



August 2024

OpenMinds 'P50' Outlook

2035 Energy and Emissions Forecast

Raymond James 2024 Aspen Energy Summit

OpenMinds' Mission & Identity



OUR MISSION

More energy. Less emissions.

Accelerate progress against the Dual Challenge by 203X

- 100+ volunteer experts
- 501(c)(3)
- Disciplined non-partisan selection process
- 360° systems engineering approach

WHAT MAKES US UNIQUE



Energy AND climate



Cross-functional expert team



Detailed solutions framework

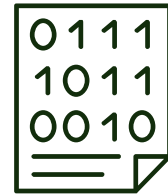


Impact progress by 203X

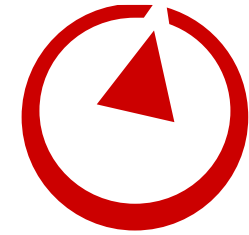
OpenMinds + Bain Approach



Energy and Climate



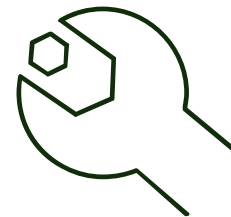
Data-Driven



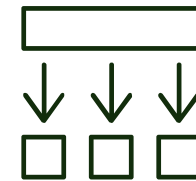
Bain Partnership



125 Experts Across Key
Energy and Climate Sectors



















Practical Solutions
Framework and 10-Year
Horizon

















Impact Projects Targeting
Key Bottlenecks

OpenMinds Impact Project Leadership





Decarbonizing Generation

 Steve Lockard Chairman TPI Composites	 Kurt Waltzer Principal Energy Systems Innovation Consulting	 Dr. Doug Arent Executive Director, Strategic PPPs NREL	 Myrtle Dawes CEO Net Zero Technology Centre
Co-Leaders			
 Michael DeBock VP of Origination NextEra Energy	 Jon Goldberg Founder & CEO Carbon Direct	 Thad Hill CEO Calpine	 Mateo Jamarillo CEO Form Energy
 Thomas McAndrew Founder & CEO Enchanted Rock	 Stan Miranda Founder & Chairman Partners Capital	 Dr. Jonas Peters Director Resnick Sustainability Institute, Caltech	 Heather Redman Co-Founder and Managing Partner Flying Fish Partners
 Jessica Uhl President GE Vernova	 Jason Wells CEO CenterPoint Energy	 Darryl Willis Corporate VP of Energy & Resources Industry Microsoft	
 Grant Dougans Partner Bain & Company	 Preston Henske Partner Bain & Company		
Bain Leads			









Connecting America

 Larry Selzer President & CEO The Conservation Fund	 Scott Brown Chairman New Energy Capital Partners	 John Arnold Co-Founder, Arnold Ventures Board Member, Meta	 Armond Cohen Executive Director Clean Air Task Force
Co-Leaders			
 Ted Craver Board & advisory roles Duke Energy, Bain & Co., Wells Fargo, etc.	 Jayshree Desai CFO Quanta Services, Inc.	 Bob Flexon Chair, PG&E Director, ERCOT	 Vicki Hollub President and CEO Oxy
 Miguel Prado CEO EnergyRe	 Dan Tishman Chairman & Principal Tishman Realty & Construction	 Al Vickers COO Grid United	 Daniel Weiss Co-Founder & Managing Partner Angeleno Group
 Cate Hight Partner Bain & Company	 Michael Short Partner Bain & Company		
Bain Leads			

Developing NextGen Leaders

 Dr. Naomi Boness Managing Director Stanford Natural Gas & Hydrogen Initiatives	 Dr. Minoo R. Program Lead, Future Worlds MIT Media Lab	 Dr. Robert Johnston Executive Director CGEP, Columbia University	 Dr. Neil Fromer Executive Director Resnick Sustainability Institute, Caltech
Co-Leaders			
 Phoebe Ho-Stone CCS Development Planner, ExxonMobil Low Carbon Solutions	 Ira Joseph Global Fellow CGEP, Columbia University	 Dr. Shannon Miller Founder & CEO Mainspring Energy	 David Pruner Executive Director TEX-E
 Ben Soltoff Entrepreneur in Residence MIT's Martin Trust Center for Entrepreneurship	 Dr. Cyrus Wadia CEO Activate	 Dr. Mike Witt Chief Sustainability Officer Northrop Grumman	 Dianne Ledingham Advisory Partner Bain & Company
	 Sam Hall MBA Candidate MIT	 Daniela Marin PhD Candidate Stanford University	Bain Lead
	Student Representatives		

Communicating to Accelerate Impact

 Jeff Katz Co-Founder OpenMinds	 Rob Shepardson Founding Partner SS+K	 Bridgett Arnold Vice President, Communications Google	 Nate Nickerson Comms and Public Affairs Partner DCVC
Co-Leaders			
 Rachael Porter CMO Oxy	 Dr. Maya Tolsoy Dean of UW College of the Environment	 Brady Walkinshaw CEO Earth Alliance	 Erika Serow Partner and CMO Bain & Company
			Bain Lead

The OpenMinds Team

/ AS OF JULY 26, 2024

Industry	Role and company
Ms. Bridgitt Arnold	VP of Communications, Google
Mr. John Arnold	Founder & CEO, Arnold Ventures
Mr. John Berger	Founder & CEO, Sunnova Energy International
Mr. Scott Brown	Founder and Chairman, New Energy Capital
Dr. Barbara J. Burger	Corporate Graduate, Energy Director, Advisor and Innovator
Mr. Adrian Corless	CEO, CarbonCapture
Mr. Ted Craver	Former Chair, President, & CEO, Edison International
Mr. Michael DeBock	Vice President of Origination, NextEra Energy
Ms. Jayshree Desai	CFO, Quanta Services, Inc.
Mr. Bob Flexon	Chairman, PG&E
Mr. Jon Goldberg	Founder and CEO, Carbon Direct
Mr. Thad Hill	CEO, Calpine
Ms. Vicki Hollub	President & CEO, Oxy
Ms. Phoebe Ho-Stone	CCS Development Planner, ExxonMobil Low Carbon Solutions
Mr. Aaron Jagdfeld	CEO, Generac Power Systems
Mr. Mateo Jamarillo	Co-Founder & CEO, Form Energy Inc
Mr. Sanjeev Krishnan	Chief Investment Officer and Senior Managing Director, S2G
Mr. Tim Latimer	Co-Founder & CEO, Fervo Energy
Mr. Steve Lockard	Chairman, TPI Composites
Mr. Thomas McAndrew	Founder & CEO, Enchanted Rock
Dr. Shannon Miller	Founder & CEO, Main Spring Energy
Mr. Stan Miranda	Founder & Chairman, Partners Capital
Mr. Nate Nickerson	Comms and Public Affairs Partner, DCVC
Ms. Lara Poloni	President, AECOM
Ms. Rachael Porter	CMO, Oxy
Mr. Miguel Prado	CEO, energyRE
Ms. Heather Redman	Co-Founder & Managing Partner, Flying Fish Partners
Ms. Starlee Sykes	CEO, Archaea Energy at BP
Mr. Dan Tishman	Chairman & Principal, Tishman Realty & Construction
Mr. Ignacio (Nacho) Torras	President & CEO, Tricon
Ms. Jessica Uhl	President, GE Vernova
Mr. Al Vickers	COO, Grid United
Mr. Andy Waite	Managing Partner - SCF Partners
Mr. Daniel Weiss	Co-Founder and Managing Partner, Angeleno Group
Mr. Jason Wells	President & CEO, CenterPoint Energy
Mr. Darryl Willis	Corporate VP of Energy & Resources Industry, Microsoft
Dr. Mike Witt	VP & Chief Sustainability Officer, Northrop Grumman

Academia	Role and Company
Dr. Steven Barrett	Regius Professor of Engineering, Cambridge University
Dr. Naomi Boness	Managing Director, Stanford Natural Gas Initiative and Stanford Hydrogen Initiative
Dr. Neil Fromer	Executive Director of Programs, Resnick Sustainability Institute
Mr. Sam Hall	MBA Candidate, MIT Sloan School of Management
Mr. Britt Harris	Former CEO & CIO, UTIMCO
Mr. Ira Joseph	Global Fellow CGEP, Columbia University
Ms. Daniela Marin	PhD Candidate, Stanford University
Dr. Kenneth Medlock III	Senior Director, Center for Energy Studies at Rice University's Baker Institute
Dr. Dava Newman	Director, MIT Media Lab
Dr. Jonas Peters	Director, Resnick Sustainability Institute
Dr. Minoo Rathnasabapathy	Research Lead, Future Worlds, MIT Media Lab
Dr. Peter Schlosser	Vice President - Global Futures Initiative Vice Provost - Arizona State University
Mr. Ben Soltoff	Ecosystem-Builder/Entrepreneur in Residence, MIT's Martin Trust for MIT Entrepreneurship
Dr. Scott Tinker	Director, Bureau of Economic Geology at the University of Texas
Dr. Maya Tolstoy	Dean of the College of the Environment, University of Washington
Policy / Influence	Role and Company
Mr. Jason Bordoff	Professor & Founding Director, Center on Global Energy Policy, Columbia University
Mr. David Crane	Under Secretary for Infrastructure, United States Department of Energy
Dr. Reginald DesRoches	President, Rice University
Mr. Hal Harvey	Founder, Energy Innovation
Mr. Mac Heller	Documentary Film Producer
Mr. John Hickenlooper	Former Governor and Current US Senator, State of Colorado
Mr. Joe Kennedy III	President, Citizens Energy
Mr. Robert Johnston	Executive Director, Columbia Center on Global Energy Policy
Ms. Janet Napolitano	Former President, University of California System



Policy / Influence	Role and Company
Mr. Rob Shepardson	Co-Founder, SS+K
Mr. Lenny Stern	Co-Founder, SS+K
NGO	Role and Company
Dr. Doug Arent	Executive Director, Strategic Public Private Partnerships, NREL
Mr. Armond Cohen	Executive Director, Clean Air Task Force
Ms. Karlynn Cory	Group Manager - Community Energy Transitions, NREL
Ms. Myrtle Dawes	CEO, Net Zero Technology Centre
Mr. Jason Grumet	CEO, American Clean Power Association (ACP)
Ms. Jennifer Layke	Global Director - Energy, World Resources Institute
Mr. Tom Light	President & CEO, Aviation Climate Taskforce
Dr. Lara Pierpoint	Director of Early Climate Infrastructure, Prime Coalition
Mr. David Pruner	Executive Director, TEX-E
Mr. Larry Selzer	President & CEO, The Conservation Fund
Dr. Cyrus Wadia	CEO, Activate
Mr. Brady Walkinshaw	CEO, Earth Alliance
Mr. Kurt Waltzer	Former CEO, Clean Air Task Force

Hosts	Role and Company
Mr. David Baldwin	OpenMinds Co-Founder Partner, SCF Partners
Mr. Jeff Katz	Founding Chairman & CEO, Orbitz / Journera
Ms. Maire Baldwin	Board Director, Permian Resources
Ms. Mara Abbott	Chief of Staff, OpenMinds
Mr. James Baird	Associate Partner, Bain & Company
Mr. Jason Corzine	President & CEO, Telluride Foundation
Mr. Julian Critchlow	Advisory Partner, Bain & Company
Mr. Grant Dougan	Partner, Bain & Company
Ms. Emily Emmett	Partner, Bain & Company
Mr. Peter Guarraia	Partner, Bain & Company
Mr. Preston Henske	Partner, Bain & Company
Ms. Cate Hight	Partner, Bain & Company
Mr. Fred Kittler	Co-Founder and Managing Director, Firelake Capital Mgmt.
Ms. Dianne Ledingham	Advisory Partner, Bain & Company
Mr. Paul Major	Board Member & Manager, Paradox Community Trust
Mr. Joseph Scalise	Partner, Head of Global Energy & Natural Resources Practice, Bain & Company
Mr. Crosby Scofield	Partner, Vinson and Elkins
Ms. Erika Serow	Partner and CMO, Bain & Company
Mr. Michael Short	Partner, Bain & Company

... and many more

'P50' Outlook Scope and Contributors

2035 forecasts included in the 'P50' Outlook

	 Global	 US
Energy Demand	✓	✓
Supply Mix	✓	✓
Emissions	✓	✓

Developed and reviewed by industry leaders

MODEL CREATION

IntersectSM
BAIN & COMPANY

Copenhagen
Economics

CE

EXPERT REVIEW

 GE VERNOVA

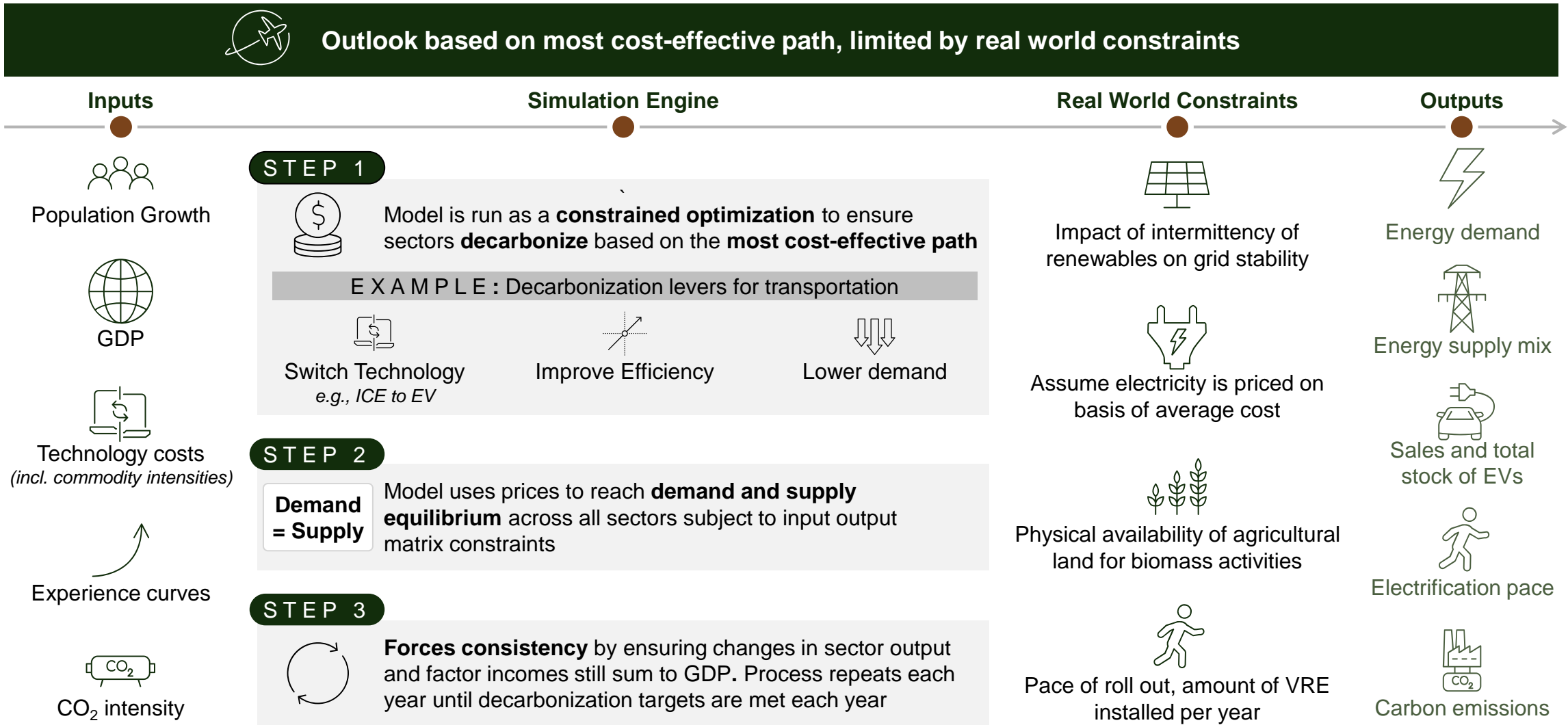
 CLEAN AIR
TASK FORCE

 tpi

SCF PARTNERS
HOUSTON | CALGARY | ABERDEEN | SINGAPORE

 NEW ENERGY CAPITAL

How the Intersect Model Works



OpenMinds 'P50' Outlook Model Assumptions

Key assumptions			2023	2030	2035
Energy and Electricity Demand	GDP growth (%)	Global	2.6	2.7	2.7
		USA	2.0	1.7	1.9
	Energy intensity ¹	Global	3.8	3.4	3.0
		USA	3.7	3.4	3.1
	EV sales penetration (% of new car sales)	Global	17	45	64
		USA	10	35	55
	Electricity demand from data centers and AI (TWh)	Global	400	1,060	1,230
		USA	117	351	410
Power Sector	US Value-Adjusted Levelized Cost of Electricity (VALCOE, \$/MWh)	Solar	60	64	62
		Wind	64	71	77
		Gas	59	59	59
		Nuclear	105	105	105
	US LCOE learning rate ² (%)	Solar	20		
		Wind	15		
	US Capacity factor (%)	Solar	18	19	20
		Wind ⁴	35	38	40
	Battery storage intensity ³ (%)	Global	2	8	11
		USA	6	19	22

Questions answered by model

- 1 What is the outlook for **energy demand** and which sectors will drive growth?
- 2 How will the **energy mix** shift in coming years?
- 3 What does **emissions trajectory** look like through 2035?

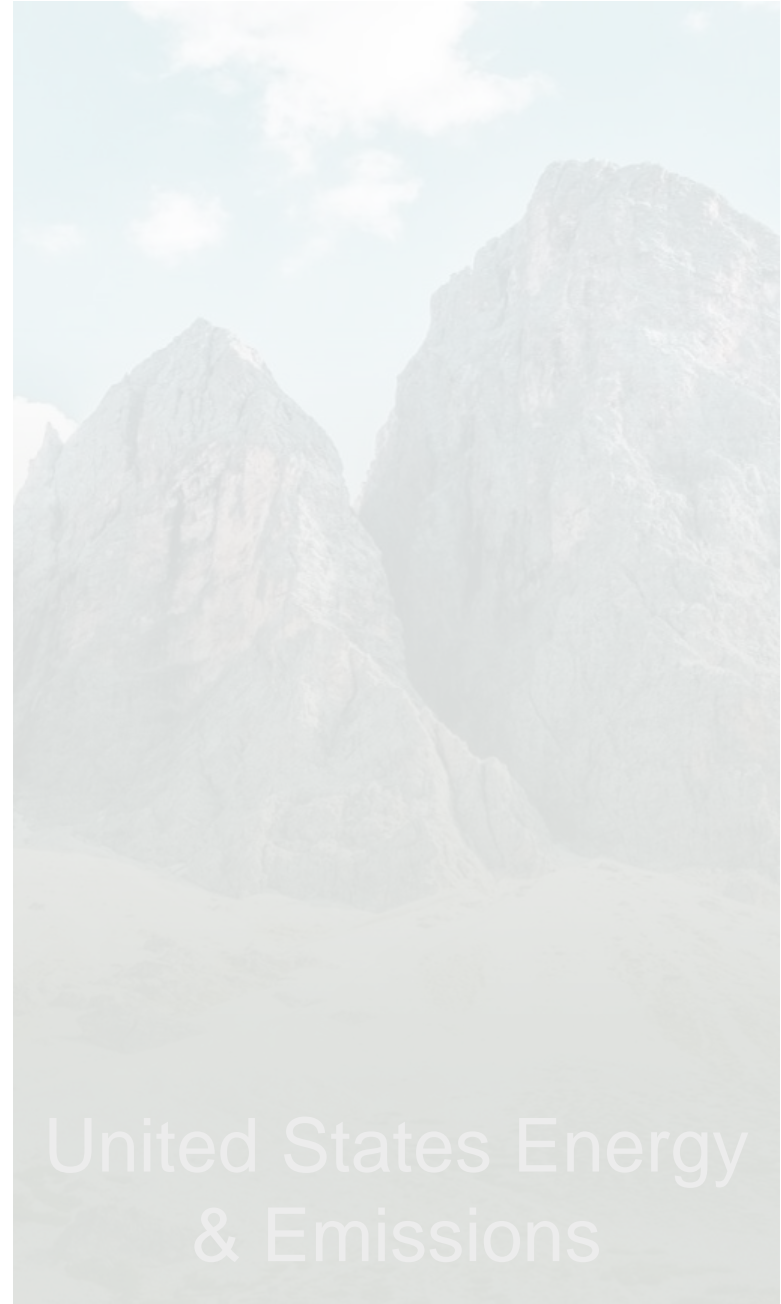
4 How will **US electricity demand and power generation** evolve?

FOCUS FOR TODAY

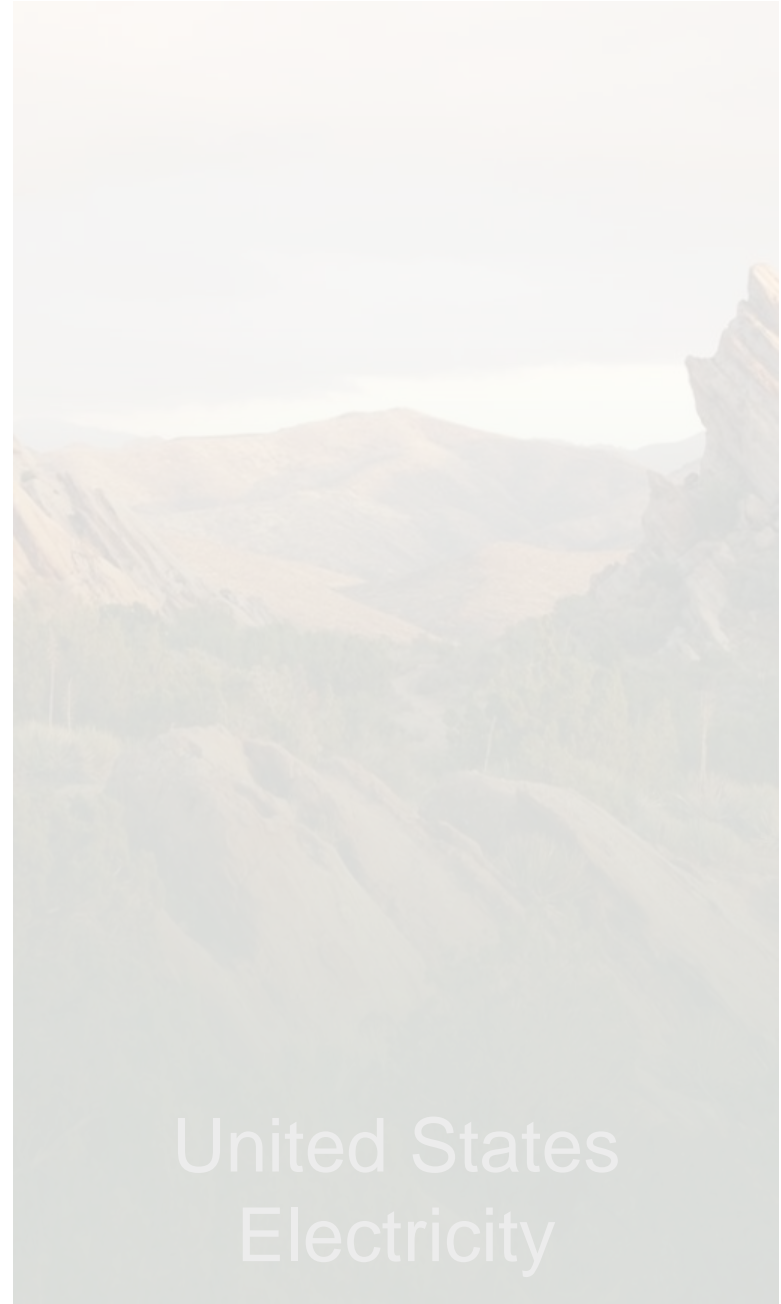
Note: ¹Energy intensity shown in terms of total final consumption (EJ) per purchasing power parity (PPP) in trillion dollars (T\$). ²LCOE learning rate is the percentage decrease in LCOE for every doubling of installed capacity. ³Battery storage intensity calculated as the total installed battery capacity as a % of total installed variable renewable energy (wind and solar) capacity. ⁴Wind capacity factor provided as weighted averages across offshore and onshore
Source: IEA, Goldman Sachs, IRENA



Global Energy & Emissions



United States Energy & Emissions

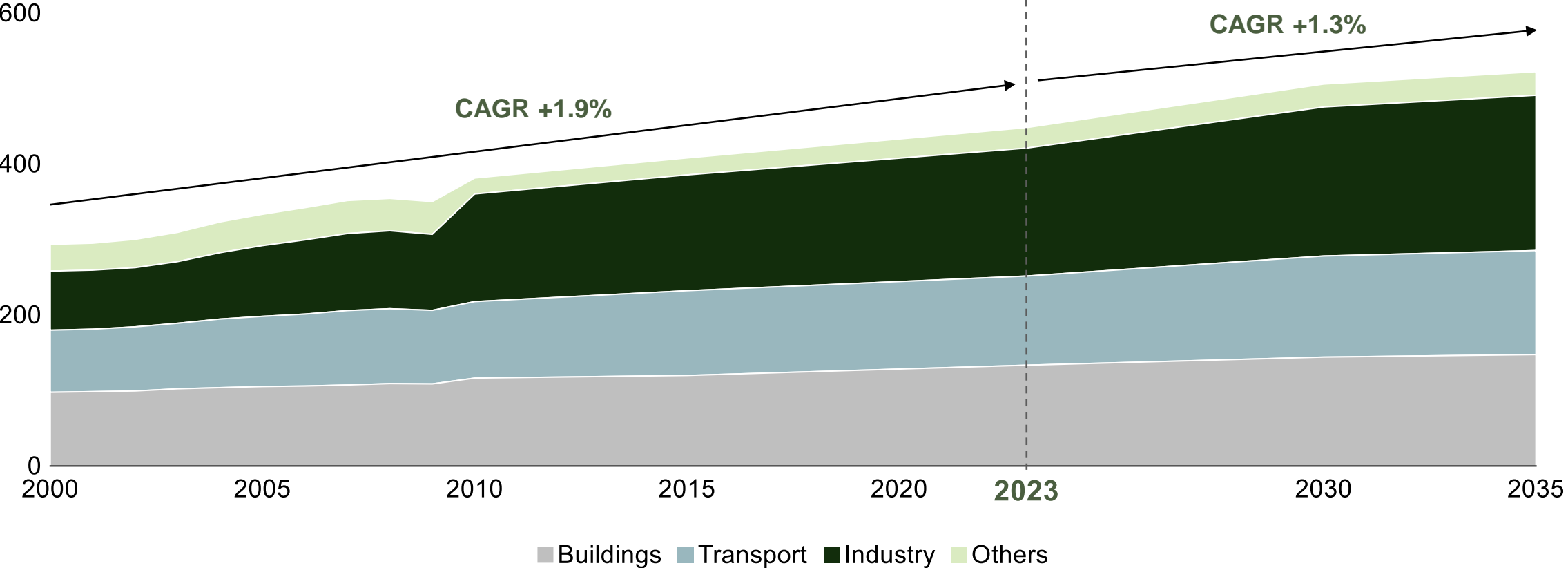


United States Electricity

Global Energy Demand is Expected to Rise Driven by Consumption Growth in Buildings and Industry Sectors

1 | ENERGY DEMAND

Total final consumption by end sector (EJ)

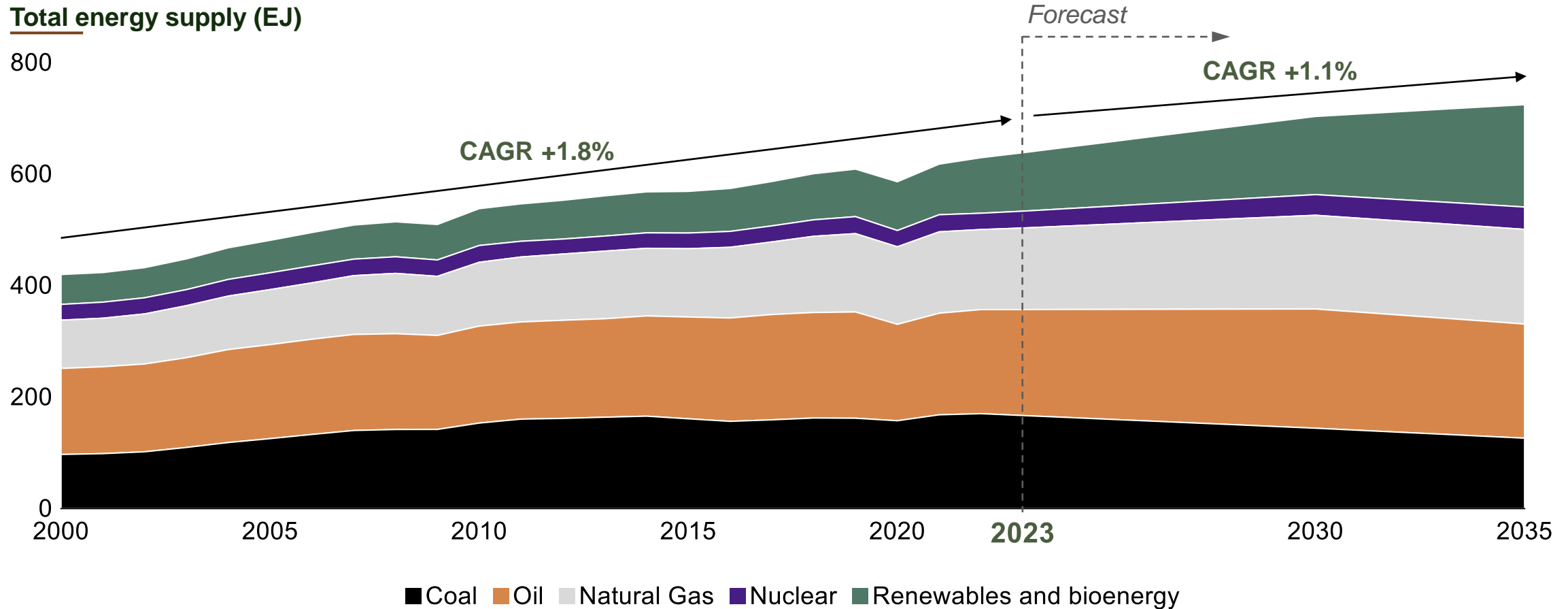


Source: Intersect_{SM} Carbon & Energy Transition CGE Model; IEA WEO 2023

Renewables are Forecast to Continue to Phase Out Coal in Global Energy Supply Mix

2 | ENERGY MIX

Total energy supply (EJ)

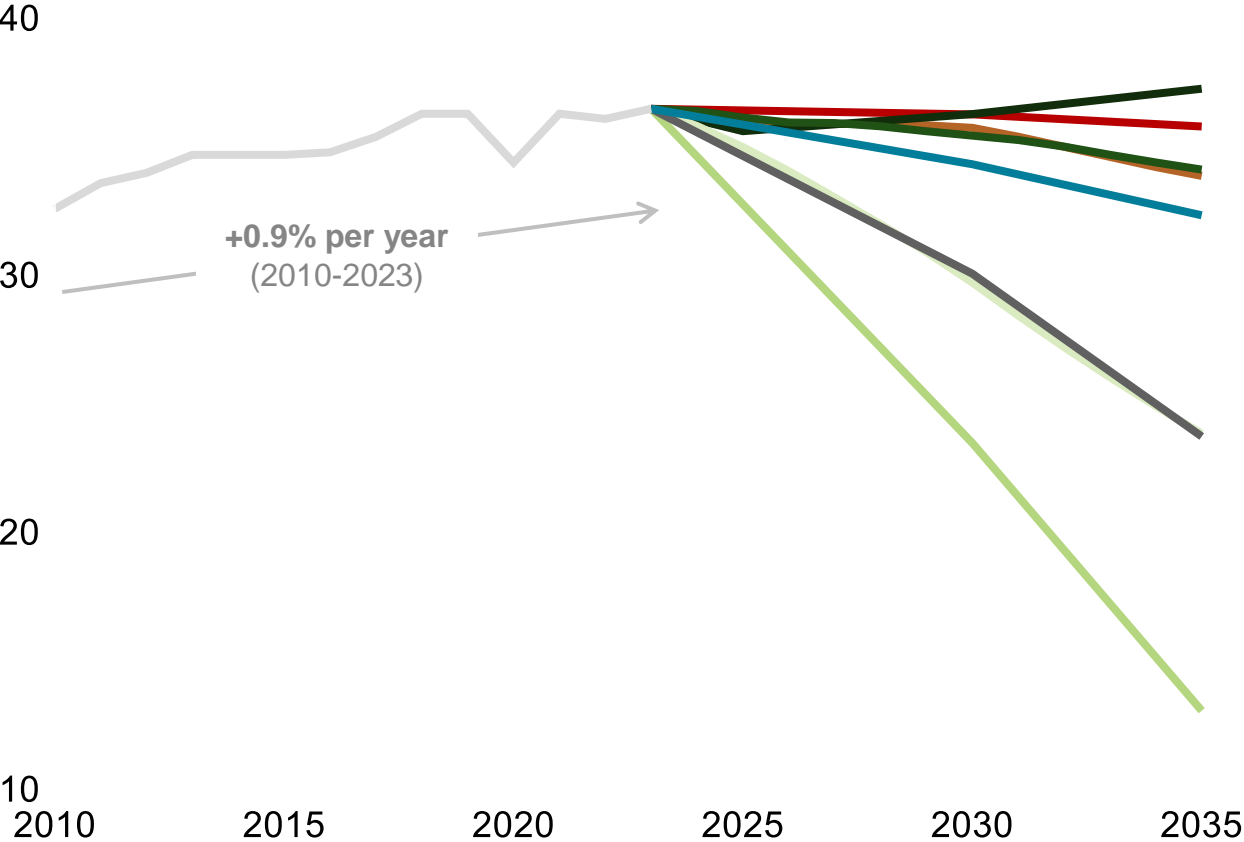


Source: Intersect_{SM} Carbon & Energy Transition CGE Model; IEA WEO 2023

Global Carbon Emissions Likely to Decline Slightly by 2035

3 | EMISSIONS TRAJECTORY

Global emissions by scenario (Gt CO₂)

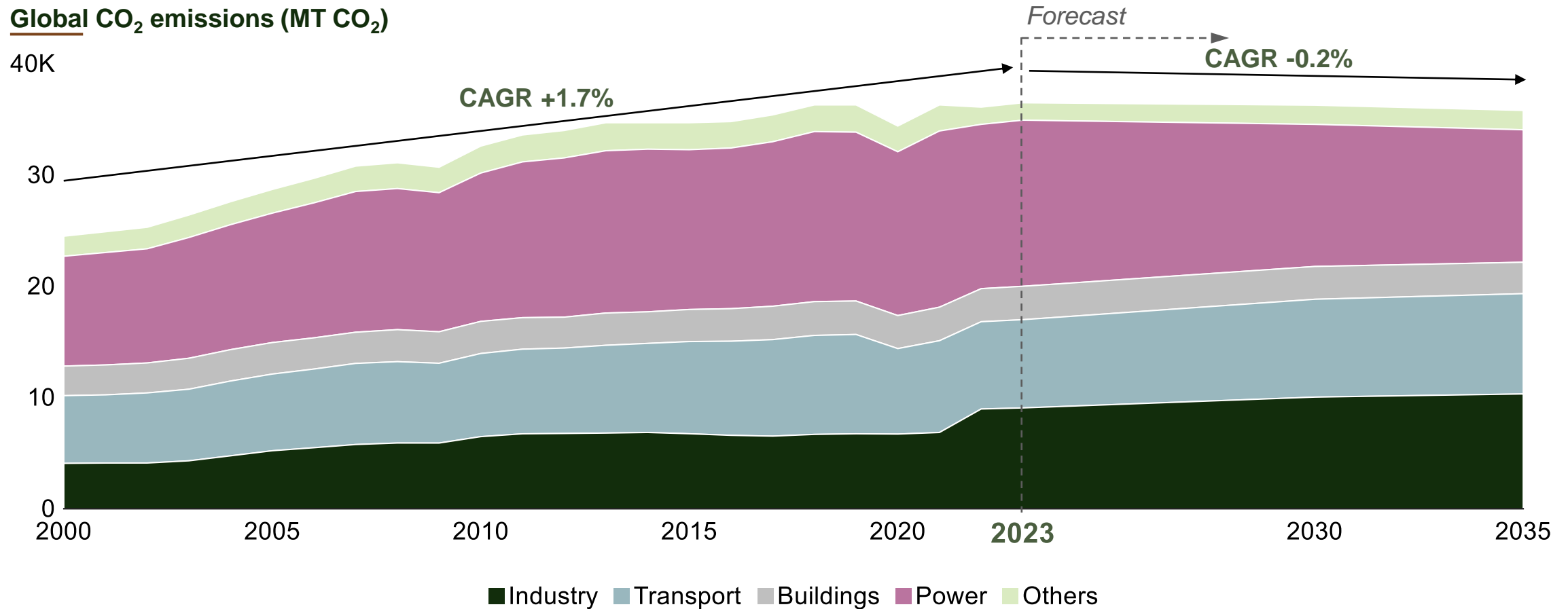


Source: BP Energy Outlook, 2021; ExxonMobil 2023 Outlook for Energy; International Energy Agency, World Energy Outlook 2023; EIA International Energy Outlook 2023

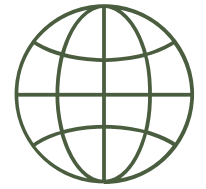
Developing Economies' Fossil Fuel-Powered Industrialization Offsets Developed Economies' Decarbonization

3 | EMISSIONS TRAJECTORY

Global CO₂ emissions (MT CO₂)



Source: Intersect_{SM} Carbon & Energy Transition CGE Model; IEA WEO 2023



Implications for Global Energy Outlook



Energy Demand...

is set to grow +15% by 2035, largely driven by developing economies

Oil Demand...

peaks in 2030, as the world passes a tipping point in EV adoption

Natural Gas Demand...

will grow in-line with total energy demand, maintaining its ~23% share through 2035

Renewable Energy...

is forecast to increase from ~15% of energy mix today to ~25% in 2035, as strong growth continues

Carbon Emissions...

will largely remain flat, decreasing ~0.2% p.a. to reach ~35 Gt in 2035

Differing Priorities...

in developing and developed world, with former focused on energy access, latter on climate change

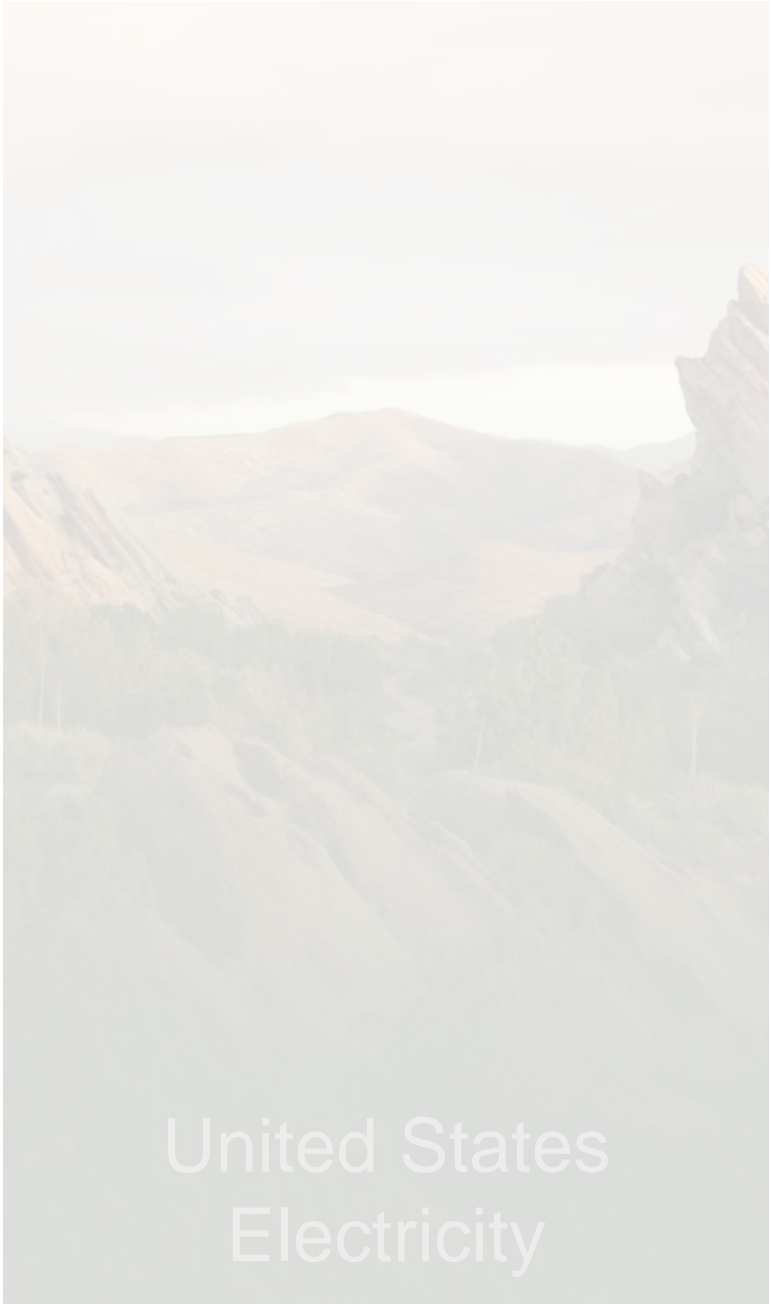




Global Energy &
Emissions



**United States Energy
& Emissions**

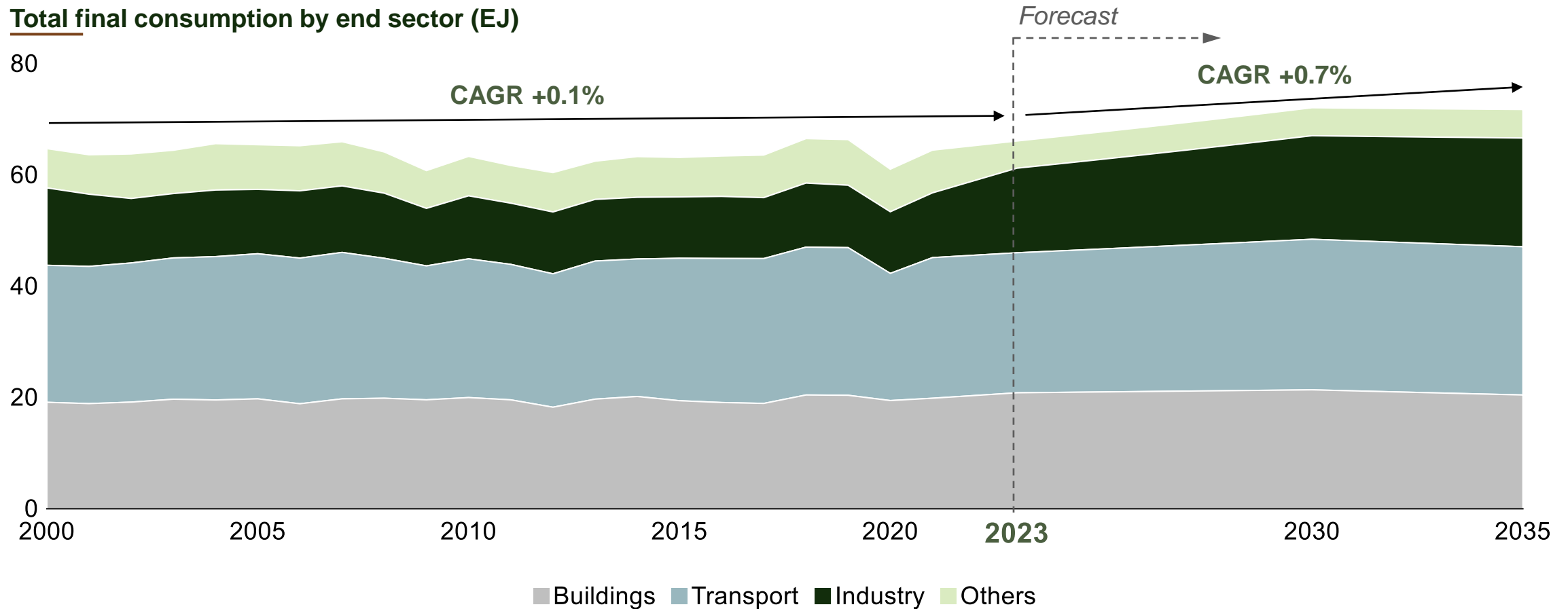


United States
Electricity

In the US, Rising Energy Demand is Expected to be Mainly Driven by Transport and Industry Sectors

1 | ENERGY DEMAND

Total final consumption by end sector (EJ)

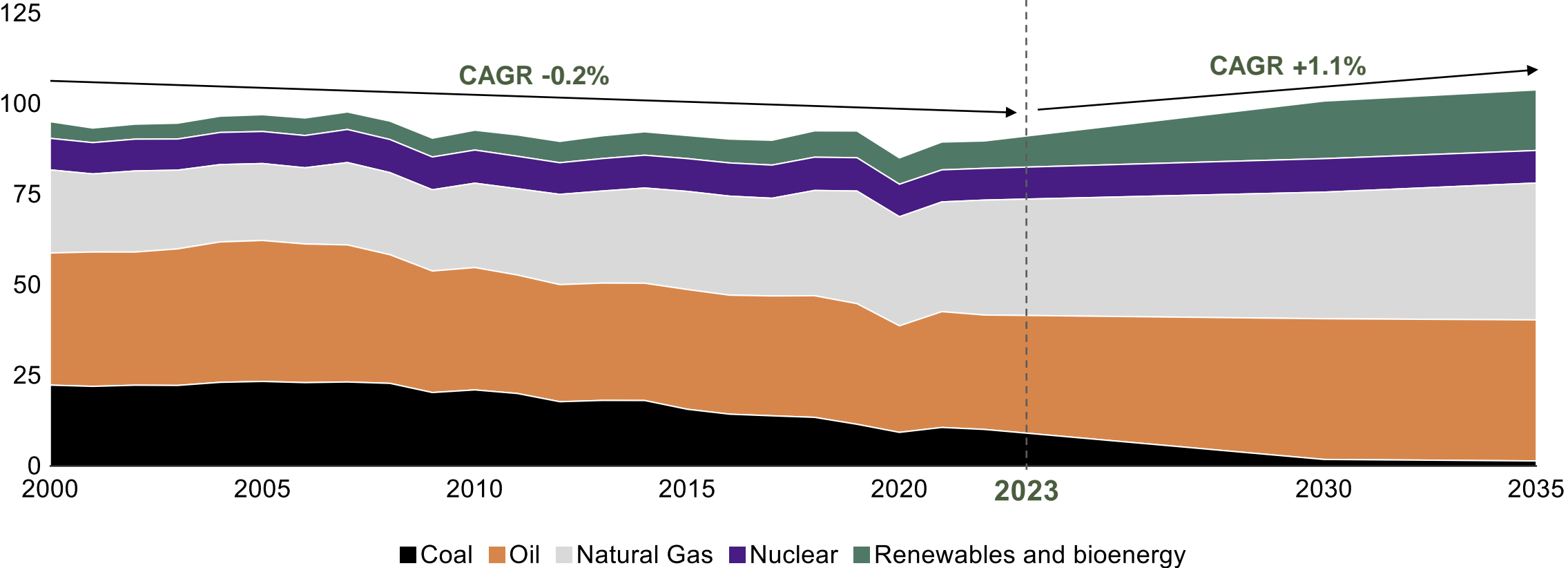


Source: Intersect_{SM} Carbon & Energy Transition CGE Model; IEA WEO 2023

The US is Projected to Rapidly Retire Coal as an Energy Source, Replacing it with Renewables and Natural Gas

2 | ENERGY MIX

Total energy supply (EJ)

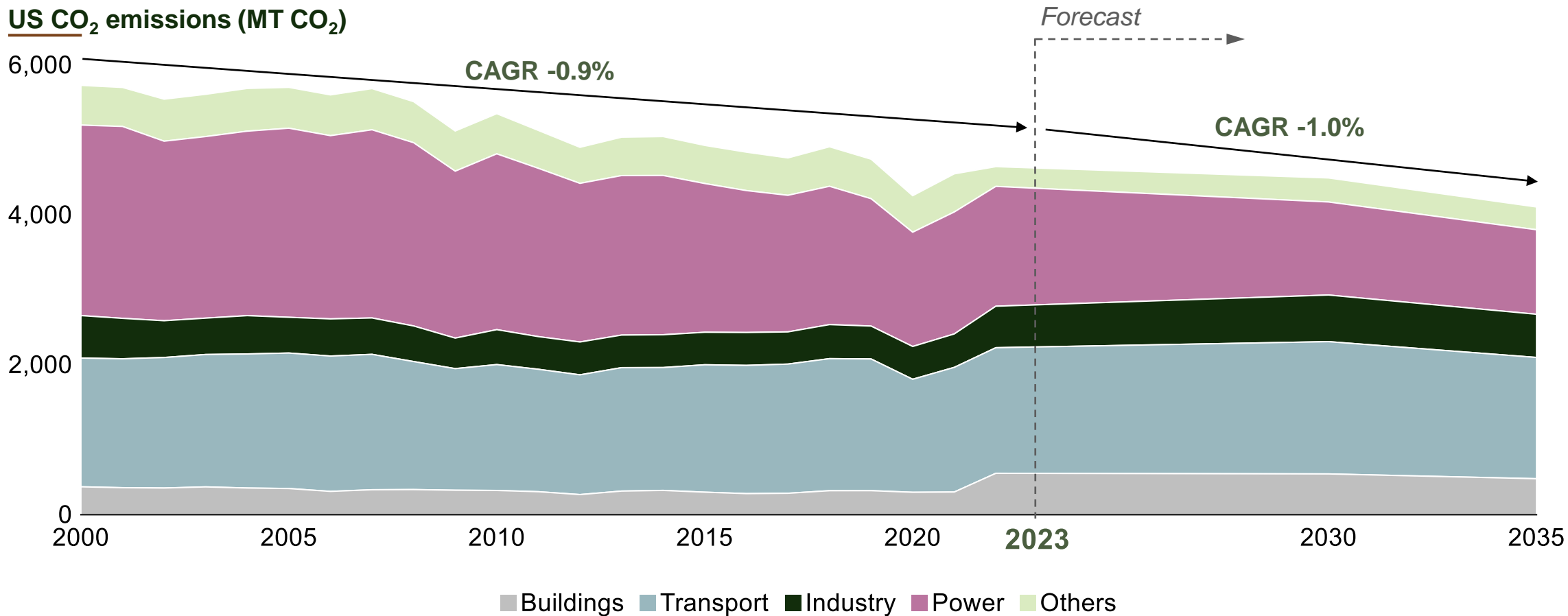


Source: Intersect_{SM} Carbon & Energy Transition CGE Model; IEA WEO 2023

US Power Generation's Continued Shift from Coal to Gas and Renewables Drives Lower Emissions

3 | EMISSIONS TRAJECTORY

US CO₂ emissions (MT CO₂)



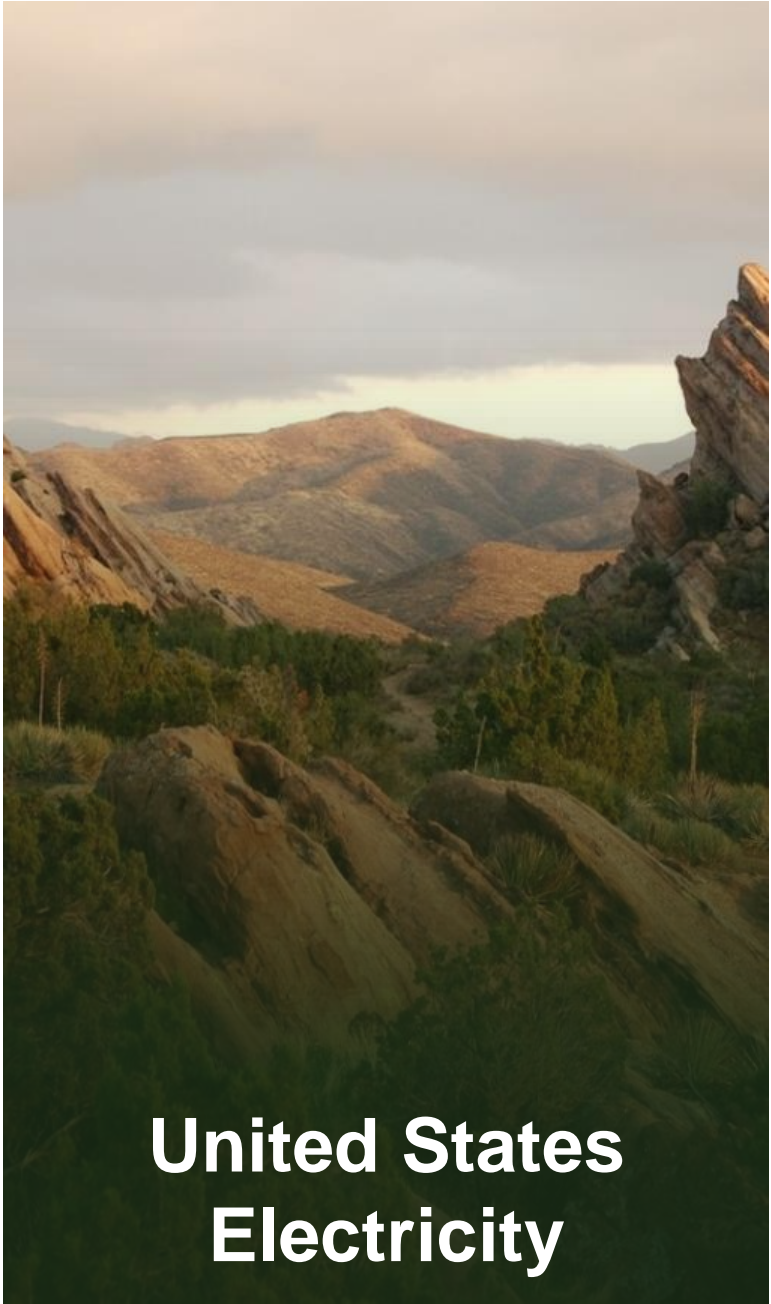
Source: Intersect_{SM} Carbon & Energy Transition CGE Model; IEA WEO 2023



Global Energy &
Emissions



United States Energy
& Emissions

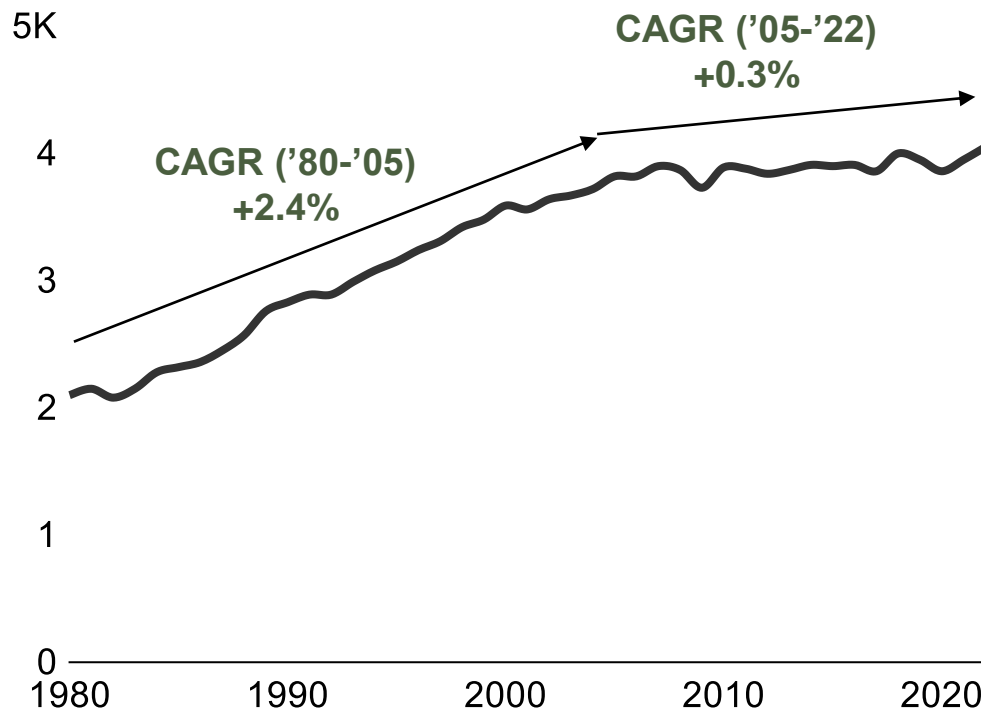


**United States
Electricity**

Historically, US Electricity Consumption Has Increased as Real Prices Have Declined

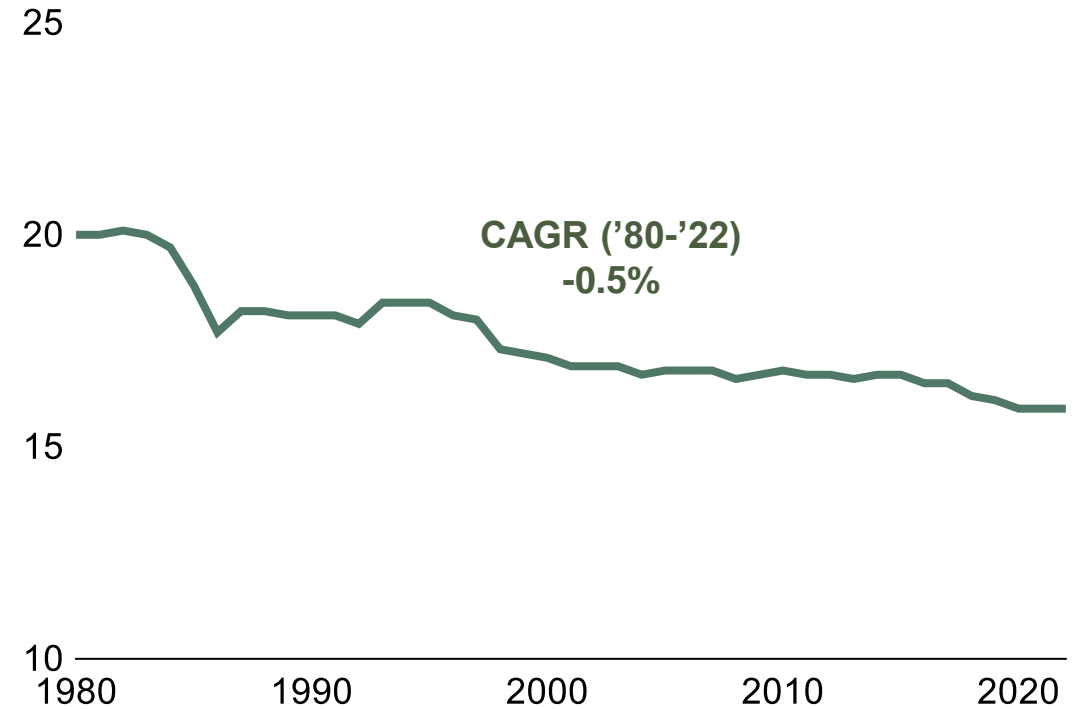
Electricity consumption plateaued after long rise

Annual US Electricity Consumption (TWh)



Real electricity prices have trended down since 80s

Real electricity prices (¢ per kWh)

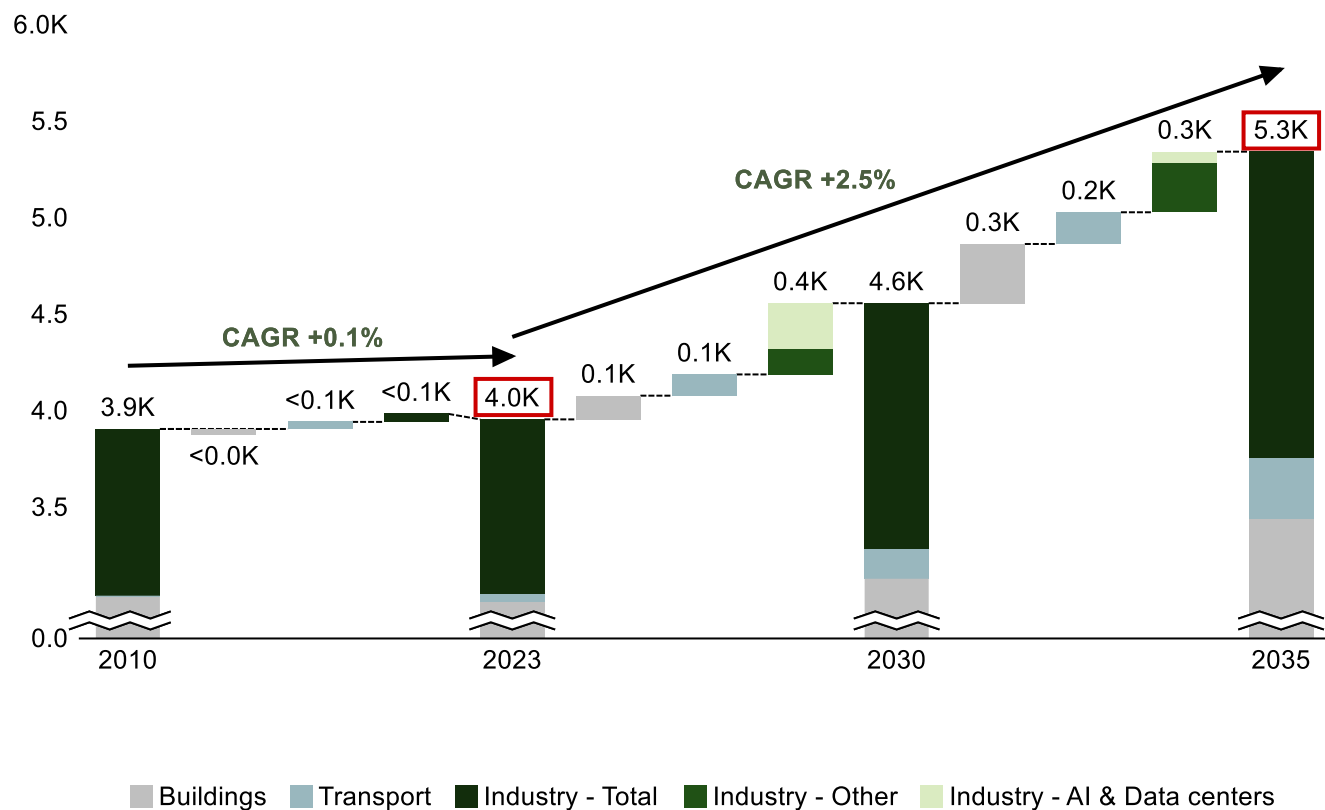


Source: EIA

Electricity Demand Expected to Grow by ~2.5% p.a., Driven by Data Centers, Increased AC Use, and EV Sales

4 | US ELECTRICITY

US electricity demand (2010A-2035F, TWh)



+35%

'23-'35 Growth in Total US Electricity Demand

~410 TWh

from Data Centers & AI by 2035
8% of total, 30% of incremental demand

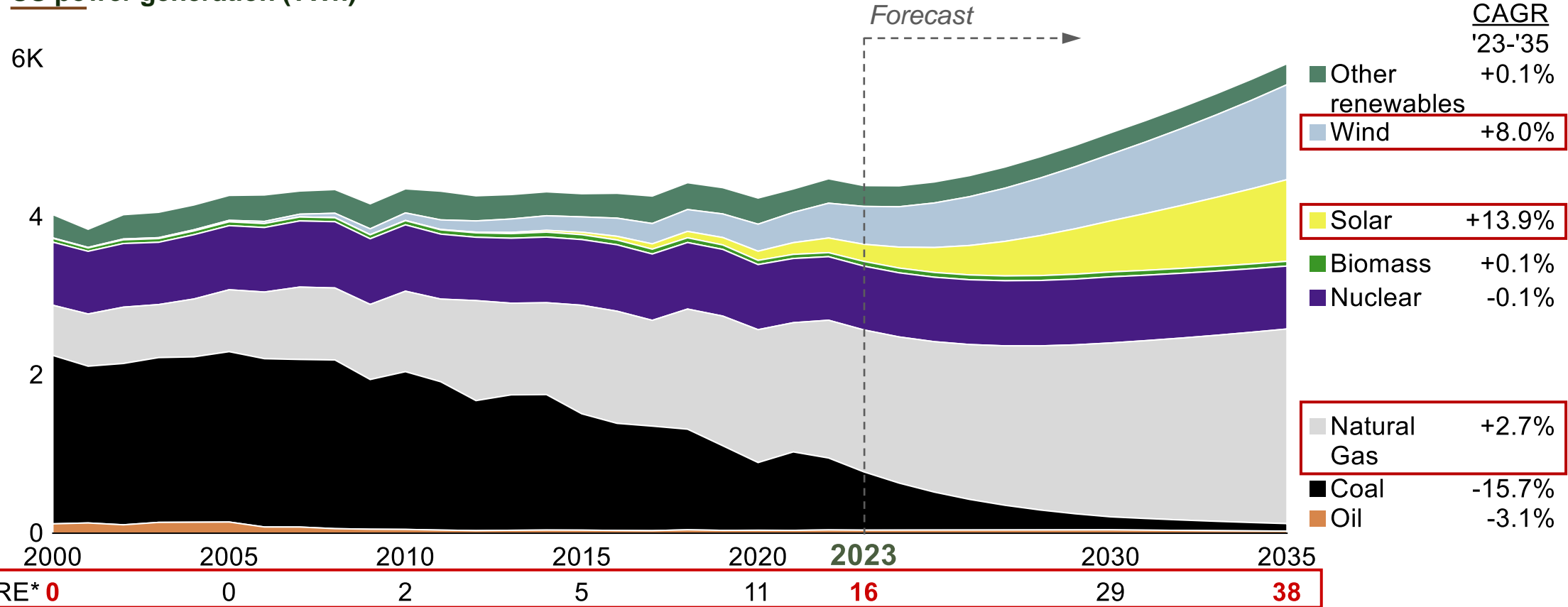
~320 TWh

from EV Transport by 2035
6% of total, 23% of incremental demand

Note: (1) "Buildings" only includes residential buildings; LDV = light-duty vehicles; ICE = internal combustion engine
Source: Intersect_{SM} Carbon & Energy Transition CGE Model, Goldman Sachs

Wind and Solar are Expected to Grow by ~3x and ~5x Respectively by 2035, While Coal is Replaced by Gas

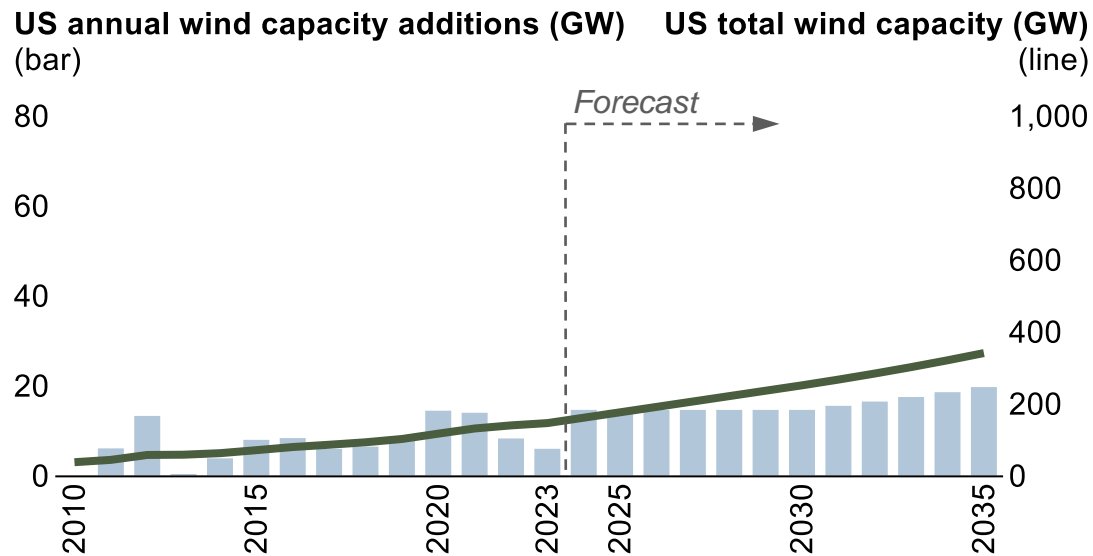
US power generation (TWh)



Note: (*) Variable renewable energy - includes percentage share of wind and solar combined; Other renewables include 'Hydropower'; IRA – Inflation Reduction Act
 Source: Intersect_{SM} Carbon & Energy Transition CGE Model; IEA

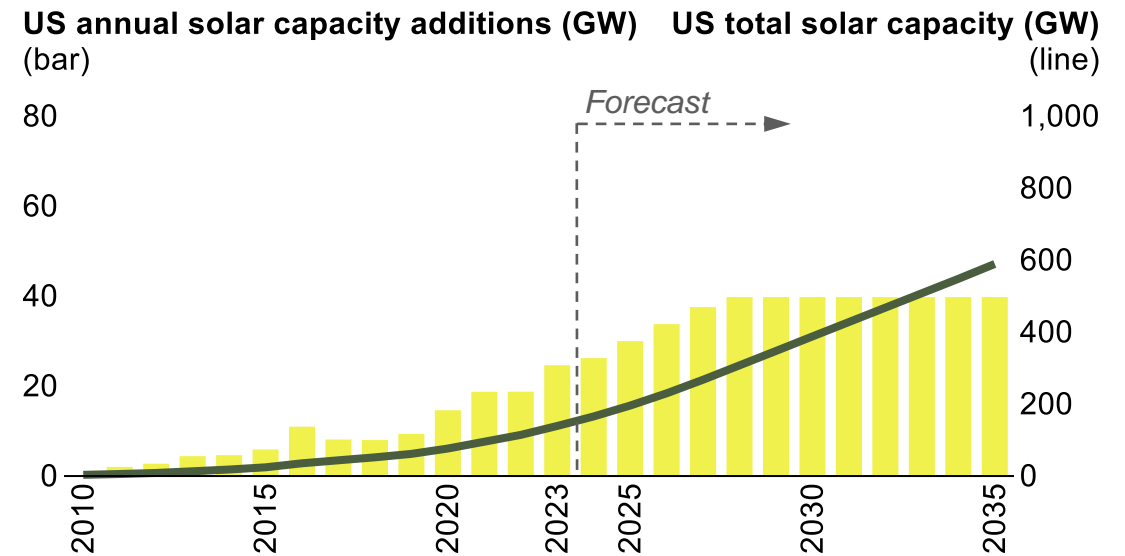
Solar Capacity Growth Will Continue to Outpace Wind

Wind capacity additions will flatline to 2030, before slowly accelerating



- Strong, but more moderate growth expected
- Elevated interest rates and increasing mix of costlier & longer-to-develop offshore wind drive deceleration

Solar capacity will more than double over the next five years



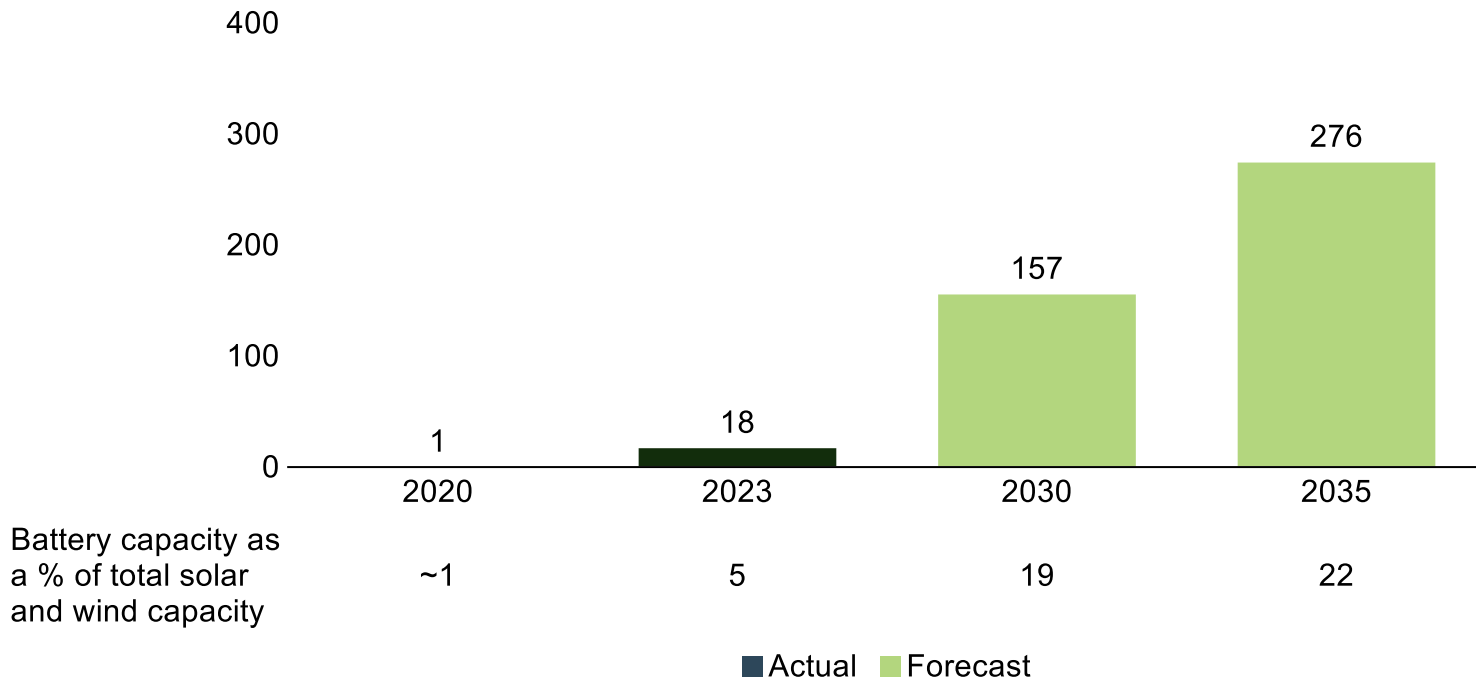
- Further cost reductions will continue to drive strong growth
- Growth beyond 2029 will level out due to US manufacturing capacity constraints (assumed to max out at 40 GW annually)

Source: Intersect_{SM} Carbon and Energy Transition CGE Model, IEA WEO 2023

The US Will Rely Heavily on BESS to Manage Intermittency

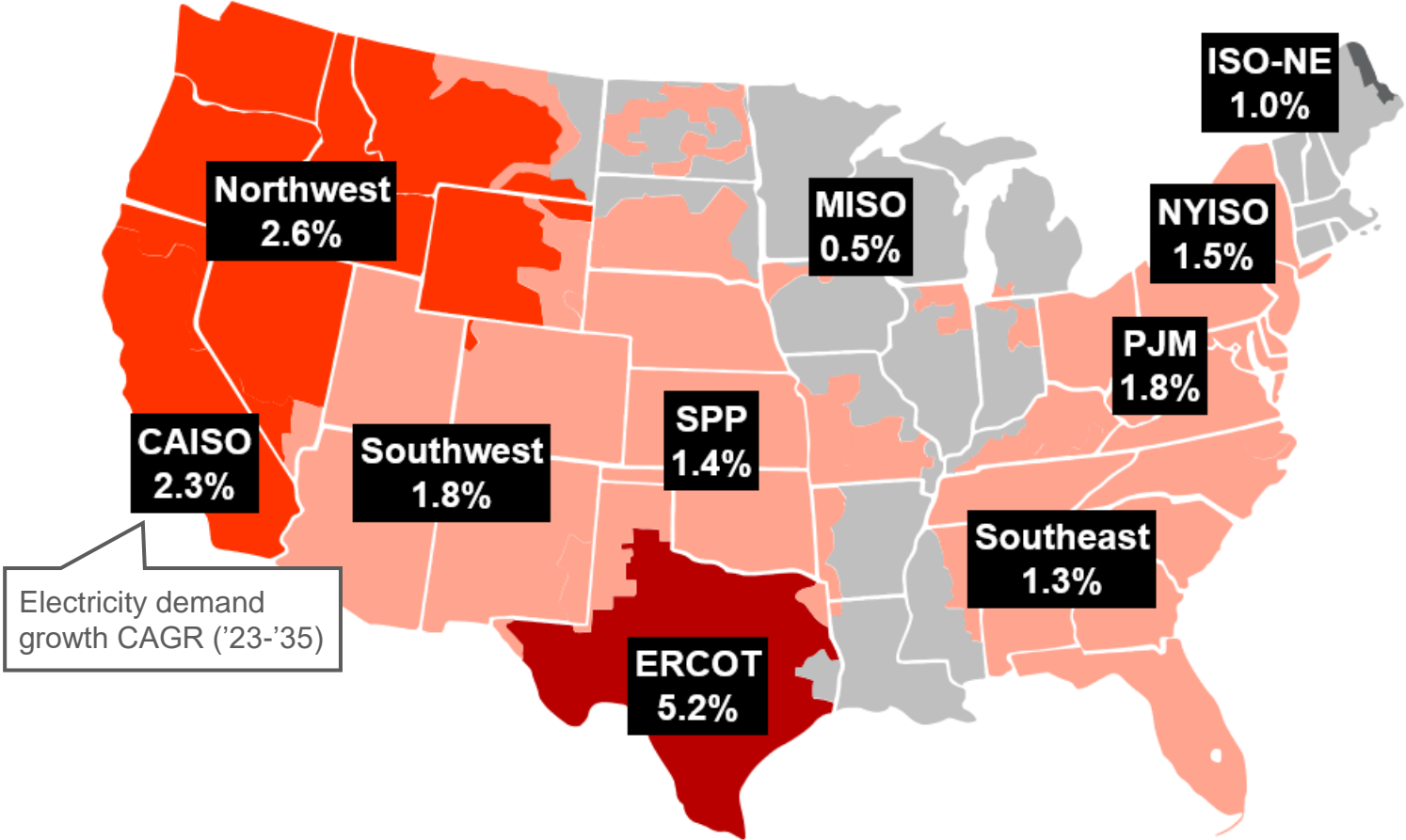
BESS outlook shows strong growth off small base

US Battery Energy Storage System (BESS) Capacity (GW)



- US is expected to have **similar share of renewables as other developed economies** by 2035
- Fragmented grid and nodal pricing are likely to cause **US to rely more on BESS** to manage intermittency
- **Forecast is highly uncertain**, dependent on extent to which other flexible supply and storage options are used (e.g., demand response, peak gas, hydrogen)

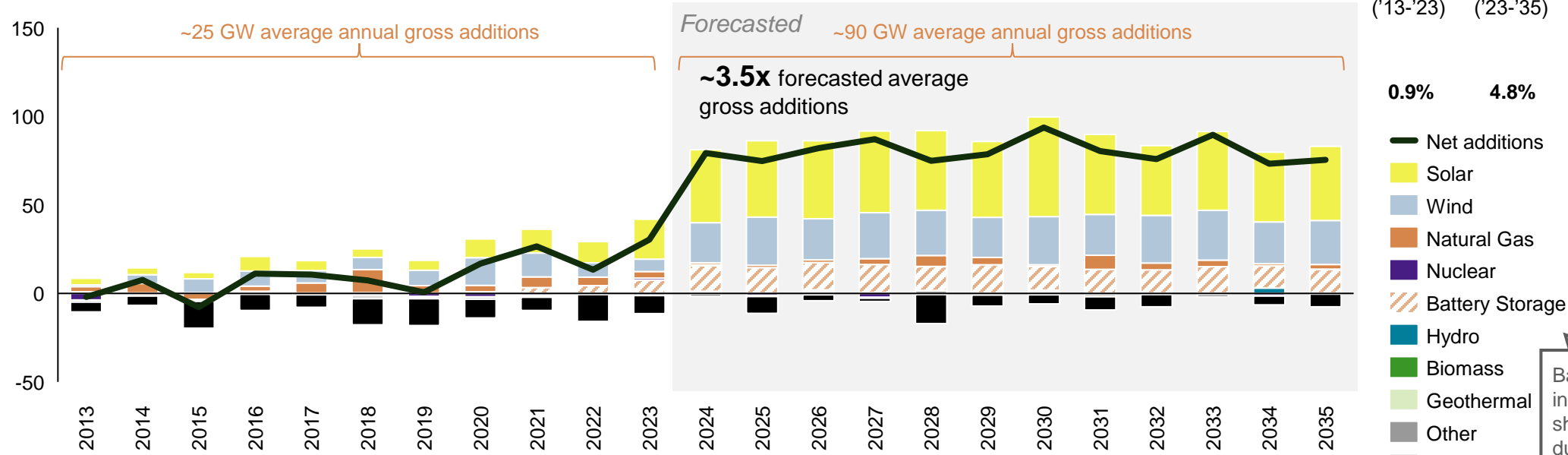
Highest Electricity Demand Growth Expected in ERCOT, CAISO, and Northwest



Source: Intersect_{SM} Carbon & Energy Transition CGE Model; IEA WEO 2023; EIA; RTO interconnection queue; S&P Energy; Regulated energy utility IRPs

Forecast Path to 2035 Includes Many Low-Carbon Additions, Requiring Unprecedented Build Levels to Achieve

Annual additions and retirements by energy source (GW, Nameplate Capacity)



Battery storage includes both short- and long-duration storage

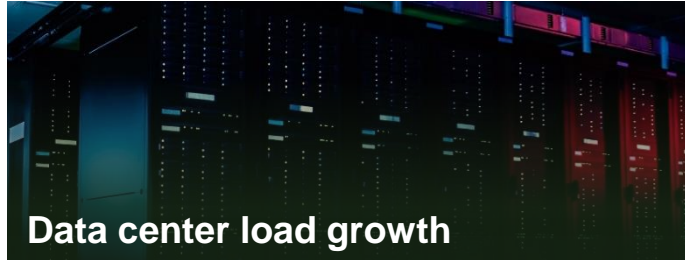
Nameplate capacity (GW)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Nameplate capacity (GW)	1,177	1,185	1,177	1,188	1,199	1,206	1,207	1,223	1,250	1,263	1,294	1,373	1,448	1,530	1,617	1,691	1,770	1,864	1,944	2,020	2,110	2,183	2,258

Build time post FID:

- Nuclear 6+ years
- Gas 3 years
- Solar 1.5 years
- Wind 0.5 years

Note: RTO gross additions are restricted to the lesser of the queued capacity or the average capacity addition over the past five years multiplied by 1.5 to account for transmission expansion constraints, no build limits applied to the IRP build plans, retirements are not discounted; RTOs' delayed pending projects of ~73 GW excluded; ELCC used for nameplate capacity adjustment; Assumes natural gas combined-cycle plants are base load, all others classified as peaker (roughly 60/40% split); "Other" is an unspecified fuel type
 Source: Berkeley Lab Queued Up; RTO demand forecast reports; RTO interconnection queue as of July 2024 (CAISO, ERCOT, MISO, NEISO, NYISO, SPP, PJM); S&P Energy; Regulated energy utility IRPs; EIA; RTO ELCC study reports

6 Macro Trends are Shaping the Utility and Power Sector



Data center load growth

Data center load growth primarily driven by **rapid expansion, development, and change in the AI and cloud computing spaces**



Manufacturing load growth

Key drivers of manufacturing load growth are largely regulatory and geopolitical, incentivizing **reshoring** of and **clean technology** investments in manufacturing



Decarbonization

Increasing focus on **emissions reduction** and need to incorporate more distributed renewable generating mix (e.g., rooftop solar)



Aging infrastructure & resiliency

Antiquated systems across the US increasingly **require repairs and upgrades** in addition to new transmission and distribution



Resource constraints

Competition for both skilled workers and material supplies are leading to a lack of resources to complete electricity investments in time to meet demand



Affordability

Increasing challenges to the rate base model with added focus on maintaining overall **customer affordability** in the face of increasing real price of electricity and increasing share of a smaller energy wallet



OpenMinds

Solving for the
Dual Challenge.