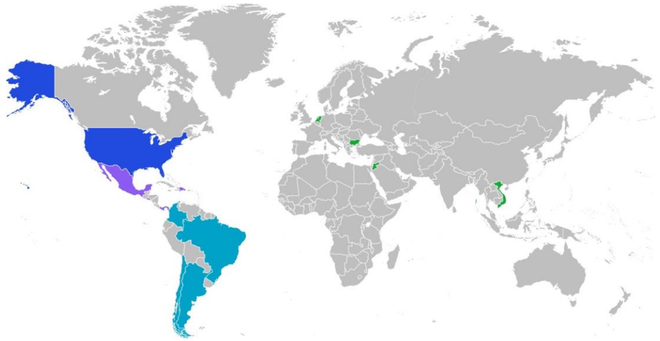
Transforming to a Digital-First Electricity Grid

Women IN Energy
October 2024

Company overview



34,906

Gross MW in operation*

*24,047 proportional MW (gross MW multiplied by AES' equity ownership percentage).

$12.7 billion

Total 2023 revenues

5,484 MW

Generation capacity under construction

$45 billion

Total assets owned & managed

4 Continents

12 Countries

6 Utility companies

2.6 million

Utility customers served

9,600 people

Our global workforce

Recognized for our commitment to sustainability

Great Place To Work.

2023 WORLD'S MOST ETHICAL COMPANIES® ETHISPHERE 10-TIME HONOREE

FTSE4Good

FAST COMPANY

Agenda

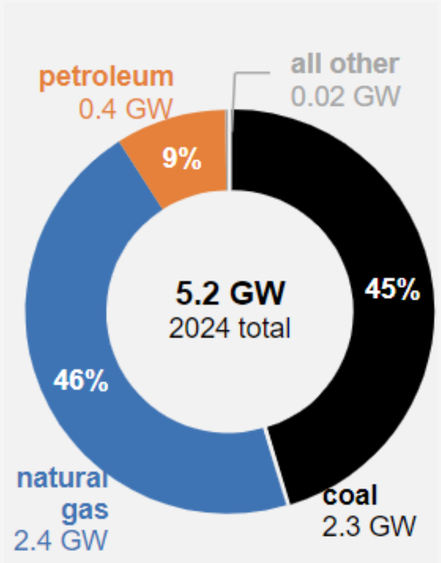
1. Introduction: The Evolving Electricity Grid
2. The Digital-First Grid: What, When, and How?
3. The Digital-First Grid: Meeting Stakeholder and Customer Expectations

Agenda

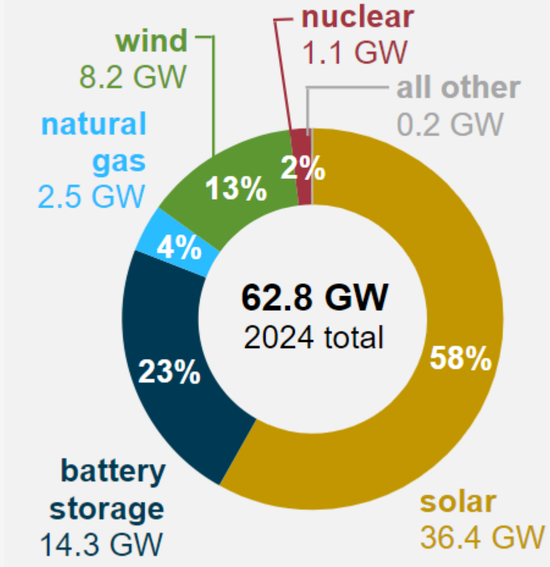
1. **Introduction: The Evolving Electricity Grid**
2. The Digital-First Grid: What, When, and How?
3. The Digital-First Grid: Meeting Stakeholder and Customer Expectations

The grid is undergoing a **generational transition** in resource type…

Planned retirements in U.S., 2024:



Planned new capacity in U.S., 2024:



Retirements source: EIA: https://www.eia.gov/todayinenergy/detail.php?id=61425#
New capacity source: EIA: https://www.eia.gov/todayinenergy/detail.php?id=61424#

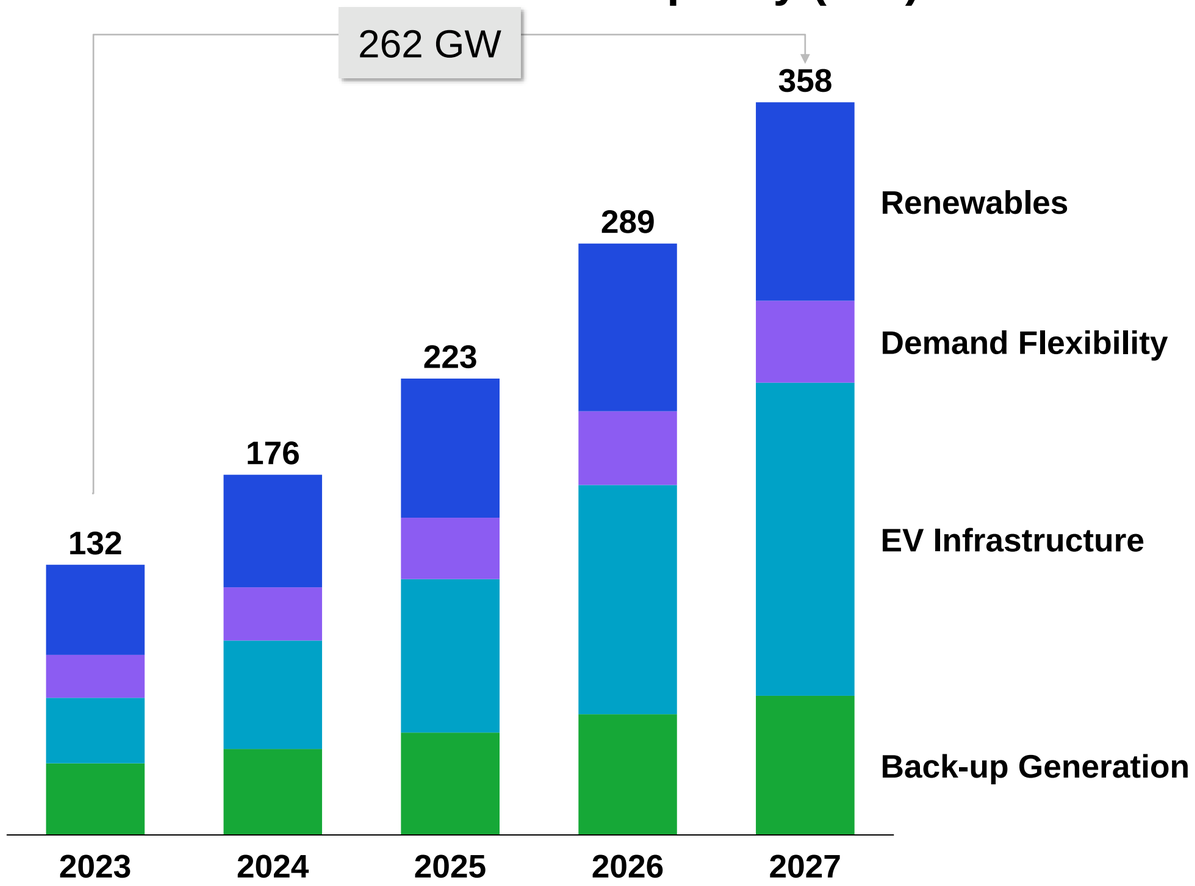
…and location

New capacity installations:

2023-2027

262 GW	272 GW
of DER	of utility-scale

DER Cumulative Installed Capacity (GW)

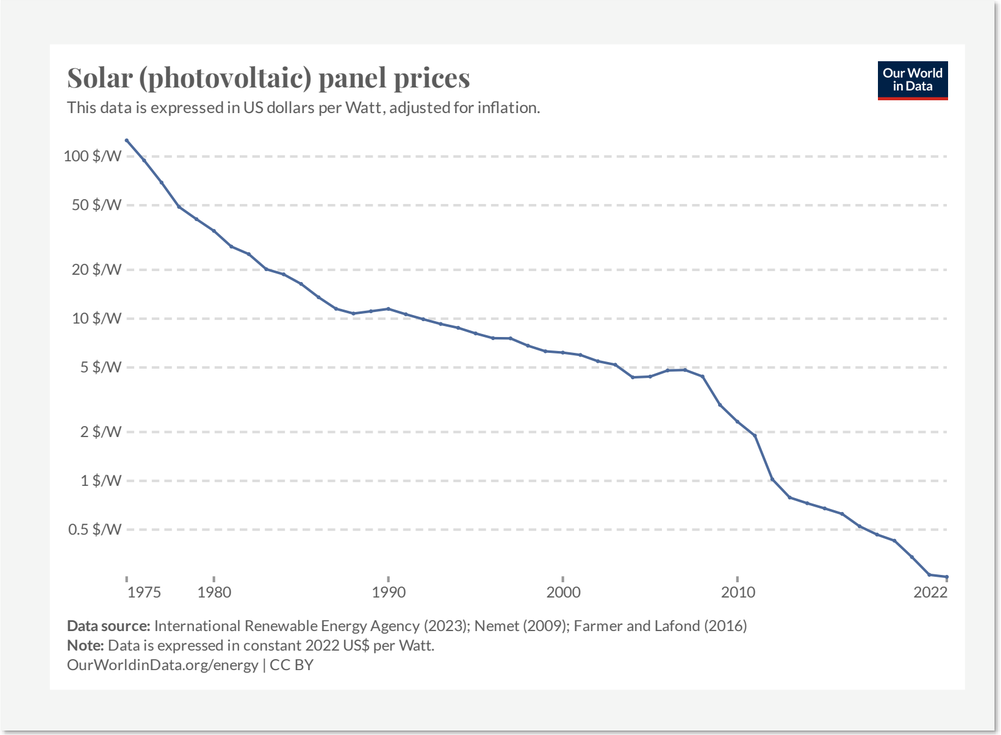


Note: DERs are Distributed Energy Resources

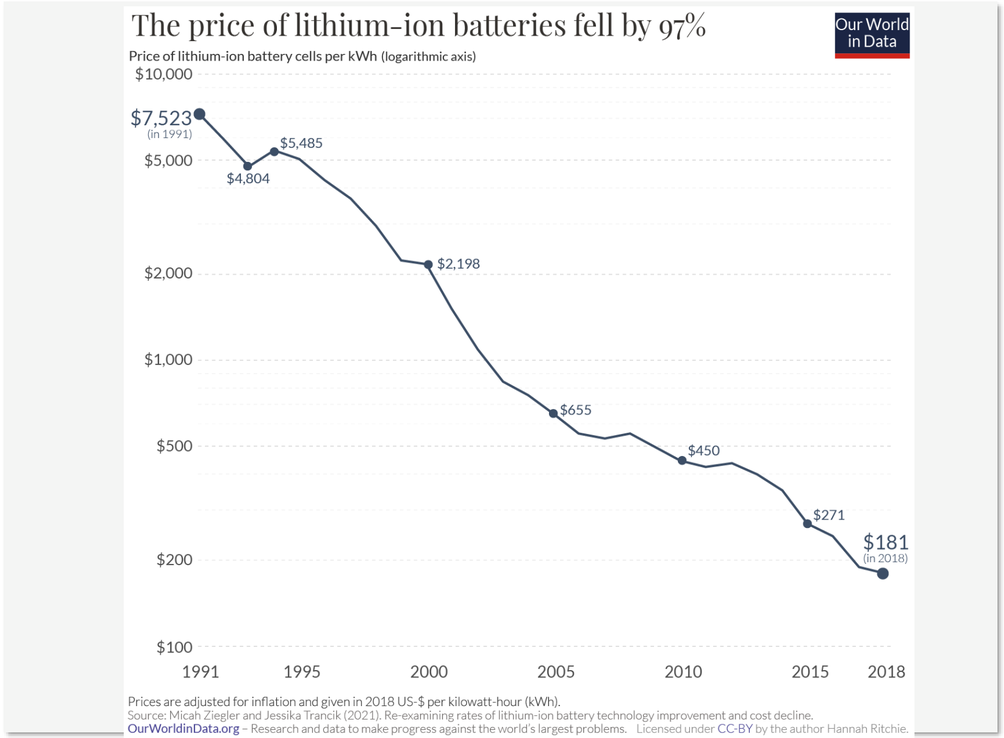
Source: US Distributed Energy Resource (DER) Outlook 2023, Wood Mackenzie (June 2023)

Today’s solar PV and energy storage costs are driving the transition…

Solar cost curve



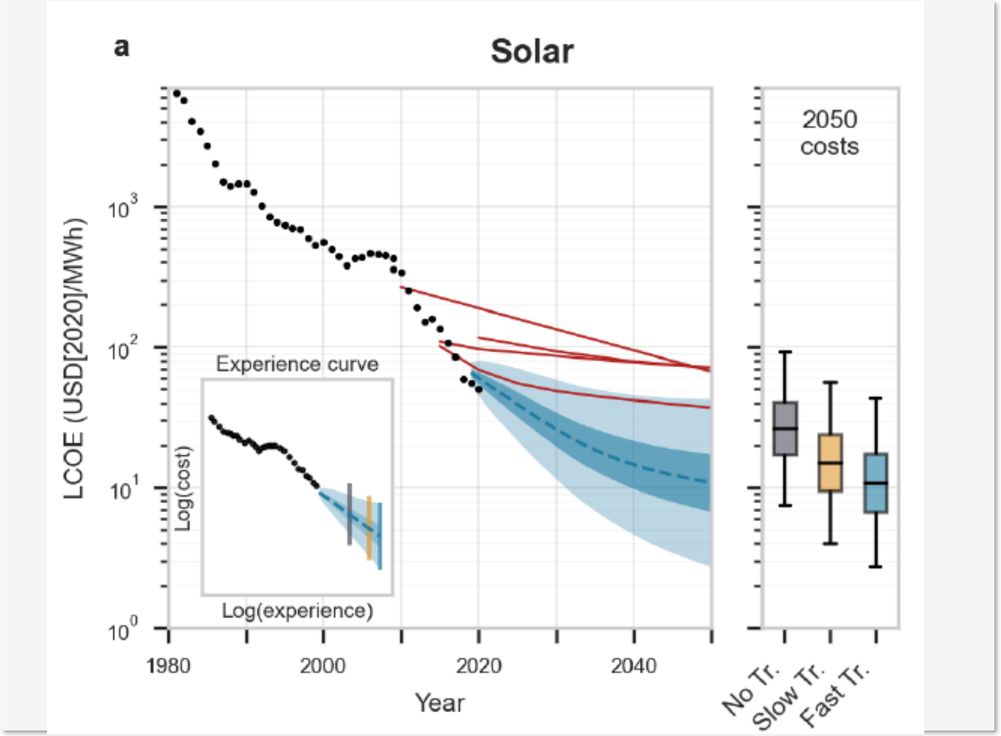
Battery cost curve



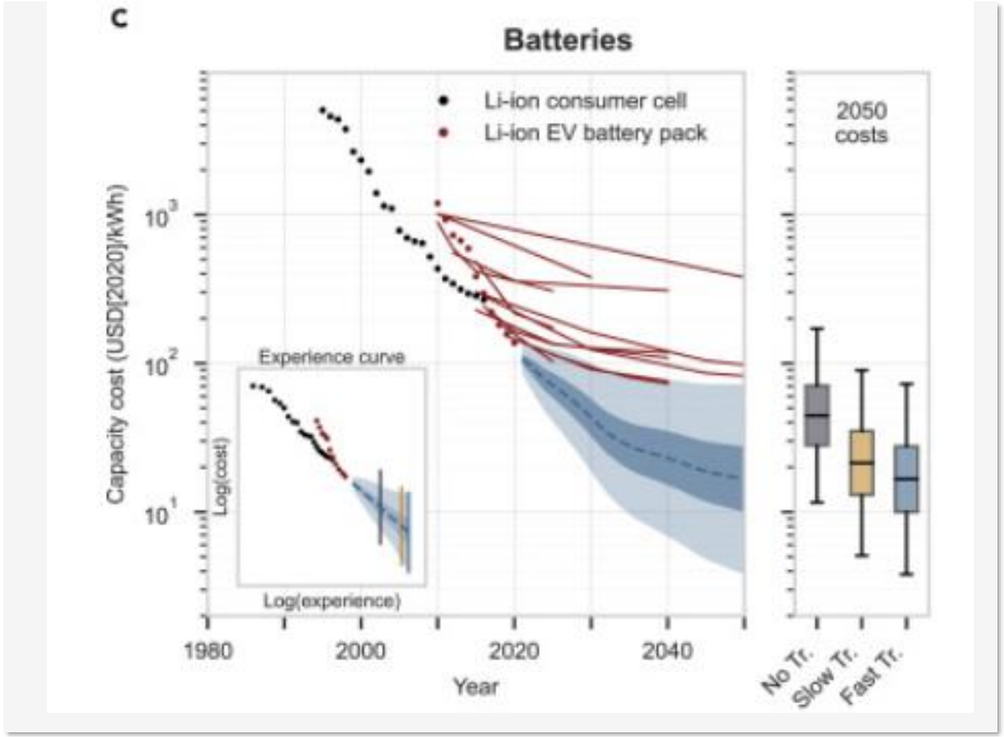
Source: https://ourworldindata.org/grapher/solar-pv-prices
https://ourworldindata.org/battery-price-decline

...And future declines may accelerate further

Solar cost curve projection



Battery cost curve projection



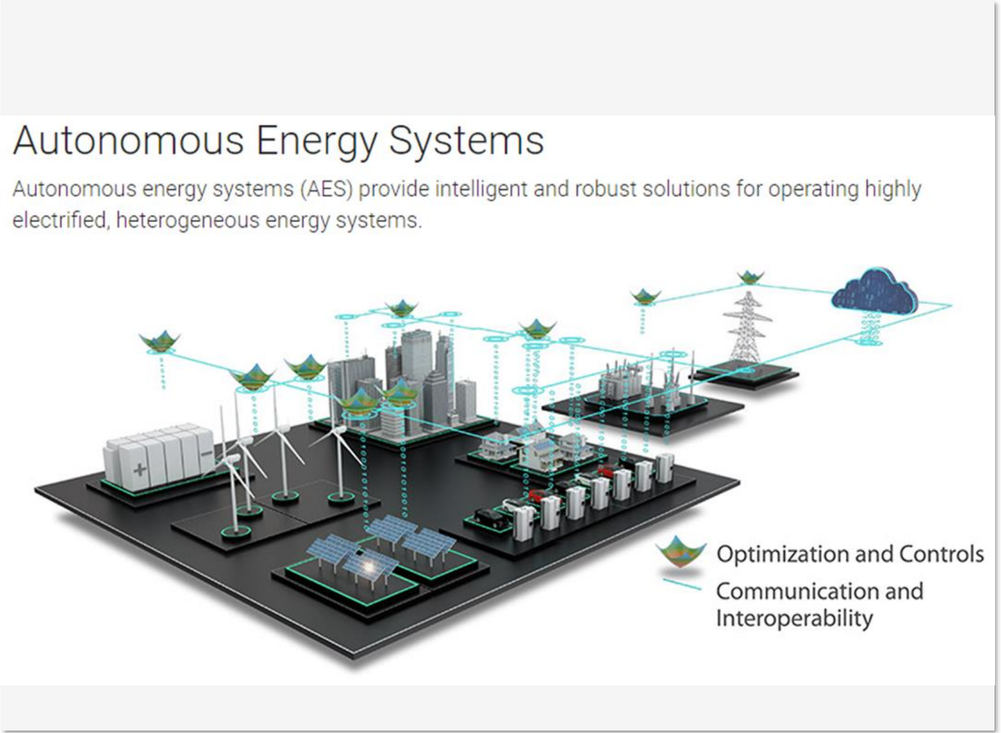
Red lines represent historical forecasts

Blue wedges represent experience curve-based forecast

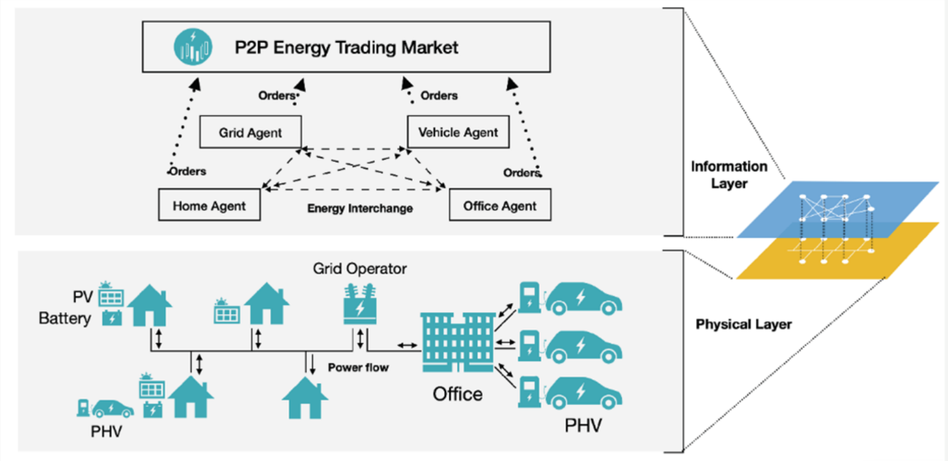
Source: Way et al. Empirically grounded technology forecasts and the energy transition, Joule,Volume 6, Issue 9,2022.

What could this mean for our energy system?

Digital, distributed, decarbonized:



Market implications:



Autonomous Energy Systems: NREL: https://www.nrel.gov/grid/autonomous-energy.html
Markets: Takeda et al. 2021. Designing a User-Centric P2P Energy Trading Platform: A Case Study – Higashi-Fuji Demonstration

Here are some possible applications…But how could today's grid and infrastructure handle it?

Today

- Regulation
- Peaking capacity
- Renewables balancing
- Advanced applications: Black Start, Inertia

2035

- Transmission services
- Intra-day, intra-week balancing, off-shore wind applications
- Community storage, resiliency-enabler

2050

- Seasonal balancing
- Home, building, device-embedded
- Energy buffer embedded at all levels of the grid

Sources: Today and 2035: AES brand website. 2050: https://www.sma-sunny.com/en/battery-storage-systems-the-path-to-100-solar-power-for-your-home/

Discussion

1. What do you see as the most exciting changes happening in the electricity industry today, and why?

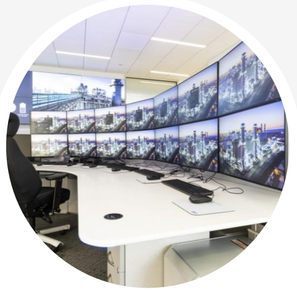
2. How will the increasing role of consumers and distributed energy resources (DERs) reshape the traditional utility-customer relationship?

3. In your view, given the energy transition, is a smarter, digital grid a “nice to have” or a necessity?

Agenda

1. Introduction: The Evolving Electricity Grid
2. **The Digital-First Grid: What, When, and How?**
3. The Digital-First Grid: Meeting Stakeholder and Customer Expectations

A digital energy asset is one where the key functionality, control, or coordination, are digital

Visualization & Control	SAT	DLR	Topology Optimization	APFC
				
Make grid assets and power flow visible	Continue serving load even when lines are congested	Continually calculate carrying capacity	Strategically reconfigure the grid's structure	Modify the magnitude of power flows

Today's grid struggles to incorporate the full value from digital energy assets

SAT is "Storage as Transmission"; APFC is "Advanced Power Flow Control"; DLR is "Dynamic Line Rating"

A digital grid is needed to fully decarbonize our electricity system. The transformation to a fully digital grid will take time and effort.

Legacy

- Large, centralized thermal assets provide most power
- Single direction flow
- Modeling is slow, but adequate for the system

Emerging

- Mix of legacy and digital asset provide power
- Some bi-directional flow
- Modeling struggles to keep pace with new resources

Scaling

- Major interconnections become digital-first
- Data-rich systems, advanced computing, and AI transform modeling in planning and operations

Transformed

- Digital electron buffer enables profound market transformations
- Modeling is fast, embedded at all levels, AI-assisted

Pre-2020s | **2020s** | **2030s** | **2040+**

AI will support decision-making in a digital-first grid

Today

- AI supports visualization and situational awareness in operator-controlled grid
- E.g. forecasting bulk renewables and net load; cybersecurity
- Humans set strategic objectives, manually execute operationally

2035

- AI can optimize and coordinate distributed resources and aggregations, including digital assets
- Humans set strategic objectives, with decreasing tactical intervention

2050

- AI enables local, autonomous coordination of digital electron buffer and other distributed resources
- Humans set strategic objectives

Today: Fluence 2023 Q2 earnings report cover image. 2035: https://x.company/projects/tapestry/. 2050: AES Brand image.

Discussion

1. What role do you believe digital technologies (like AI) will play in enhancing grid reliability and efficiency, if any?

2. How can decentralized energy resources and delegated control improve grid flexibility and resilience?

3. Which innovations do you think have the most potential to accelerate the transition to a digital-first grid?

Agenda

1. Introduction: The Evolving Electricity Grid
2. The Digital-First Grid: What, When, and How?
3. **The Digital-First Grid: Meeting Stakeholder and Customer Expectations**

How do we ensure an **orderly transition** to a **digital grid**?

Structures

- Frameworks, markets, and regulatory policies
- Methods to balance innovation with reliability and security

Interactions

- Ensure efficient interoperability
- Protocols for communications
- Data structures for sharing grid information and commands

Infrastructure

- Observational, sensing, and control devices
- Physical assets, digital and analog
- Energy generation assets including electron buffer

Source: A Digital Grid Architecture. AES and Tapestry. September 2024.

First, understand the **evolving grid architecture** over different stages

	Legacy	Emerging	Scaling	Transformed
Structures	Centralized, monopolistic	Increasing collaboration between participants	Coordinated decisions are delegated into a dynamic, distributed and participatory system of flexible and responsive assets	Commercial and market innovations emerge on top of the energy system, enabled by rapid and continuous market clearing
Interaction	System is dominated by a few proprietary and standard approaches	The value of data and AI insights and the need to manage increasing complexity drive open approaches backed by security	Coordination involves AI, common data formats, and increased delegation of decision making to digital assets	Material parts of the system are managed by autonomous agents and are provided continuously clearing information
Infrastructure	Largely static and conservatively estimated view of assets	Individual grid areas are modernized, visible, and controllable with digital assets and coordinating software systems	Interconnections are modernized and digital-first, enabled by optimization that also coordinates reliability, stability	New assets emerge that bundle in energy elements such as stability maintenance, energy buffering, and dispatch strategy

Pre-2020s **2020s** **2030s** **2040+**

Source: A Digital Grid Architecture. AES and Tapestry. September 2024.

Next, we acknowledge **“tipping points”** toward a digital grid

tip·ping point
[tipping point]

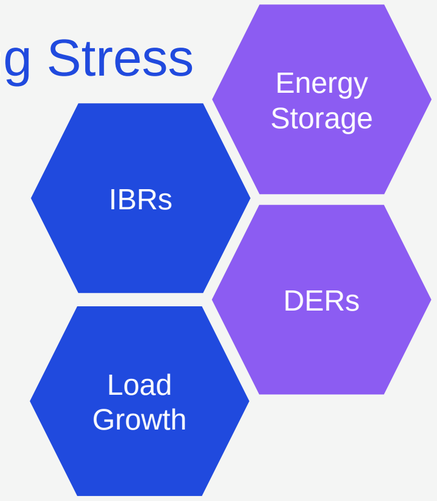
noun

tipping point *(noun)* · ***tipping points*** *(plural noun)*

1. the point at which a series of small changes or incidents becomes significant enough to cause a larger, more important change.

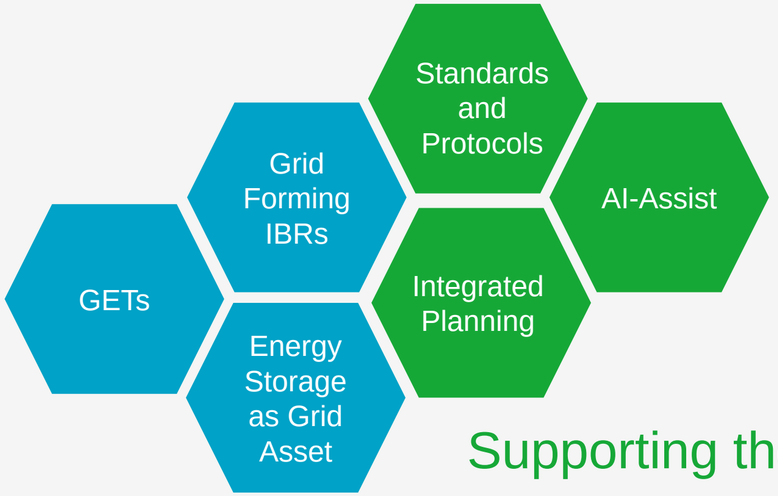
A digital-first grid will provide meaningful value to customers, so we should accelerate

Causing Stress



Physics-first grid

Digital-first grid



Supporting the grid

Pre-2020s | **2020s** | **2030s** | **2040+**

GETs: Grid enhancing technologies; DER: Distributed energy resource; IBR: Inverter-based resource

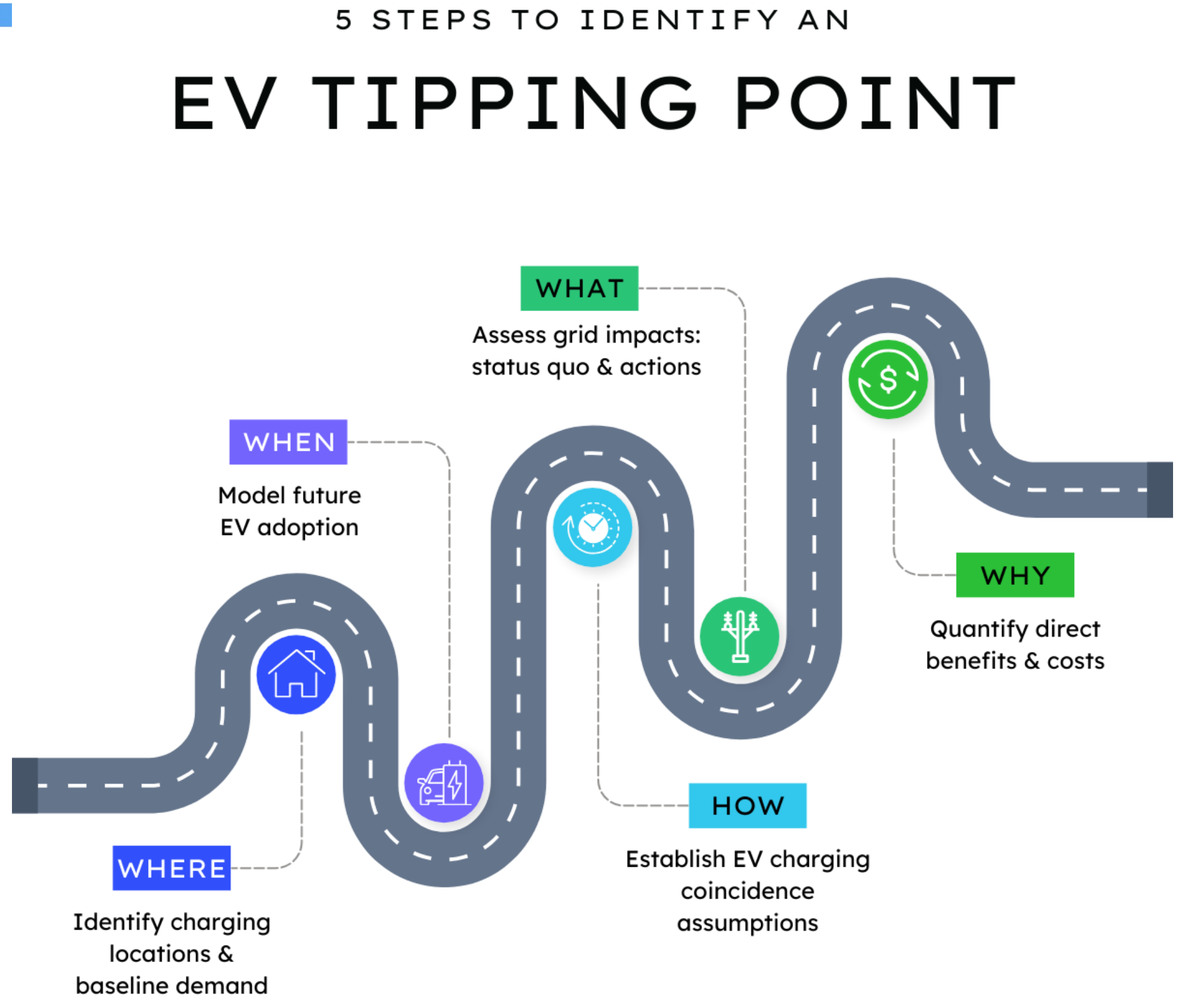
Finally, we ask “How do **customers benefit** from the **digital grid**?”

Case Study: Getting ahead of the EV tipping point in Indiana

AES partnered with Camus Energy to perform a bottoms-up analysis of the entire AES Indiana distribution system to understand impacts from EV adoption.

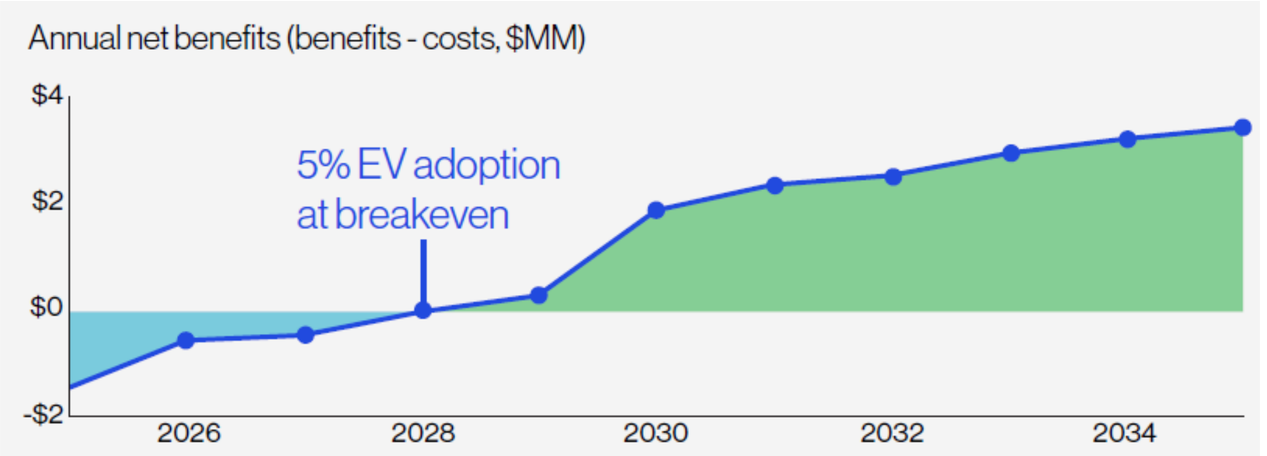
Collaboration across multiple utility teams:

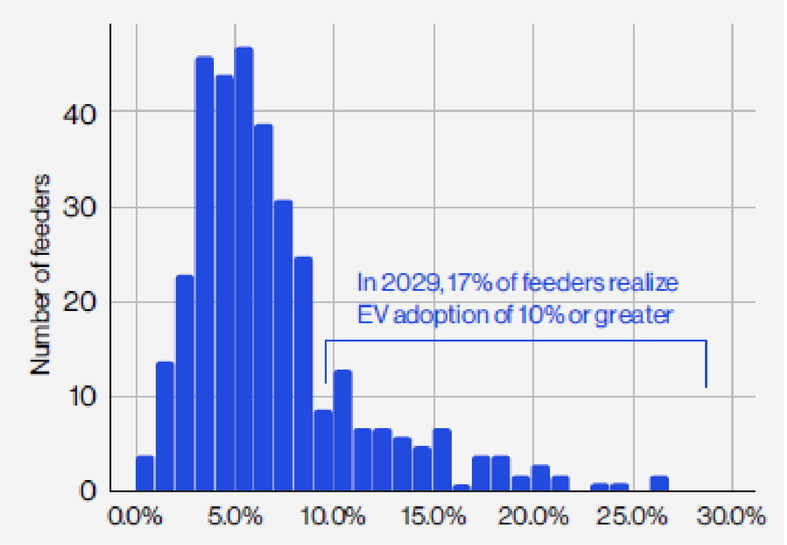
- Data Science
- Resource Planning
- Distribution Planning
- Customer Solutions



Findings: Benefits from real-time visibility and management of EVs

- The EV adoption "tipping point" occurs at a lower percentage of EVs (5%), and in an earlier year (2029), than expected
  - Not all feeders are alike – EV adoption ranged from nearly 0% to almost 30% at the tipping point
- Managed charging quickly becomes more beneficial than TOU rates in deferring asset upgrades
- Data-driven, bottoms-up planning creates opportunities for capital deferral & flexibility
  - Unlocks more than $1000 per new EV





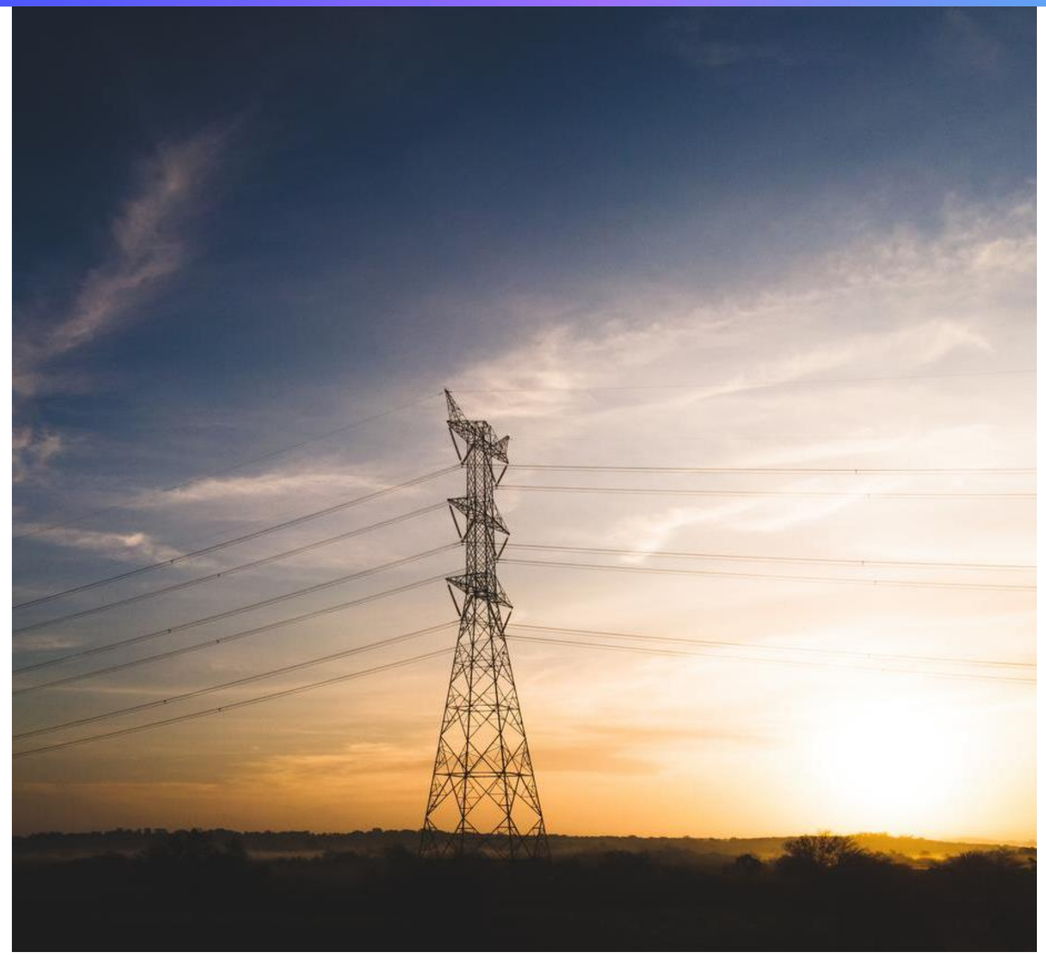
Discussion

1. What tipping points do you anticipate in your areas related to transitioning to a digital-first grid?

2. What challenges do you foresee in transitioning to a digital-first grid?

3. Your questions and comments!

Accelerating the future of energy, together



Thank you

QR codes to four AES papers

Digital Grid/Tapestry

EV Tipping Points Study/Camus

Dynamic Line Rating

Grid Enhancing Tech