Unprecedented growth in AI data centers requires clean energy solutions

Number of Data Centers Globally and Projected US Growth

U.S. data center power consumption may grow by ~10% a year until 2030
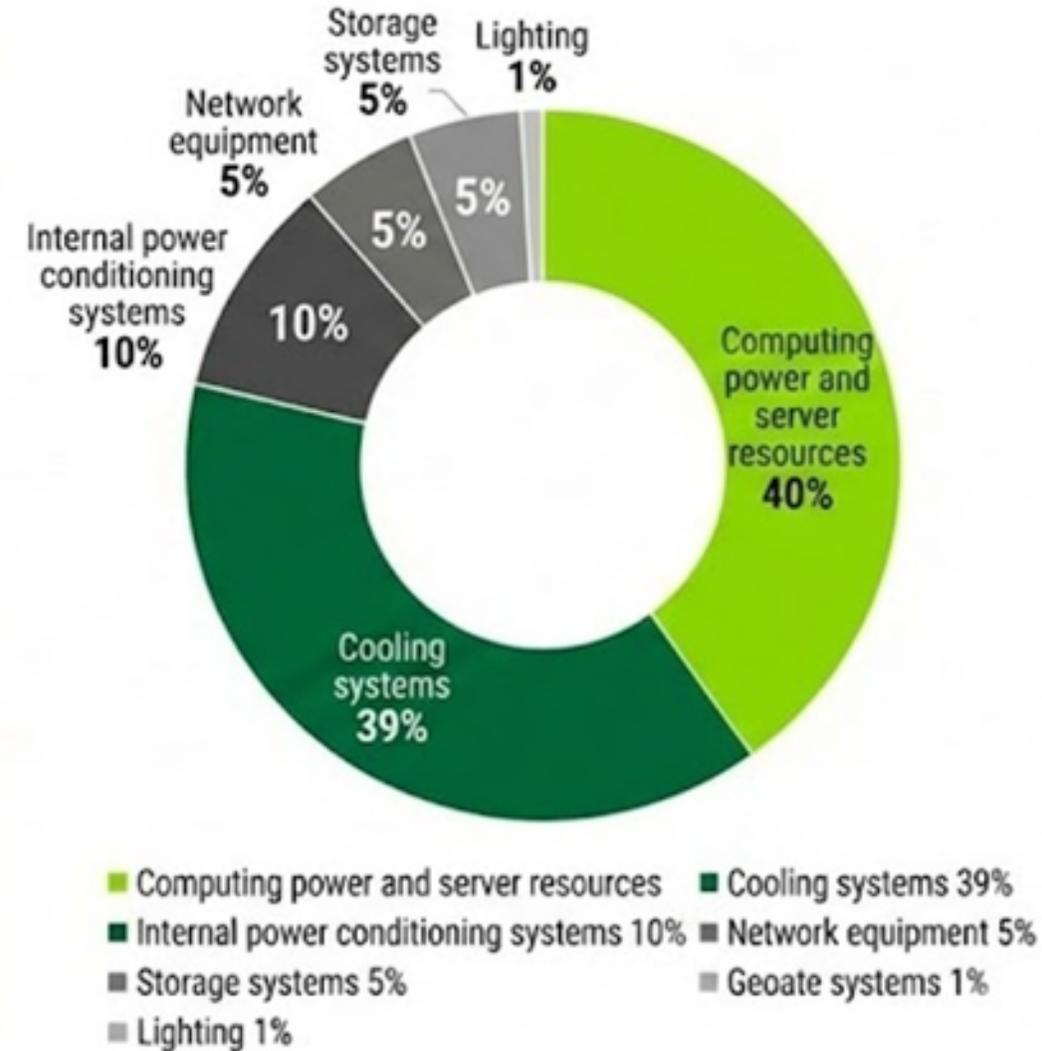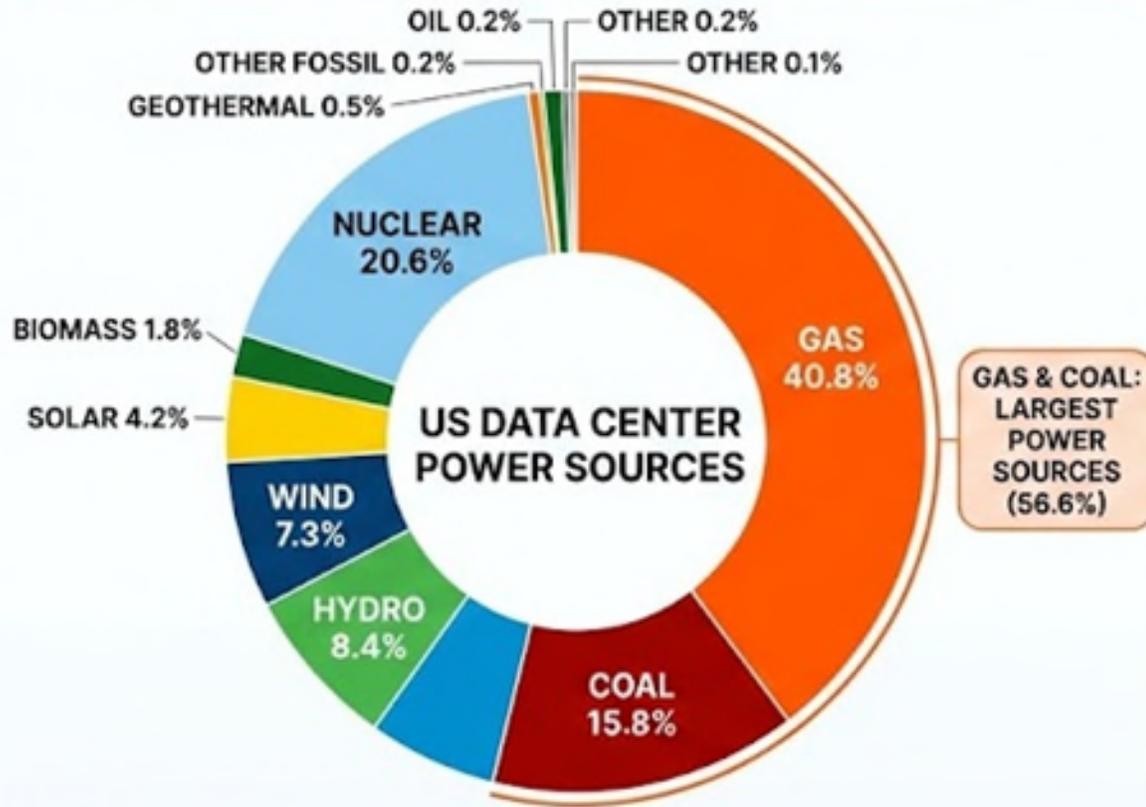
35 GW

CAGR +13.0%

+11.9%

+9.6%

+8.7%

2014 2015 2016 2017 2018 2020 2022 2022 2025 2026 2027 2028 2029 2030

United States 5,426
Germany 529
UK 523
France 322
Australia 314
Netherlands 298
Russia 251
Italy 168
Mexico 173
Poland 144
Spain 143
China 449
Japan 222
Brazil 196
Switzerland 121
Hong Kong 122

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ENERGY CONSUMPTION IN AI DATA CENTERS

Storage systems 5%
Lighting 1%
Network equipment 5%
Internal power conditioning systems 10%
Computing power and server resources 40%
Cooling systems 39%

- Computing power and server resources
- Cooling systems 39%
- Internal power conditioning systems 10%
- Network equipment 5%
- Storage systems 5%
- Geoate systems 1%
- Lighting 1%

Sources: McKinsey, Deloitte Insights

US Data Centers: Power Sources & Rising CO_2 Emissions

CURRENT POWER MIX: HEAVY RELIANCE ON FOSSIL FUELS

OIL 0.2%
OTHER 0.2%
OTHER FOSSIL 0.2%
OTHER 0.1%
GEOTHERMAL 0.5%

NUCLEAR 20.6%

BIOMASS 1.8%

SOLAR 4.2%

WIND 7.3%

HYDRO 8.4%

GAS 40.8%

COAL 15.8%

US DATA CENTER POWER SOURCES

GAS & COAL: LARGEST POWER SOURCES (56.6%)

Data centers predominantly rely on non-renewable energy, primarily natural gas and coal, to meet their high power demands.

GROWTH & EMISSIONS: A DIRECT CORRELATION

DATA CENTER TOTAL POWER LOAD (TERAWATT HOURS)
- 0.00 - 1.80
- 1.81 - 5.85
- 5.86 - 11.53
- 11.54 - 18.84
- 18.85 - 52.22

GROWTH IS DRIVING INCREASED EMISSIONS

DATA CENTER TOTAL CO_2e EMISSIONS (MEGATONNES)
- 0.00 - 1.03
- 1.04 - 3.27
- 3.28 - 6.23
- 6.24 - 9.62
- 9.63 - 30.07
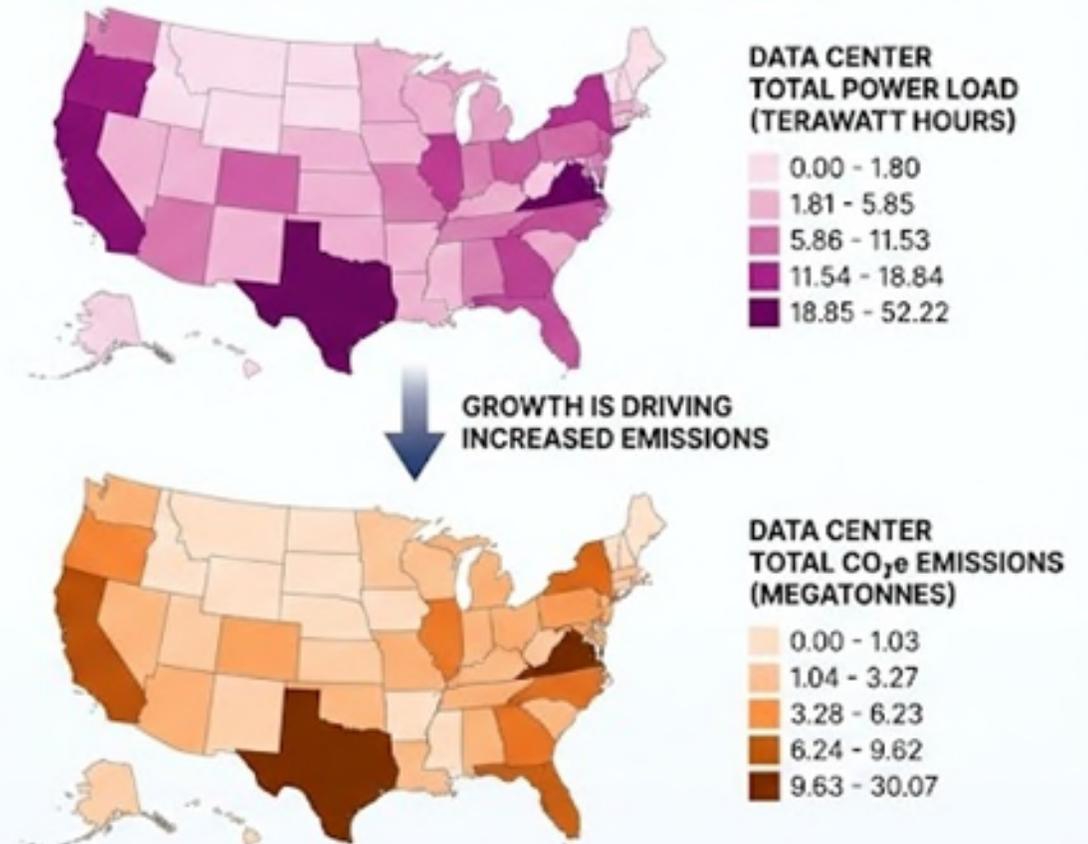
The **increasing power consumption by data centers** across the U.S. is directly leading to **higher carbon dioxide emissions**, particularly in states with heavy fossil fuel reliance.

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THE INDUSTRIAL HEAT CHALLENGE
>70% Of Industrial Energy is Heat & Major Emissions Source

HARD-TO-ABATE SECTORS (600-1400°C)
Firm, high-temperature needs transform Cement, Steel, Chemicals. Difficult to electrify efficiently.

HIGH-GRADE HEAT: CRITICAL GAP (600-950°C+)
Steel, Cement, Hydrogen Production.
Requires Advanced Reactors (HTGR/MSR).
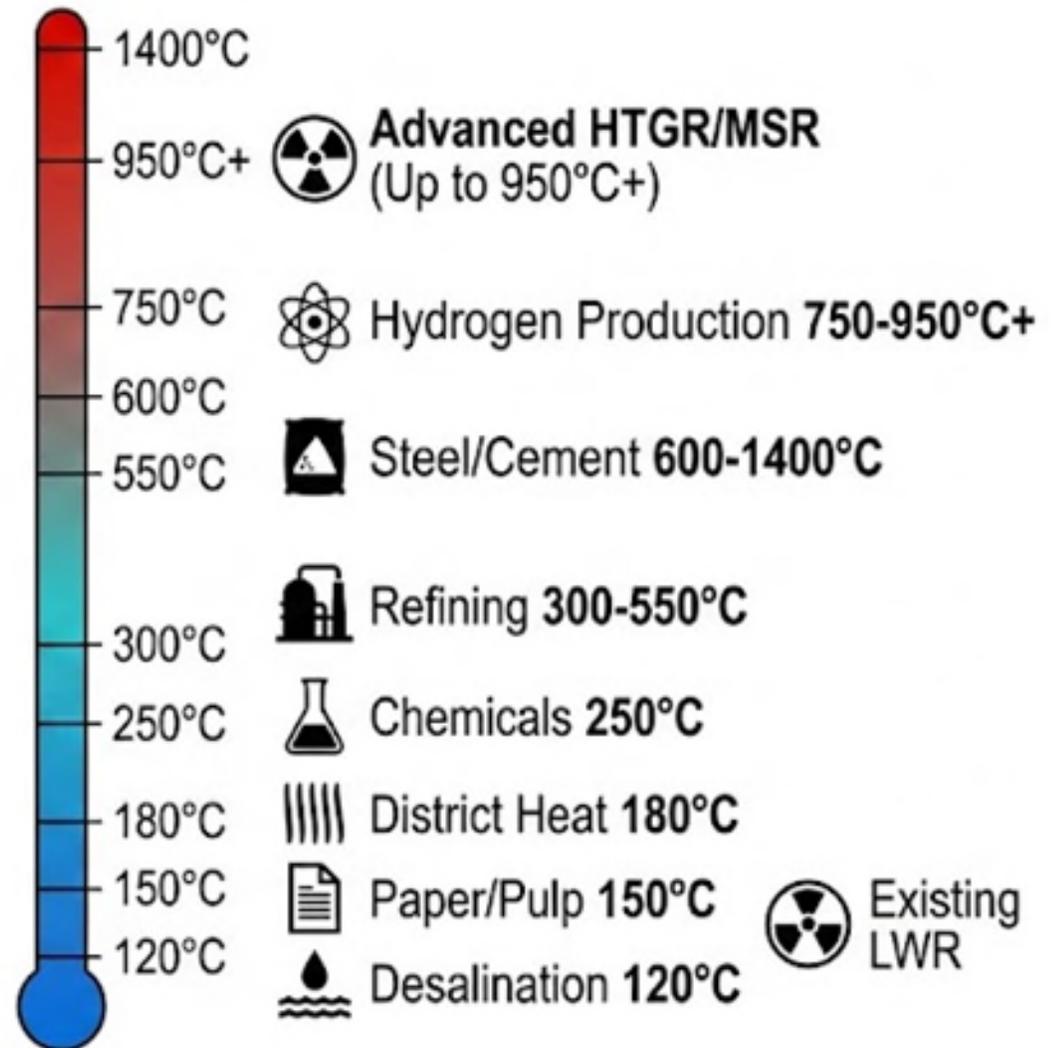
MEDIUM-GRADE HEAT (300-550°C)
Chemicals, Refining.
VRE + electrification limited by cost & storage.

LOW-GRADE HEAT (<300°C)
Paper, Pulp, Food, Desalination.
Existing LWRs can supply steam/heat.

Source: NEA, IAEA, C2ES

- 1400°C
- 950°C+ — **Advanced HTGR/MSR** (Up to 950°C+)
- 750°C — Hydrogen Production **750-950°C+**
- 600°C
- 550°C — Steel/Cement **600-1400°C**
- 300°C — Refining **300-550°C**
- 250°C — Chemicals **250°C**
- 180°C — District Heat **180°C**
- 150°C — Paper/Pulp **150°C**
- 120°C — Desalination **120°C**

Existing LWR

Combined Heat and Power from Nuclear Reactors: Supporting the Overall Energy Ecosystem
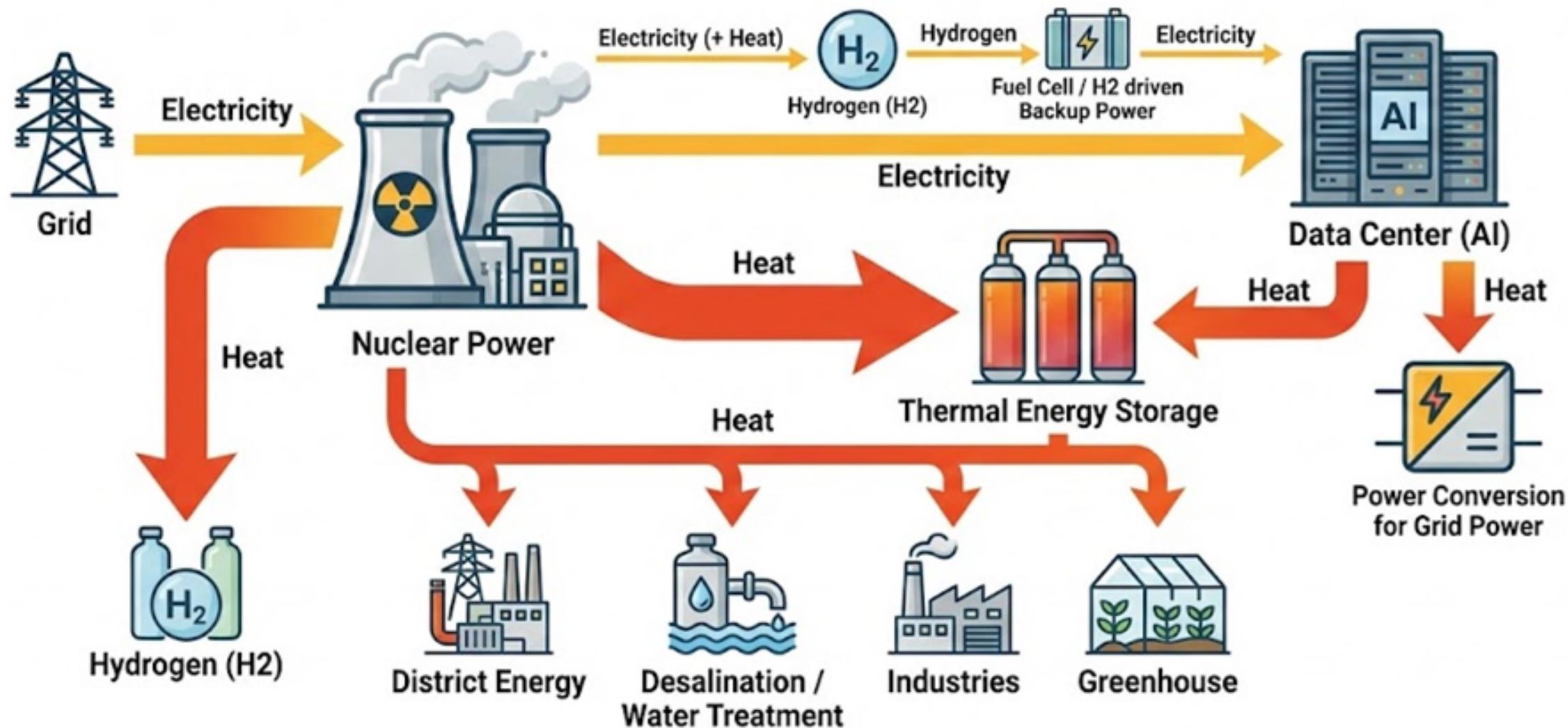
Combined Heat and Power Unlocks Nuclear's Full Economic Potential

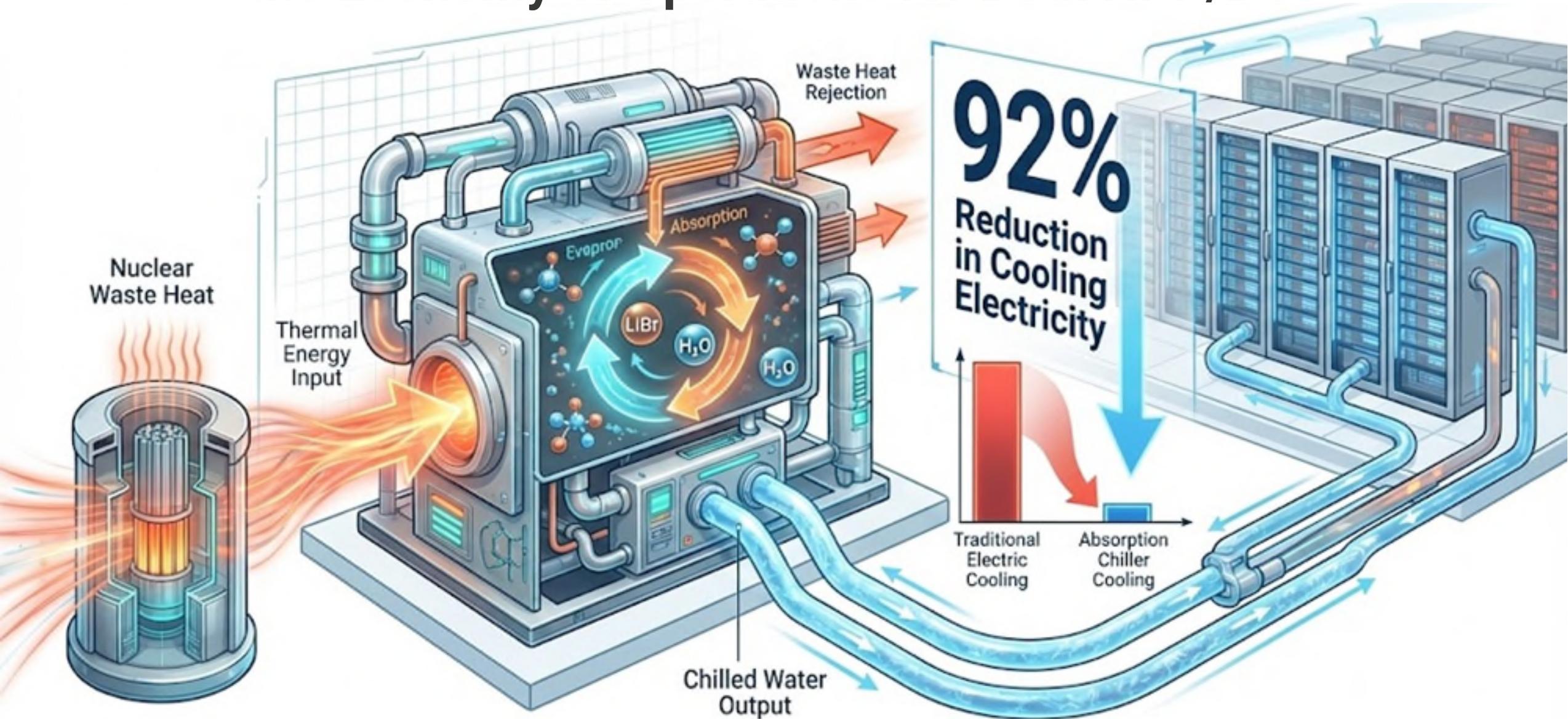**3X** Energy Utilization vs. Electricity-Only

Baseload Electricity

Process Heat 70-230°C

Thermal Cooling

Waste Heat Powered Absorption Chiller Systems can Improve the Economy of Operations for Both NPP/DCs

Established Use Cases: District Heating

- Switzerland's Beznau plant

- Two PWRs, 365MWe

- On Grid 1969

- Supplying district heating since 1984

- China's Haiyang NPP,

- Two AP1000, 1250MWe

- On Grid 2018

- Supplying heat to 200k Haiyang residents

- Russia's Akademik Lomonosov Floating Nuclear Power Plant
- Two KLT-40S PWRs, 35MWe

- On Grid 2019

- Serving space heating and domestic hot water to the Russian port city of Pevek on the East Siberian Sea

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Established Use Cases: Desalination

PHOTO CREDIT: dianuke.org

- Japan's Ohi plant

- Two PWRs, 1180MWe

- On Grid 1991-93

- Desalination capacity of 14,000 m^3 per day

- USA's Diablo Canyon NPP

- Two PWRs, 1100MWe

- On Grid 1985-86

- Desalination capacity of 6000 m^3 per day

- India's Madras Atomic Power Station
- Two PHWRs, 220MWe

- On Grid 1983-85

- Desalination using multi-stage flash (4500 m^3 per day) and RO (1800 m^3 per day).

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New Use Cases: Chemical, Hydrogen and Data Centers....

- Dow Chemical and X-energy Demonstration

- Four-unit 320-MWe Xe-100 advanced nuclear

- Dow's Seadrift site in Texas
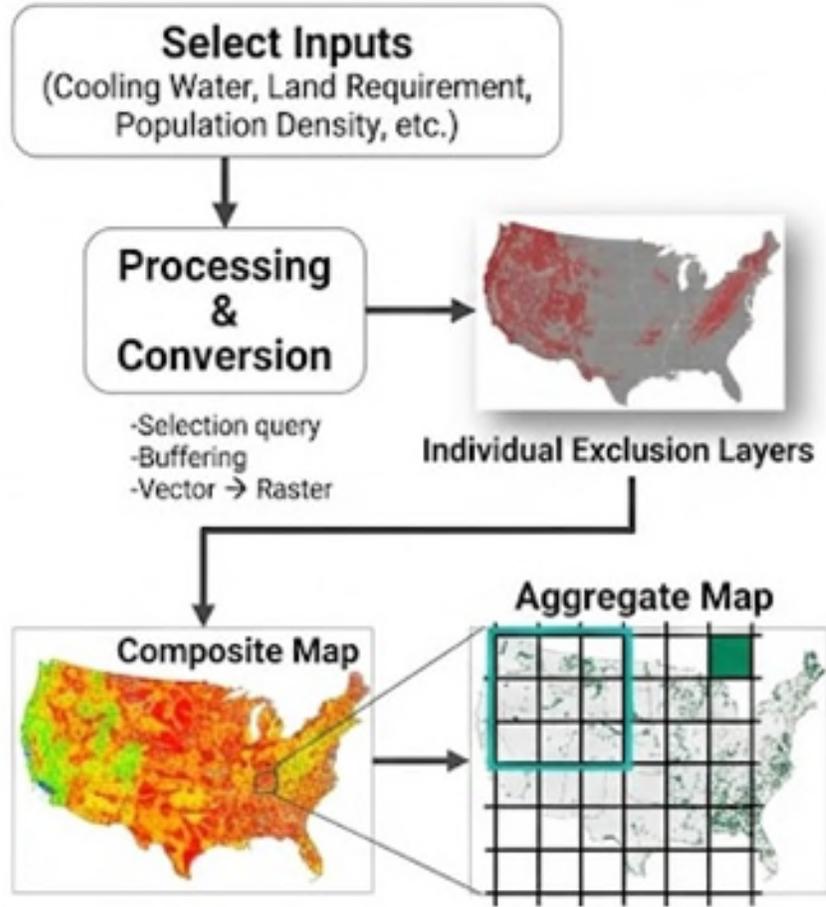
- Support chemicals production

- Constellation's Nine Mile Point Nuclear Station (General Electric BWR units)

- In Oswego, New York

- Produced hydrogen in March 2023, at its 1-MW demo facility through an electrolyzer system

- Constellation is working with Microsoft to restart the Unit 1 of the former Three Mile Island nuclear plant

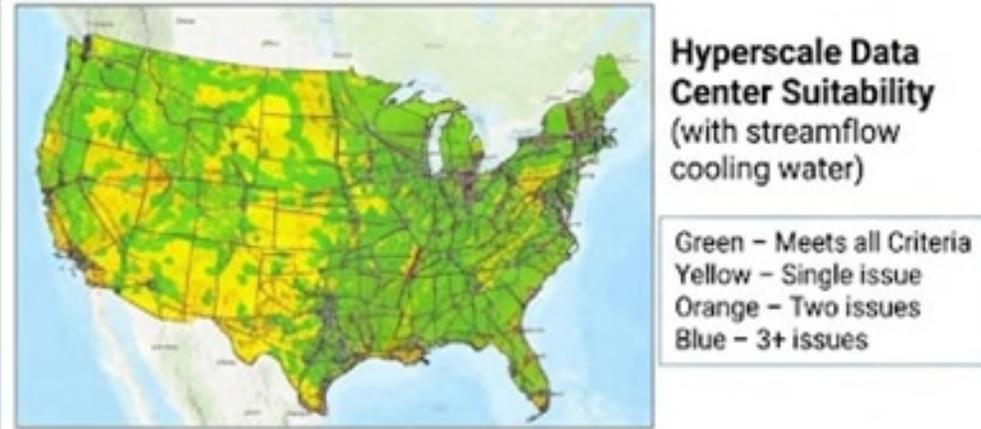- Crane Clean Energy Center to power Microsoft's AI data centers

ORNL's OR-SAGE Tool for Collocated NPP & Data Center Siting
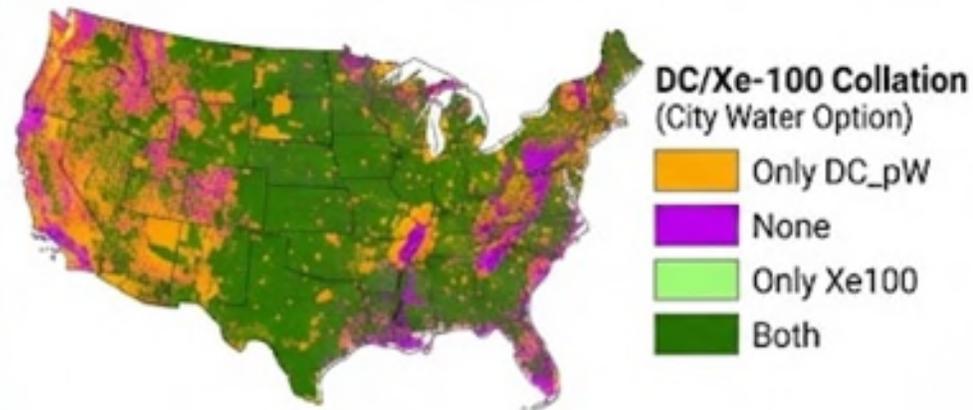
OR-SAGE Siting Criteria & Process

Select Inputs
(Cooling Water, Land Requirement, Population Density, etc.)

↓

Processing & Conversion

-Selection query
-Buffering
-Vector → Raster

Individual Exclusion Layers

Composite Map

Aggregate Map

Tool integrates multiple criteria to create composite suitability maps

Analyzing NPP/DC Collocation

Hyperscale Data Center Suitability
(with streamflow cooling water)

Green – Meets all Criteria
Yellow – Single issue
Orange – Two issues
Blue – 3+ issues

Access to cooling water is a primary limiting factor

DC/Xe-100 Collation
(City Water Option)

- Only DC_pW
- None
- Only Xe100
- Both

Key Findings for Siting

- Cooling water is the primary limiting factor.

- Existing NPP sites: 24% support gigawatt-scale, 87% support megawatt-scale.

- Retired CPP sites: 70 sites for gigawatt-scale, 136 for megawatt-scale.

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ORNL's TRANSFORM Tool for Engineering Feasibility & FEED Studies

- Built using the Modelica programming language
  - A powerful and modern dynamic system modeling tool
  - Ideal for rapid, flexible, and collaborative system modeling
- Create physics-based models of nuclear reactors coupled with energy generation, energy storage, and industrial users for subsequent analysis and optimization.
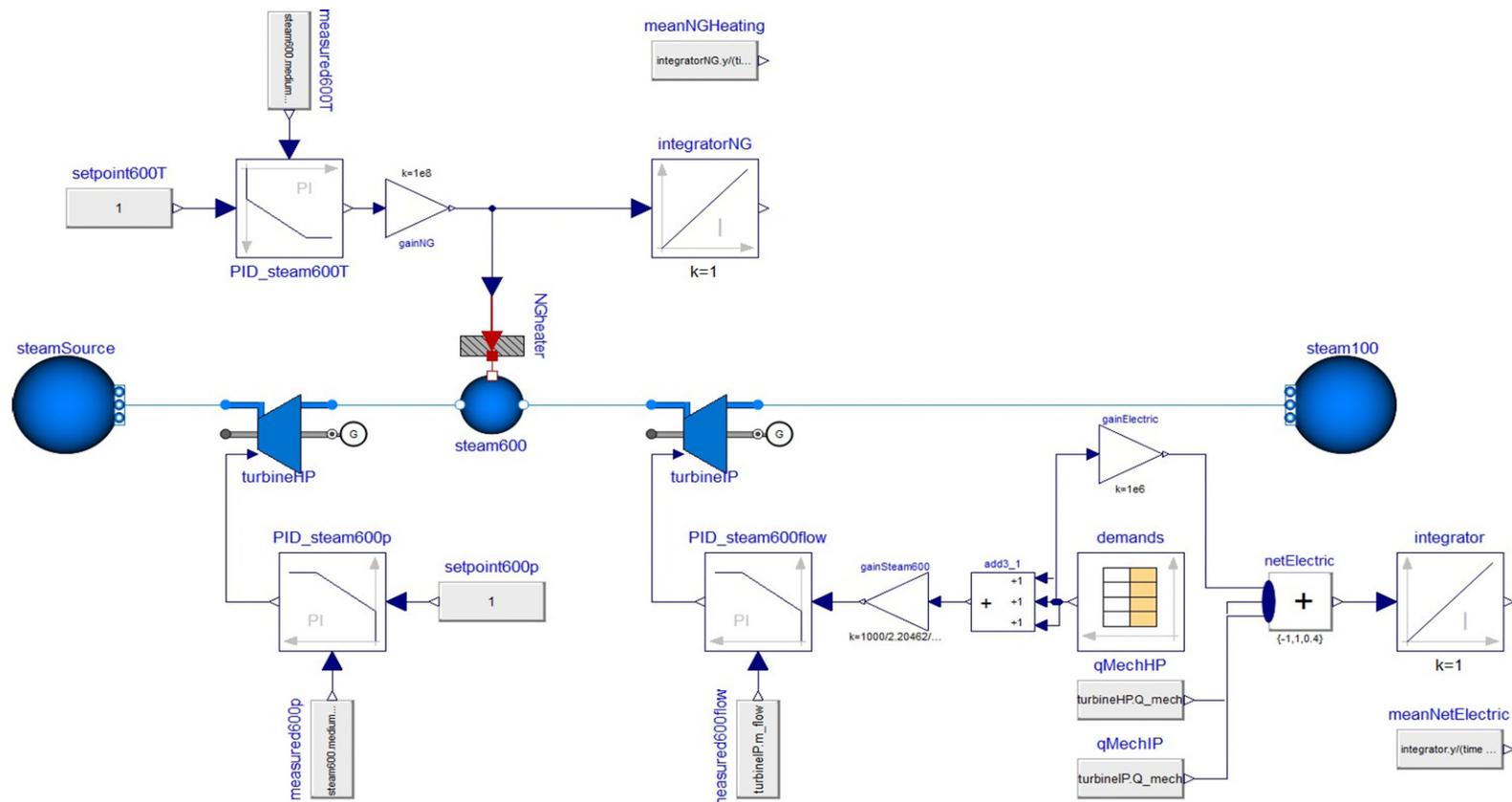
TRANSFORM model of delivering high-quality steam to the steam distribution network of an industrial chemical facility

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