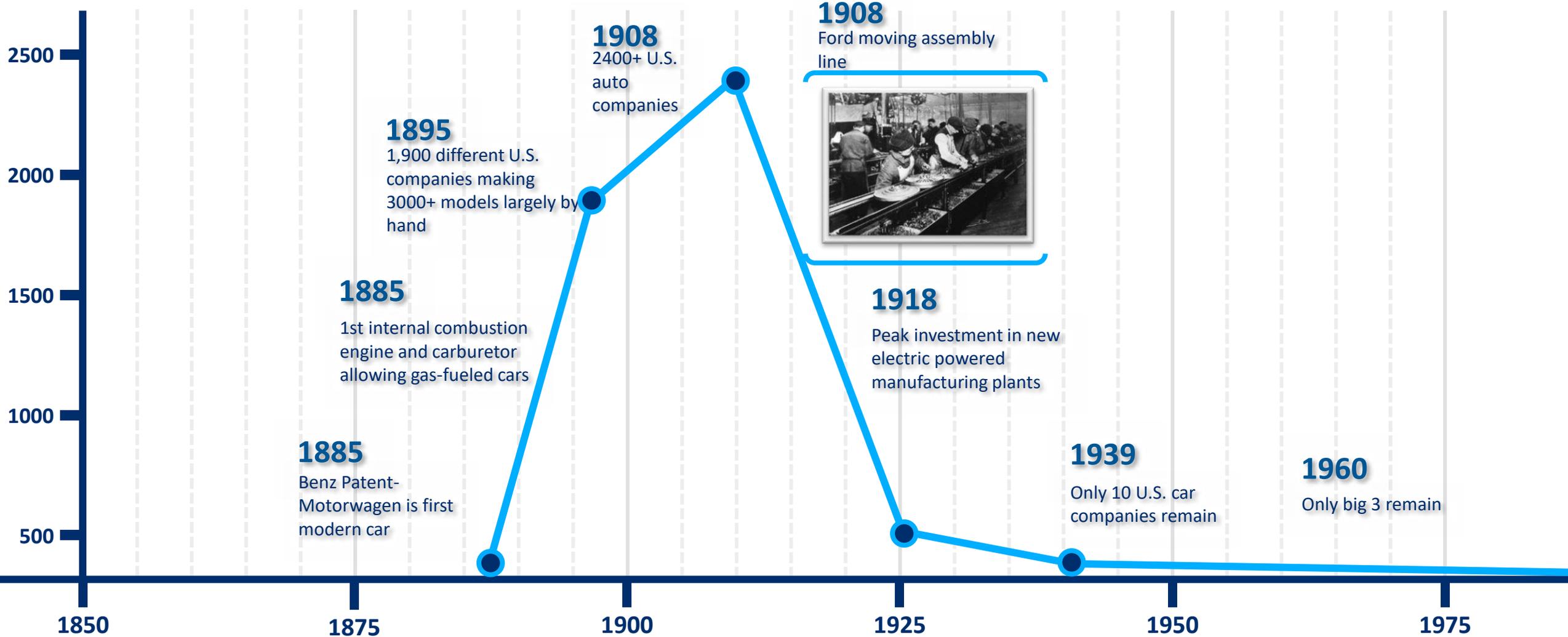
First Comes Solving the Problem

(i.e., making the car)

Second Comes Solving the Problem at Scale

(i.e., making 10M cars/yr)

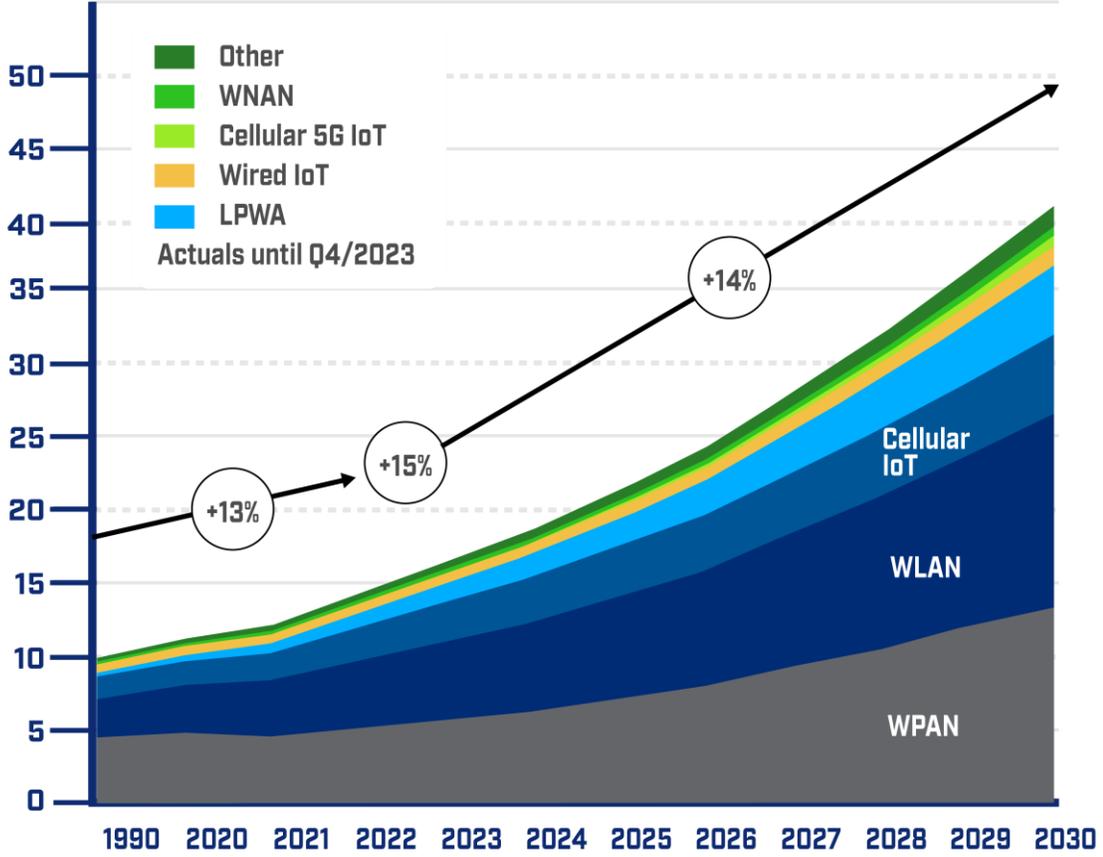
Necessitates Multi-disciplinary Engineering Performance



Automotive Industry in the 2nd Industrial Revolution

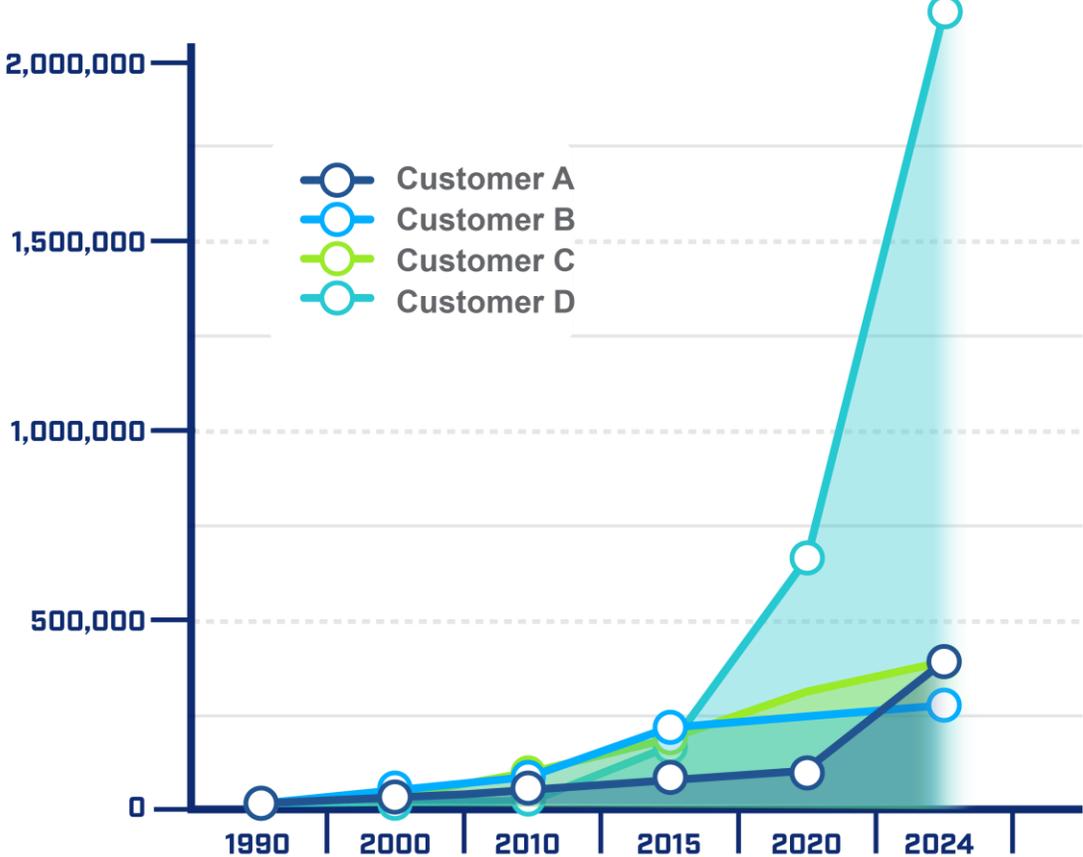
Internet of Things: World of Network-connected Devices

Global IoT Market Forecast 40 Billion IoT Devices by 2030



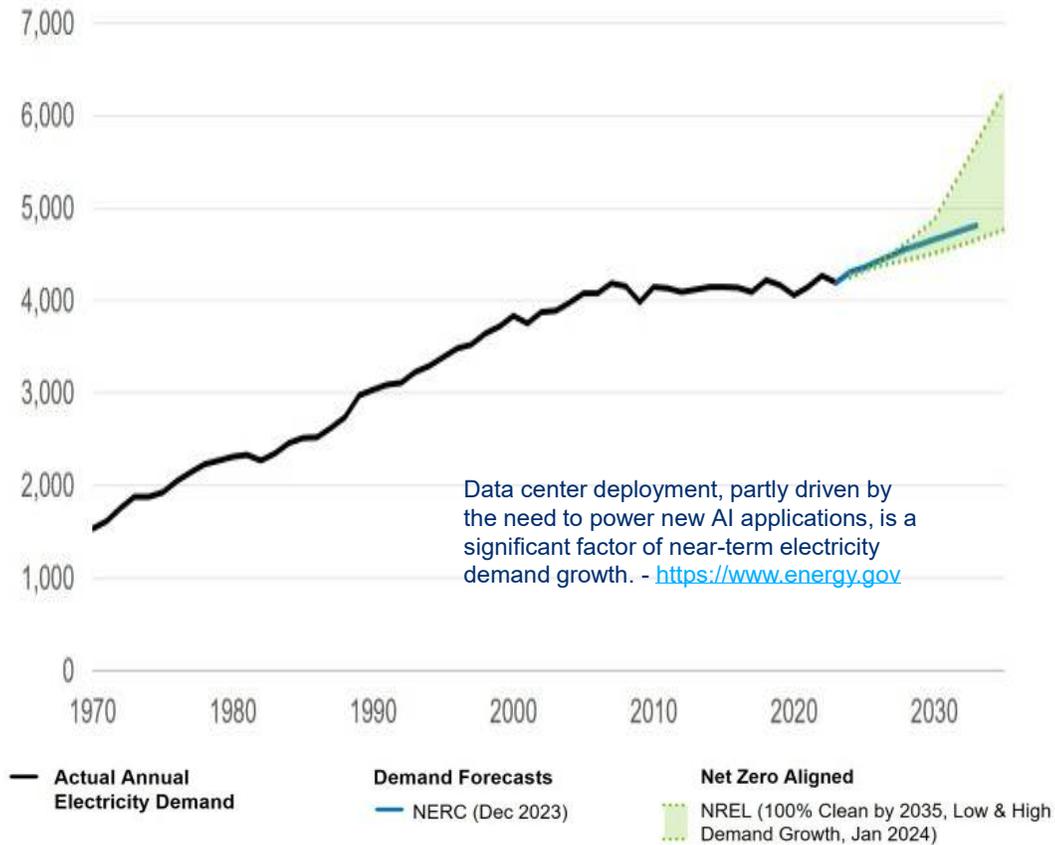
Source: IoT Analytics

Observed in M.C. Dean Customers Enterprise Connected Devices (Estimated Device Count)

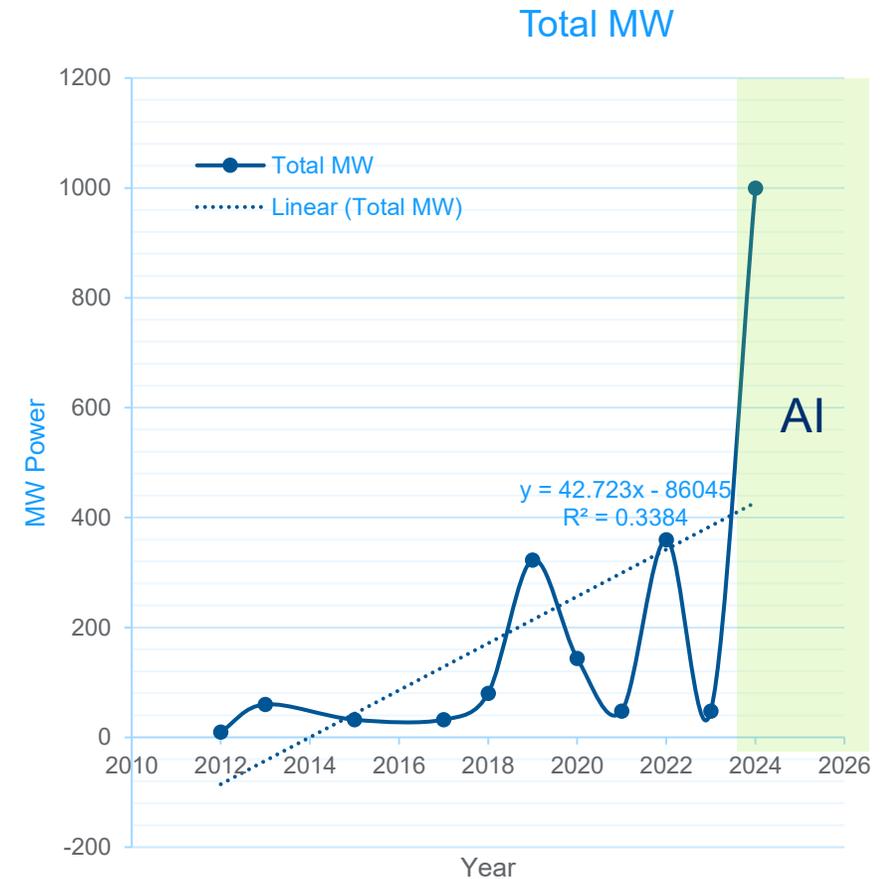


AI/ML → Driving Power Demand

Electricity Demand (TWh)



DC Power Demand Observed

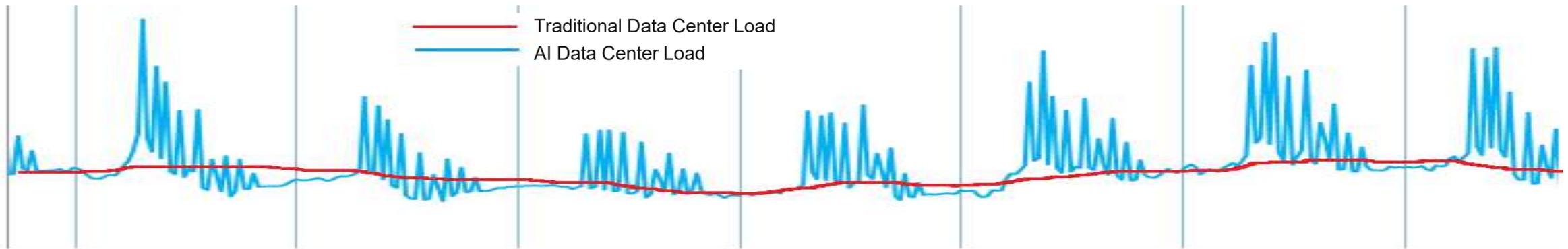
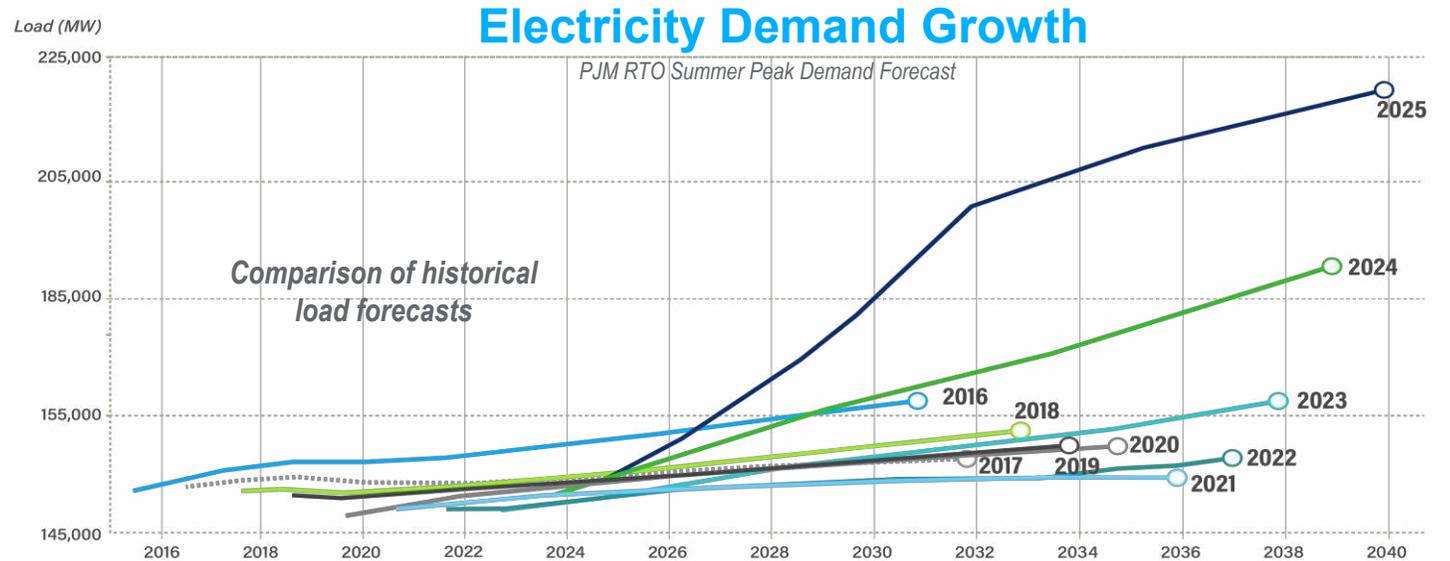


Traditional data centers are designed with 5-10 kW power per rack, while AI data centers require 60 or more kW per rack. - <https://www.datacenterknowledge.com>

AI/ML → Straining Energy Reliability & Demand

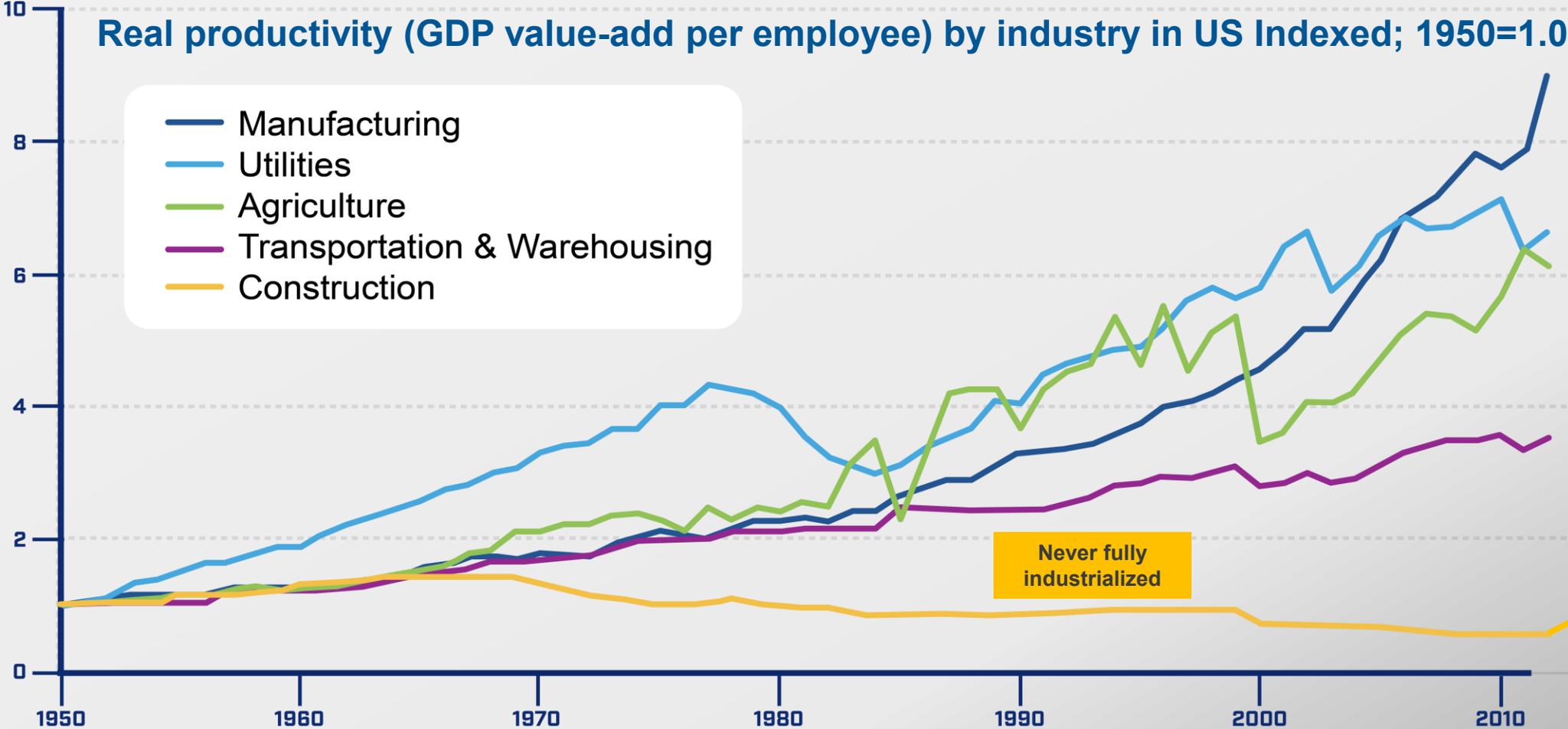
AI FACTORIES

- Load profiles
- Escalating demand



Capital Infrastructure lagged in prior Industrial Revolutions

Mass Customization Eluded Capital Infrastructure – UNTIL NOW



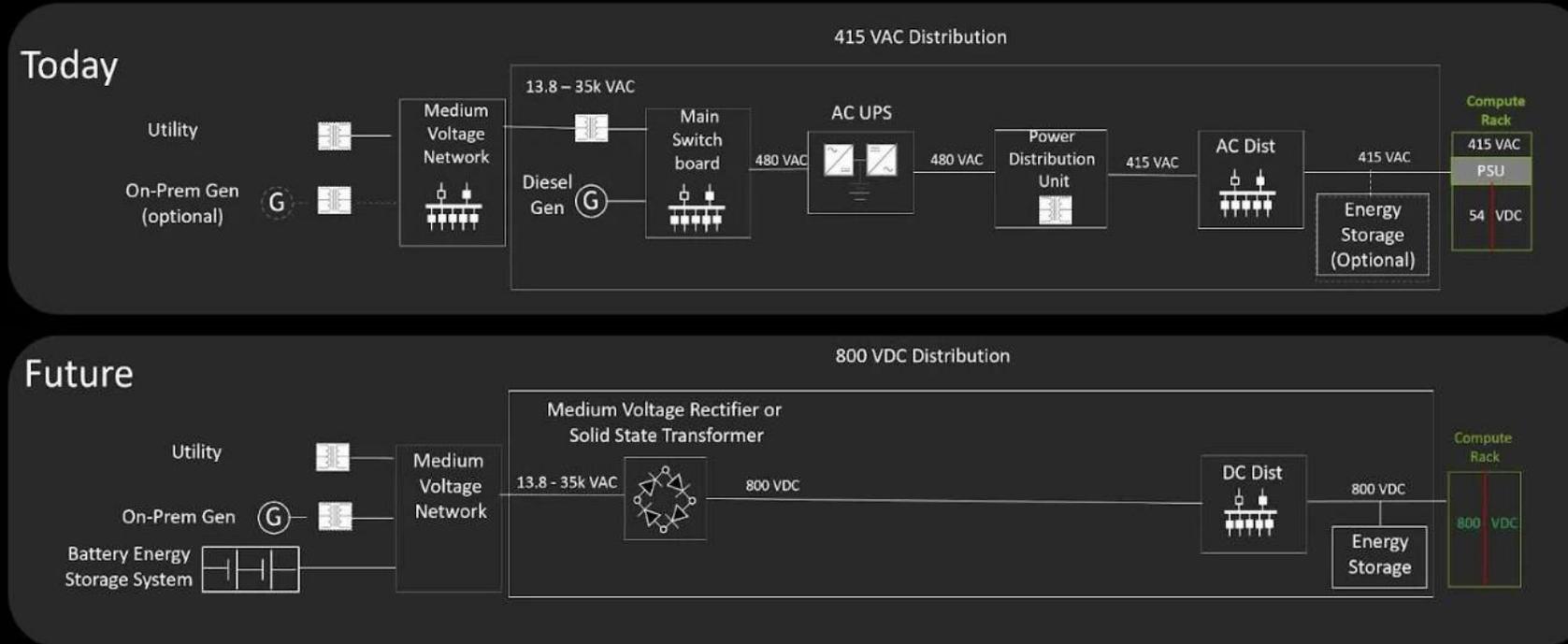
It takes
**3-5yrs &
1000x to BUILD**
what it costs to
MODEL

UNTIL NOW

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

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 ”

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



Physical Design Tools



Planning & Operations Tools

Primavera | CMMS | Prologic



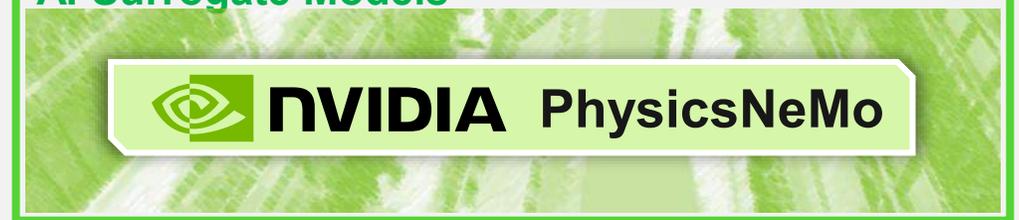
FUTURE STATE

AI-DRIVEN • INTEGRATED • REAL-TIME

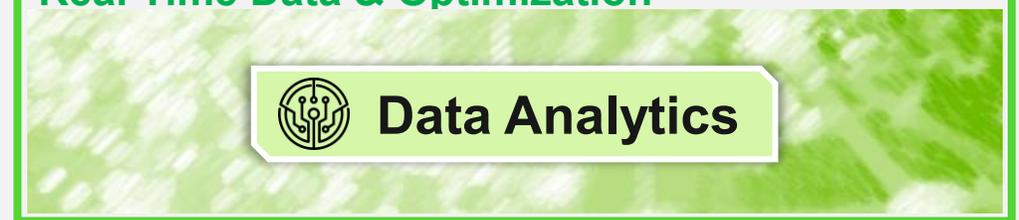
Unified Digital Twin Platform



AI Surrogate Models



Real Time Data & Optimization

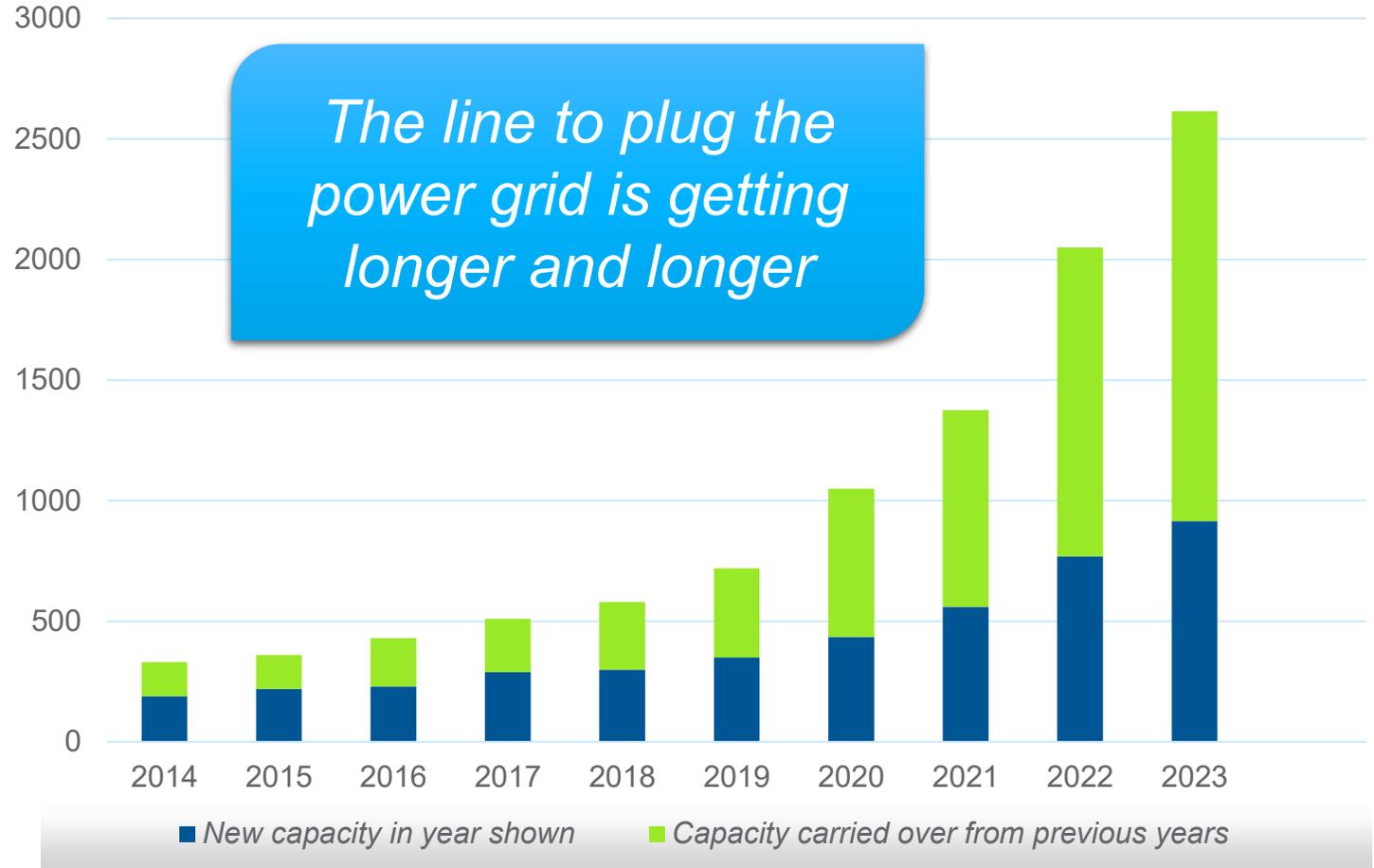


Grid Interconnection Challenges

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

Capacity (GW)



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

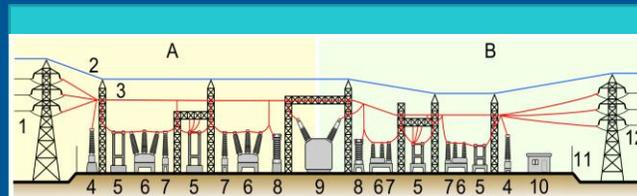
Grid Interconnection Challenges & Emerging Solutions

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

- ⑩ FERC Interconnection Final Rule
- ⑩ Early transformer procurement and spares strategy
- ⑩ Standardized substation designs & modular builds
- ⑩ Microgrid / On-site Generation Integration
 - On-site BESS for ramp control and peak shaving
 - Microgrid controller to manage UPS-gen-BESS transitions

Technology Advancements

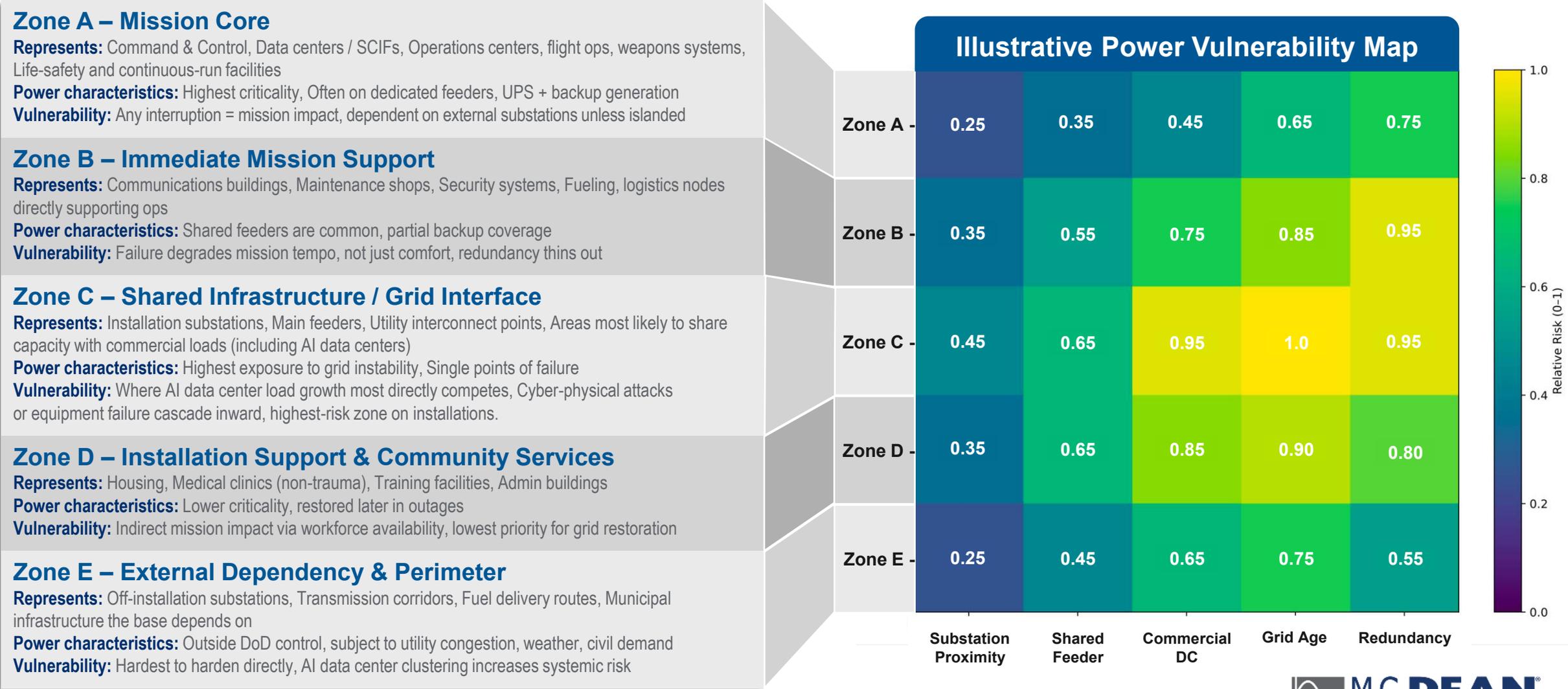
- ⑩ STATCOM/SVC for dynamic voltage support
- ⑩ Synchronous condenser where system strength is weak
- ⑩ Harmonic filtering + PQ monitoring at the POI
- ⑩ Protection coordination + validated dynamic/EMT models
- ⑩ Grid-enhancing techs (DLR, power-flow control, topology optimization)

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

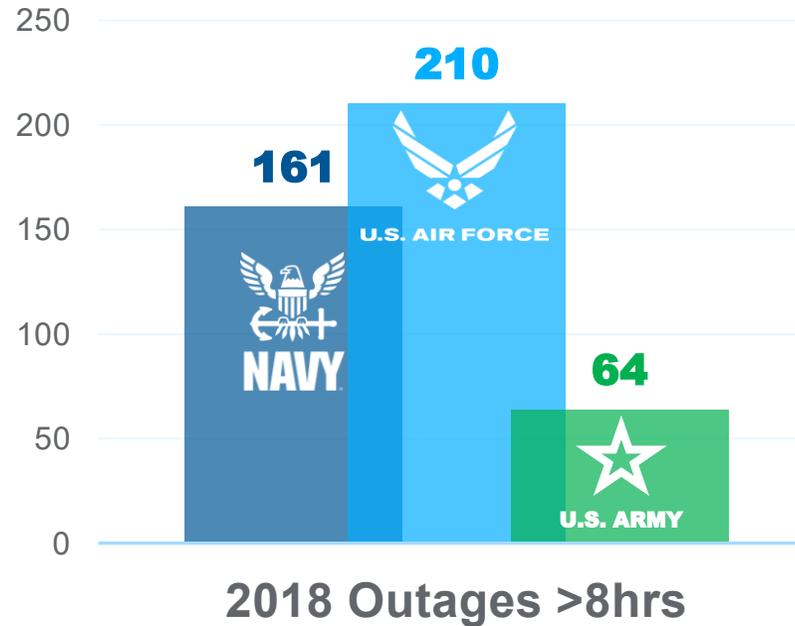
REQUIREMENTS FOR

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



INFRASTRUCTURE
REPORT CARD
ASCE

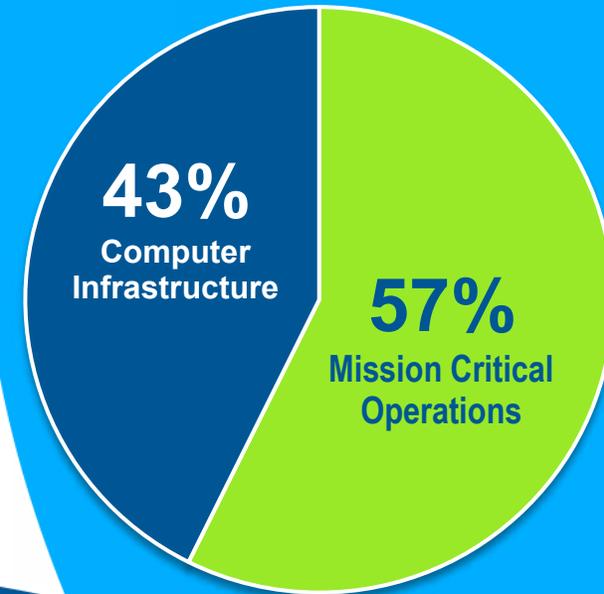


Source: DoD FY19 Energy Performance, Resilience & Readiness Report

CASE STUDY
MAJOR DoD CAMPUS

100% | Supporting Mission Critical Expansion

300% ↑ | Power Capacity in Last Decade

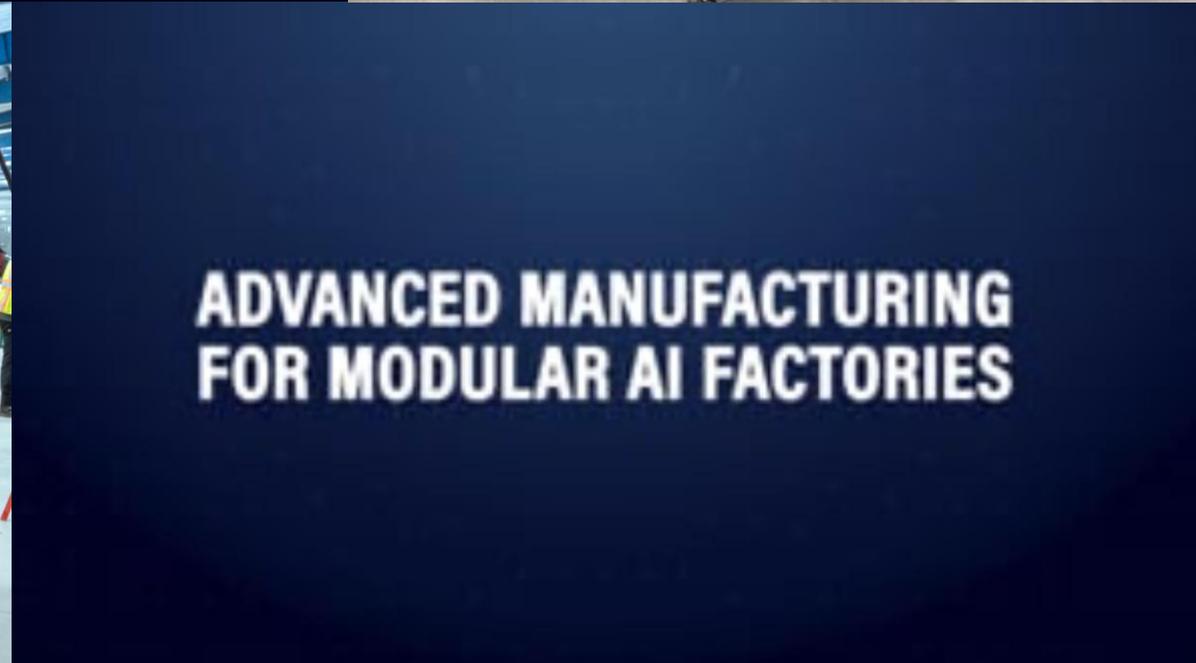


In FY21, **6,000+ outages** at DoD installations in the U.S. totaled **3,000+ days of lost power.** - *Utility Dive*

Accelerated Delivery of AI Infrastructure Solutions

Advanced
Manufacturing
of Complex
Infrastructure

- Multi-Disciplinary
- Modular



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



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



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



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



OpenAI's Stargate 1 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



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

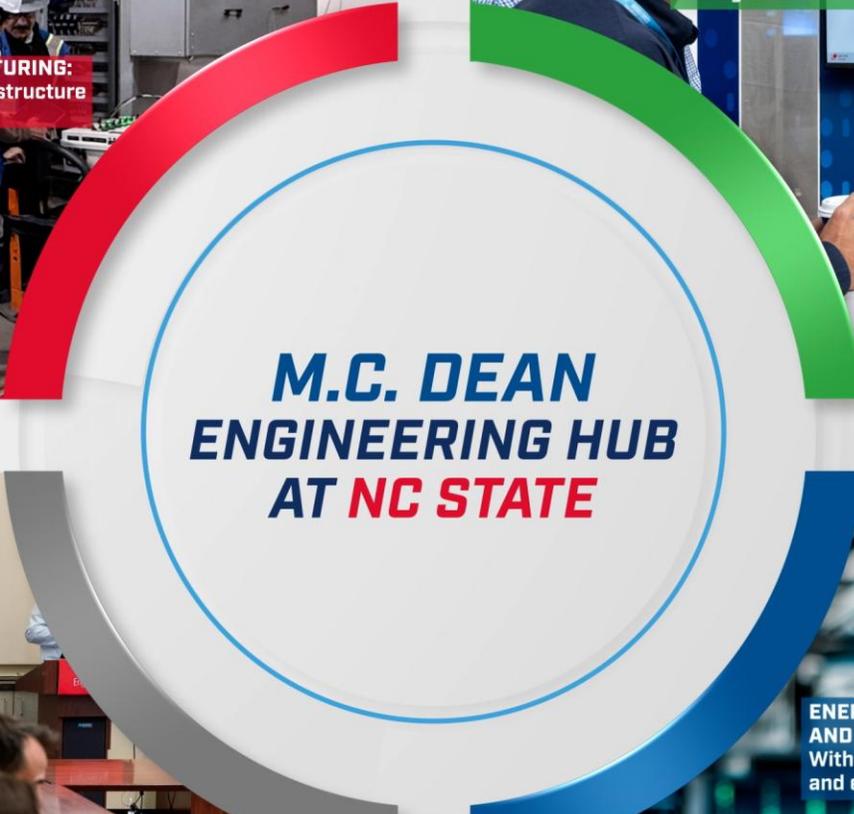
Sat, 16th Aug 2025



ADVANCED MANUFACTURING:
Reliable, complex infrastructure
at scale.



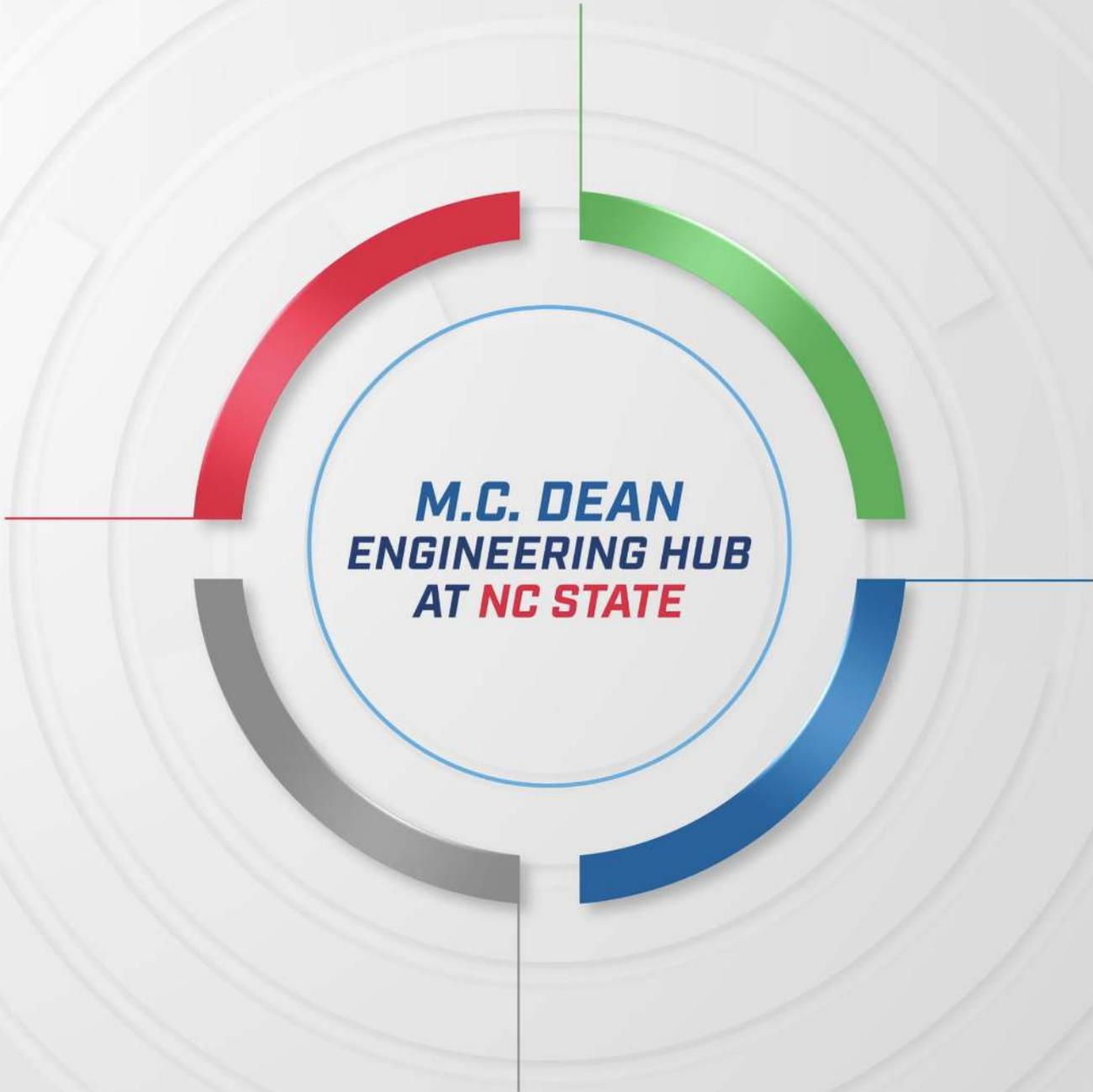
GRID INNOVATION: Islanding, hybrid mode operation, and next-generation microgrid management.



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.

The logo features a central blue circle containing the text. This circle is surrounded by a larger ring composed of four colored segments: red (top-left), green (top-right), blue (bottom-right), and grey (bottom-left). Four thin lines extend from the gaps between these segments: a red line from the top-left, a green line from the top-right, a blue line from the bottom-right, and a grey line from the bottom-left. The background consists of concentric, embossed circular patterns on a light grey surface.

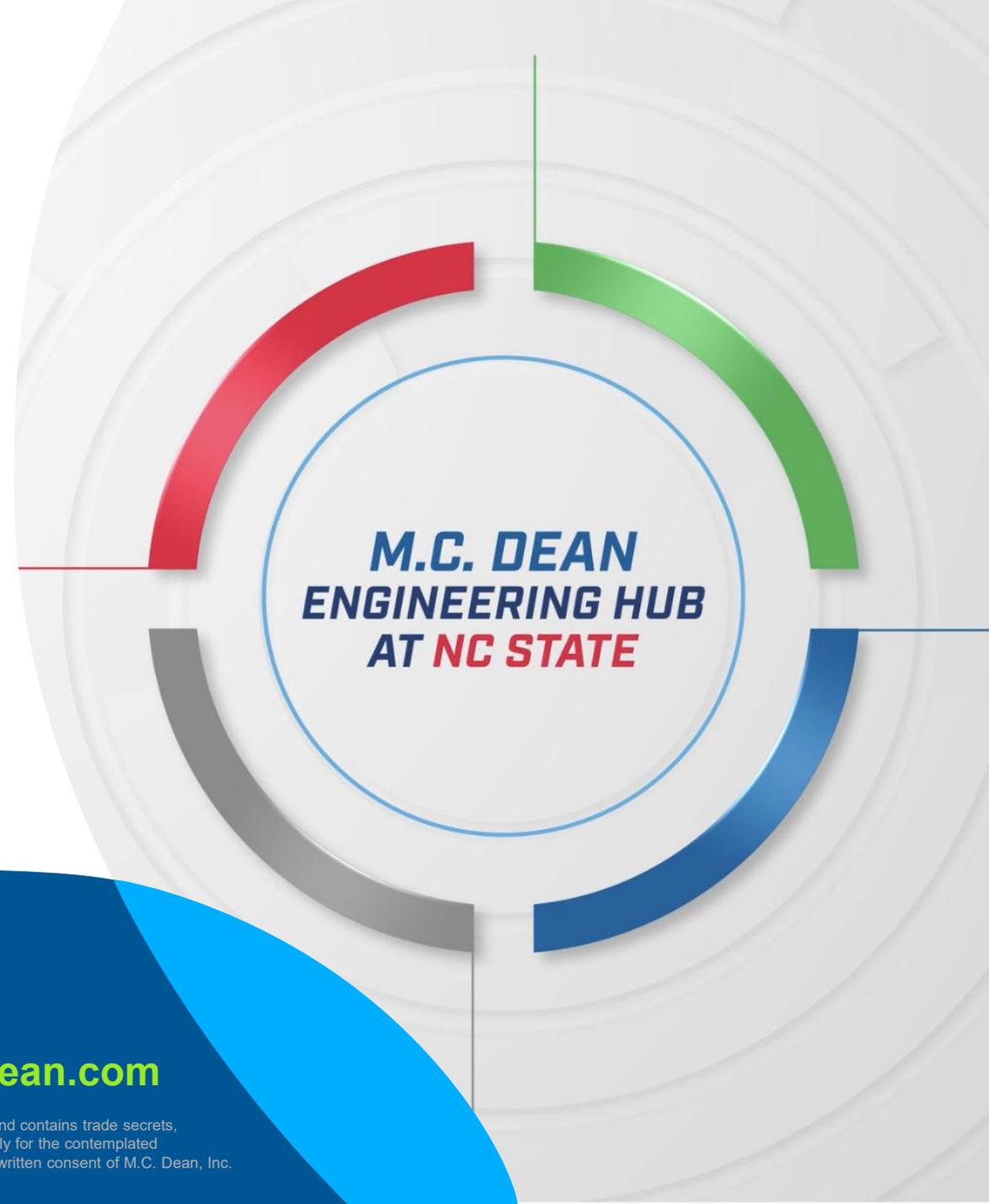
**M.C. DEAN
ENGINEERING HUB
AT NC STATE**



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