Examining the National Energy Modeling System of the United States

for

Bruegel Workshop on Energy modeling for policy making

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by

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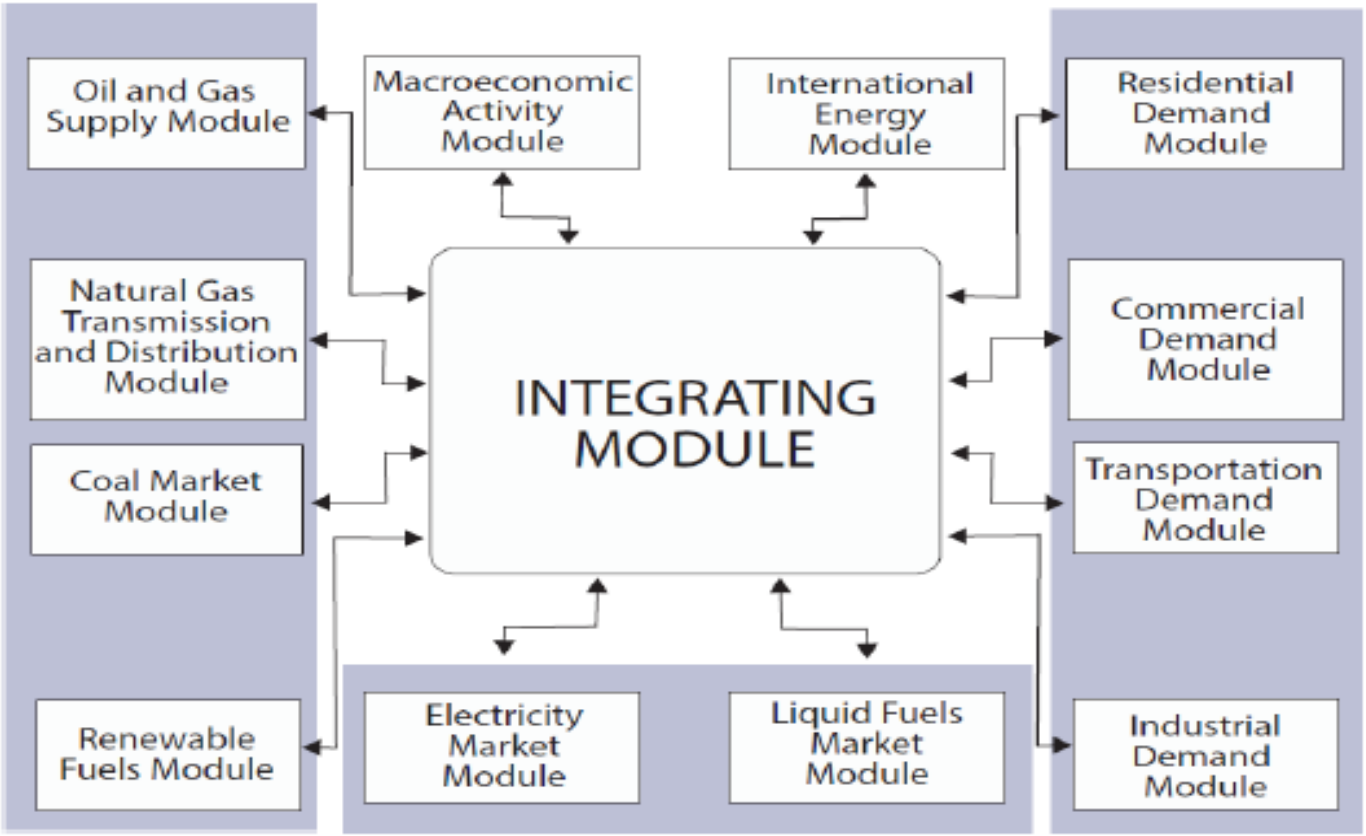
Overview

- National Energy Modeling System (NEMS) Description
- Use of NEMS
- Operation and maintainance of NEMS
- Illustration of model results

NEMS is a state of the art U.S. energy modeling system

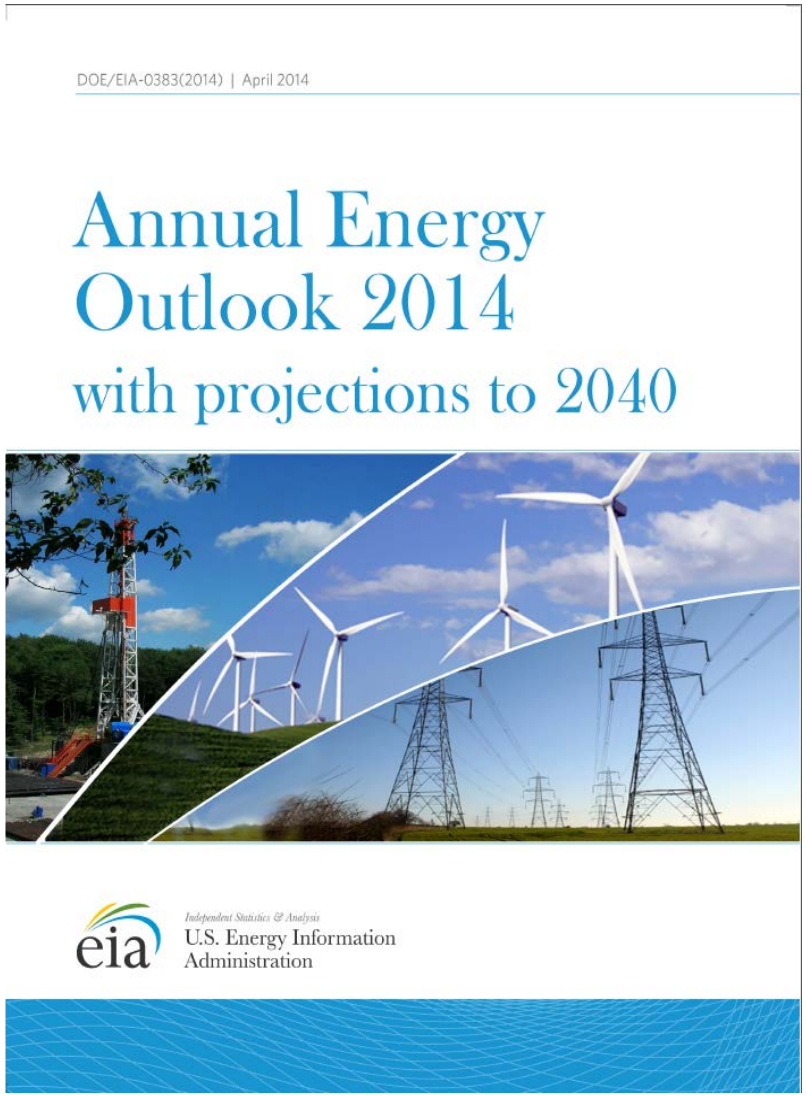
- Designed to facilitate analysis of energy policies
- It is a hybrid energy model that employs operation research and econometric methods
- A key aspect of the NEMS is its modular structure



Source: U.S. Energy Information Administration, Office of Energy Analysis.

NEMS provides projections for the *Annual Energy Outlook* and other special studies

- *Annual Energy Outlook 2014* features a Reference case with 29 side-case projections including:
  - Energy consumption by sector, fuel type, region
  - Production by fuel and region
  - Energy imports/exports
  - Energy prices
  - Technology trends
  - Carbon dioxide emissions; environmental policy indicators
  - Macroeconomic measures and energy market drivers
- Other special studies include:
  - Policy analyses for Congress
  - Policy analyses in support of the Administration (Climate Action Report)
  - EIA stand alone analyses



NEMS is a technology-rich, economic energy model providing both national and regional results

- Regional, technology-rich, energy-economy model of the United States
- Currently solves annually to 2040 for energy-economy equilibrium subject to possible constraints (e.g., regulations) guided by economic rationale
- Represents energy supply, conversion and consumption activities in a unified system with energy-economy feedbacks
- NEMS represents the consumer decision making process (i.e., operational and planning activities). For example, it represents households' appliance decisions in the residential sector, power companies' capacity planning activities in the electric power sector, and car manufacturers' product line decisions
- Technology is explicitly represented for energy consumption and production with exceptions for the industrial and coal production sectors
- Explicit technology based on researched attributes: efficiency, capital cost (and associated financial parameters), operation and maintenance cost, capacity factors, and commercial availability date

NEMS has several important limitations

- Maintenance takes substantial effort to stay abreast of energy consumption and production developments
- Unable to provide results beyond the regional level
- Projections do not fully factor in seasonal and other cyclical changes over time
- Greatest challenge is projecting energy prices while doing much better on consumption and better still on production
- Energy projections are limited in their making assumptions on an uncertain future regarding:
  - Economic growth,
  - Technological change,
  - Consumer behavior,
  - Future regulations,
  - And other factors

EIA invests considerable effort to maintain and operate NEMS

- Operations: The Office of Energy Analysis manages NEMS and its production of results and their publication for the Administrator with support from other EIA offices. Production of the *AEO* with NEMS is about a 14 month process. EIA can completed special studies using NEMS in much less time. Once modeling cases are specified, case projections typically run overnight on servers

- Review: NEMS and *AEO* are routinely considered in a working group process, participation in modeling fora (e.g. Energy Modeling Forum), and routine customer feedback. As NEMS was built, EIA conducted a rigorous external peer review

- Resources: For the full *AEO*, EIA is using the full-time equivalent (FTE) of 17 staff and $2.5 million for extramural support (data, subscriptions, and contractors) summing to about $ 5.6 million. Estimate a short version of the report could be done with the equivalent of 10 FTE staff and $2.0 million in extramural support for a total of $4.0 million

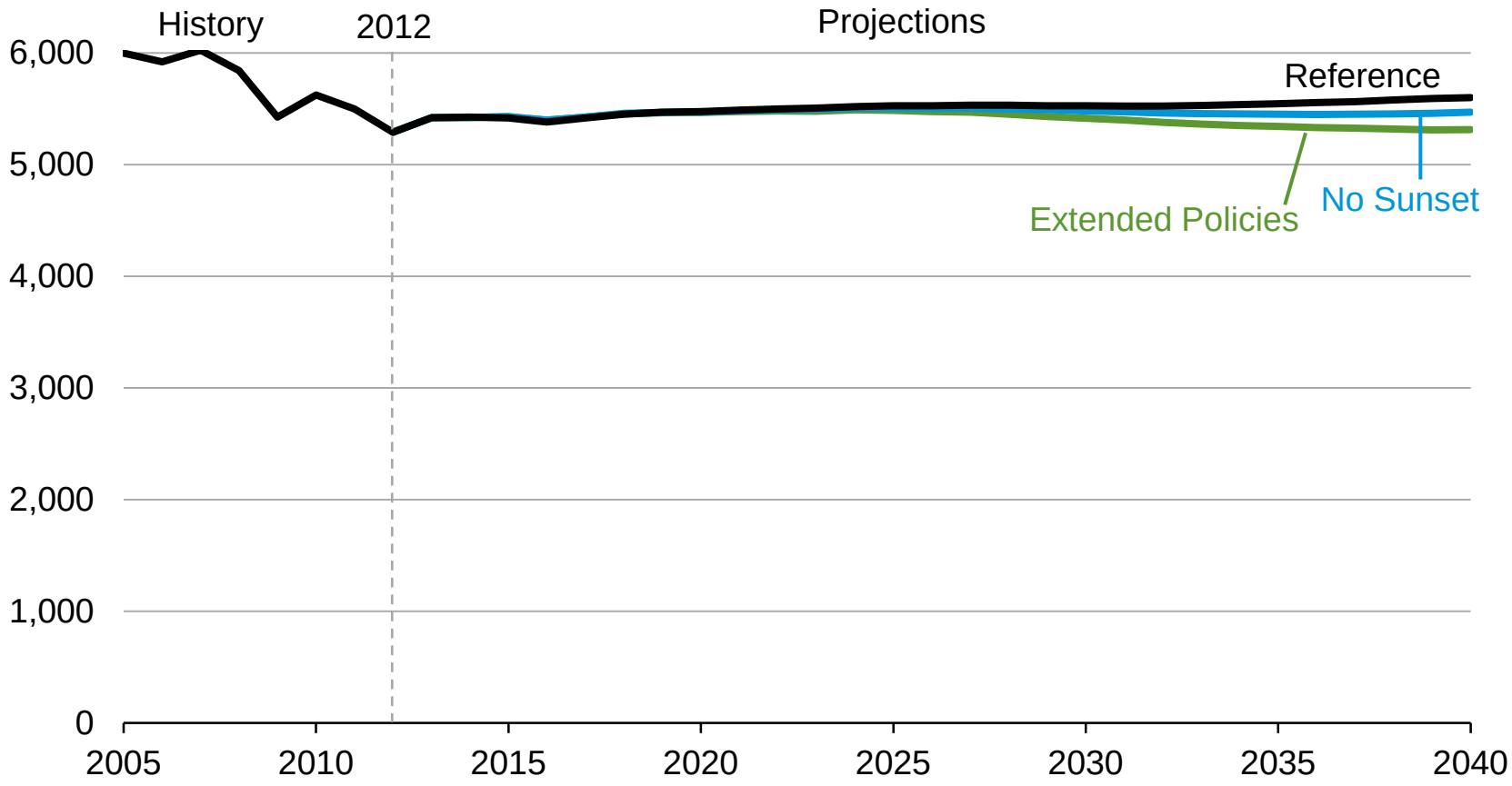
- Data requirements: EIA updates recent historical data, resource data sets and other relevant energy and economic historical statistical data sets

- Updating assumptions: Update assumptions related to macroeconomic models, energy technology performance and costs for production and consumption, and behavioral aspects of energy consumption

- Transparency: EIA provides a detailed assumptions report, model documentation, model and result archive/dvd, working groups, and responses to inquiries

AEO 2014 Illustration
Energy-related carbon dioxide emissions in three cases, 2005-2040

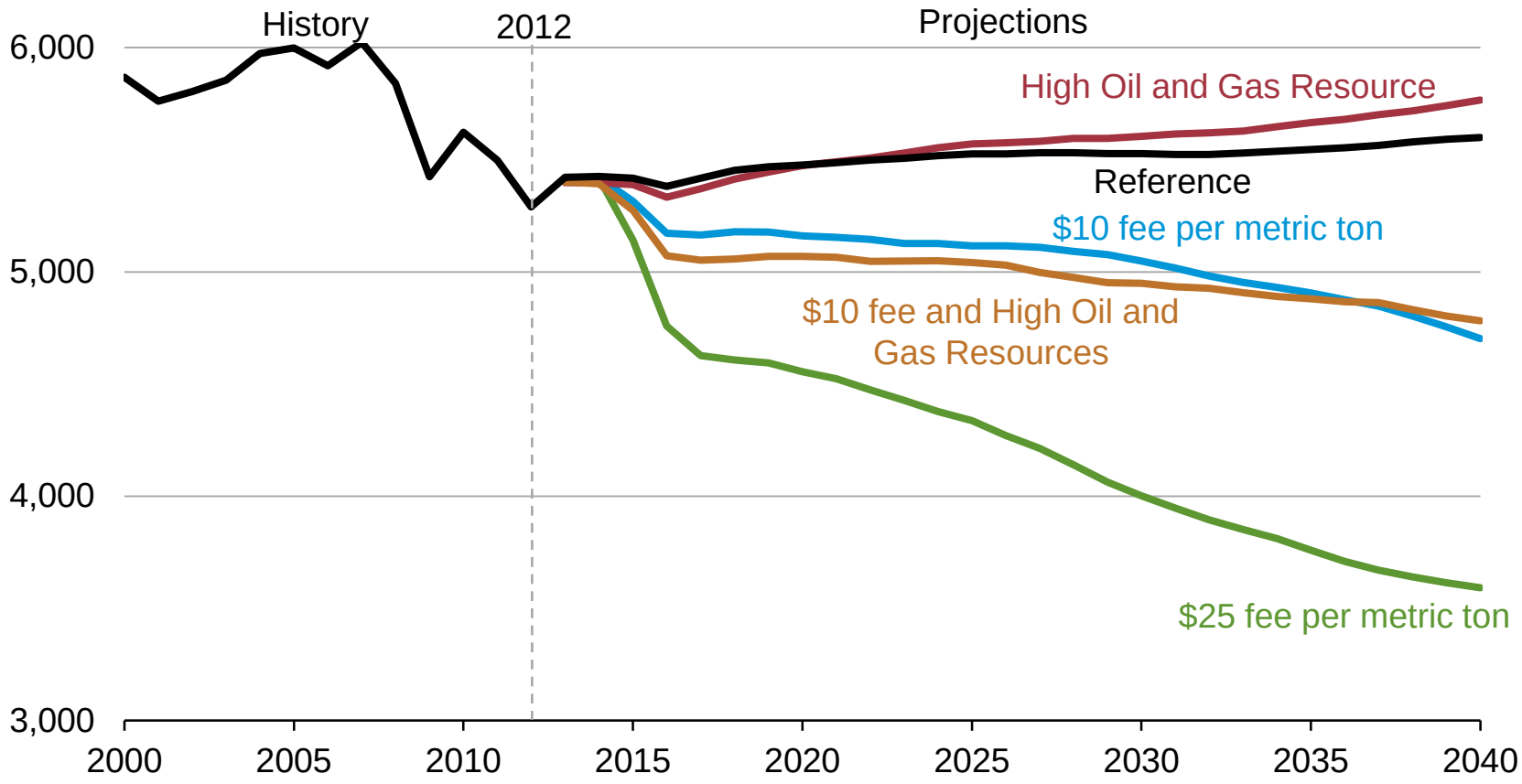
carbon dioxide emissions
million metric tons



Source: EIA, Annual Energy Outlook 2014

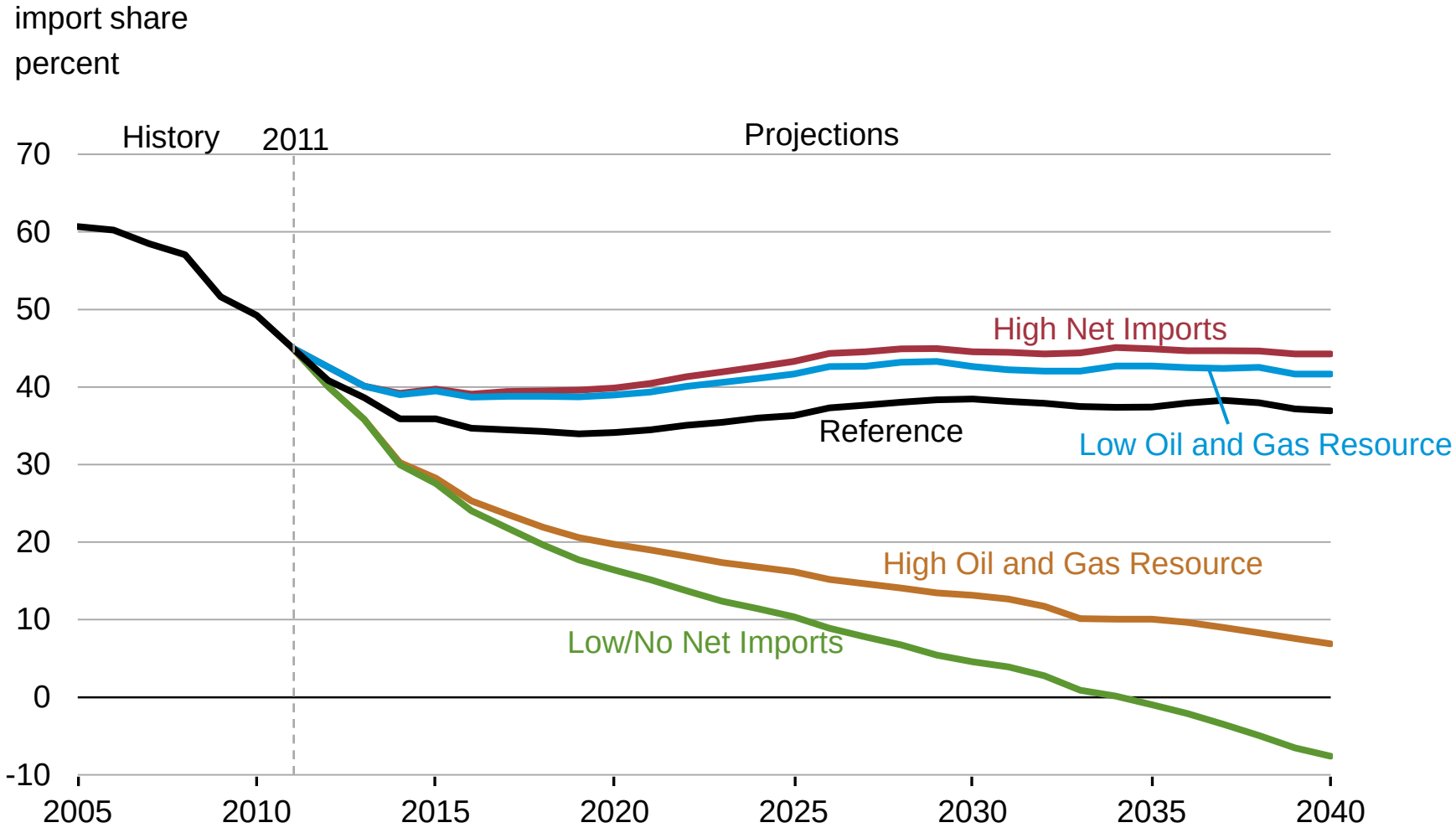
AEO 2014 Illustration
Energy-related carbon dioxide emissions in five cases, 2000-2040

carbon dioxide emissions
million metric tons



Source: EIA, Annual Energy Outlook 2014

AEO 2013 Illustration
Net import share of liquid fuels in five cases, 2005-2040



Source: EIA, Annual Energy Outlook 2013

For more information

U.S. Energy Information Administration home page | www.eia.gov

Annual Energy Outlook | www.eia.gov/forecasts/aeo

Short-Term Energy Outlook | www.eia.gov/forecasts/steo

International Energy Outlook | www.eia.gov/forecasts/ieo

Today In Energy | www.eia.gov/todayinenergy

Monthly Energy Review | www.eia.gov/totalenergy/data/monthly

State Energy Portal | www.eia.gov/state

What is included (and excluded) in developing EIA's "Reference case" projection?

- The Reference case is <u>not a forecast</u>, but a projection
- Generally assumes current laws and regulations
  - Excludes potential future laws and regulations (e.g., no proposed greenhouse gas legislation)
  - Sunset provisions as specified in law (e.g., renewable production tax credits expire in 2013)
- Includes technologies that are commercial or reasonably expected to become commercial over next decade or so
  - Includes projected technology cost and efficiency improvements, as well as cost reductions linked to cumulative deployment levels
  - Does not assume revolutionary or breakthrough technologies
- It's a reasonable extension of trends in consumer behavior
- There are some grey regulatory areas
  - Adds a premium to the cost of financing CO_2-intensive technologies to reflect current market behavior regarding possible future policies to mitigate greenhouse gas emissions
  - Assumes implementation of existing regulations that enable the building of new energy infrastructure and resource extraction

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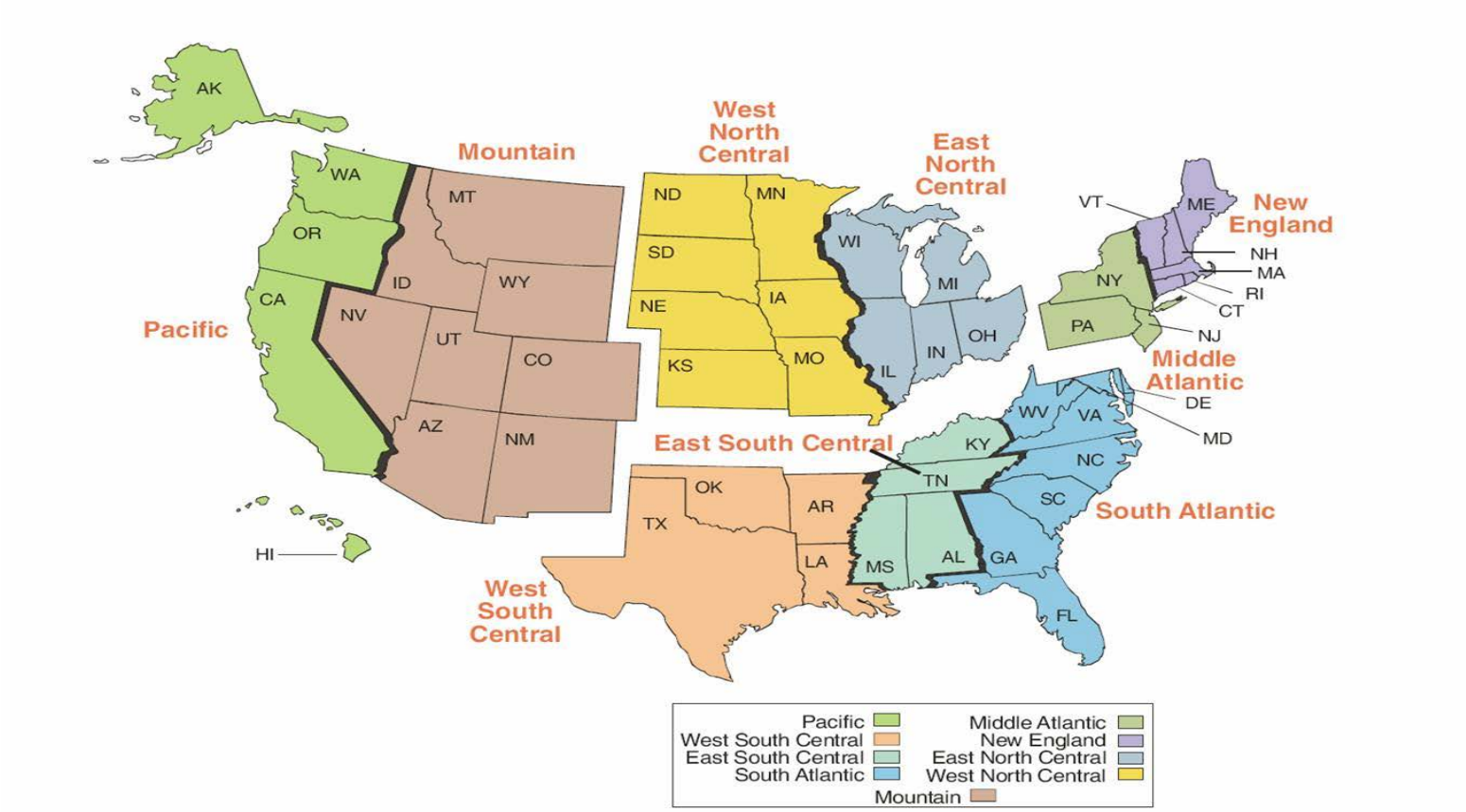
Some major NEMS data sources

- EIA data collection and reporting systems: energy consumption surveys (residential, commercial, manufacturing), mandated energy production data collection (e.g., power plant owners, refineries, coal companies, etc.), integrated data systems (Annual Energy Review, State Energy Data System).
- Many other government, private sources: Transportation Data Book (ORNL), Federal Highway Administration, McGraw-Hill Construction, Annual Survey of Manufacturers, U.S. Geological Survey, Department of Interior, etc.)
- Diverse sources for technology-related assumptions: U.S. Department of Energy research programs, EIA-commissioned studies to consulting companies (e.g., SAIC (R.W. Beck) for the electric power technologies, Navigant for buildings technologies), trade associations, etc.

NEMS regionality

- NEMS primary regional structure is based the nine Census divisions (map below)
- Supply and conversion operate at other regional levels.



Key AEO publications vary in coverage and purpose

- ***Annual Energy Outlook Full Report (e.g. AEO2014)***
  - Detailed summary of entire *AEO*, including reference case and alternative cases. Major source of distribution is through web, but limited number of printed copies made for distribution to Congress and others. One of only two printed EIA publications.
  - Major sections:
    - Executive Summary: Concise summary of key points from projection
    - Legislation and Regulations: Discussion of policy changes newly incorporated in current *AEO* and/or major new proposed policies
    - Issues in Focus: Discussion of selected energy market issues using side cases that the projection results could be sensitive to
    - Market Trends: Column summary of projection by area (macro, international energy, end use, etc.)
    - Comparisons with Other Projections: Brief comparison of *AEO* reference case to other contemporary projections
    - Tables: Tables summarizing reference, economic growth, price, and other alternative cases
    - Appendix E: Brief NEMS overview and definition of alternative cases

Key AEO products vary in coverage and purpose (continued)

- **Early Release Overview**
  - Short summary of Reference case with comparison to previous Reference case released as part of early release at press conference. Distributed via web
- **Assumption to Annual Energy Outlook**
  - Detailed summary of key assumptions used in each module of the National Energy Modeling System. Distributed via web
- **Documentation of NEMS Modules**
  - Individual report completed for each of the 13 NEMS modules summarizing methodology and any changes made for the particular *AEO*. Posted to web, no hardcopies made. Record of model changes
- **Annual Energy Outlook Brochure**
  - Simple tri-fold summary of the *AEO* Reference case used as part of early release to press. Made in house. Updated for final reference case and about 1,000 copies are printed for distribution at conference presentations, etc.
- **NEMS Overview**
  - Brief summary of NEMS model including all modules in about 35 pages. Typically, updated once every 3 to 5 years, but current version has not been updated since 2003. Used as short summary of model format. Posted to web
- ***AEO* Retrospective Review**
  - Short analysis comparing realized energy outcomes and projections included in previous editions of the *AEO*. Examines the absolute value of the percentage difference between the reference case projection and the actual value for selected data items. Posted to web
- **Supplemental Tables**
  - Expanded set of *AEO* tables including more detail and regional tables. Posted to web in table browser
- **Previously Featured Articles from *AEO***
  - Complete list of previously published articles in the *AEO* Legislation and Regulation and Issues In Focus sections of the *AEO*. Posted to web

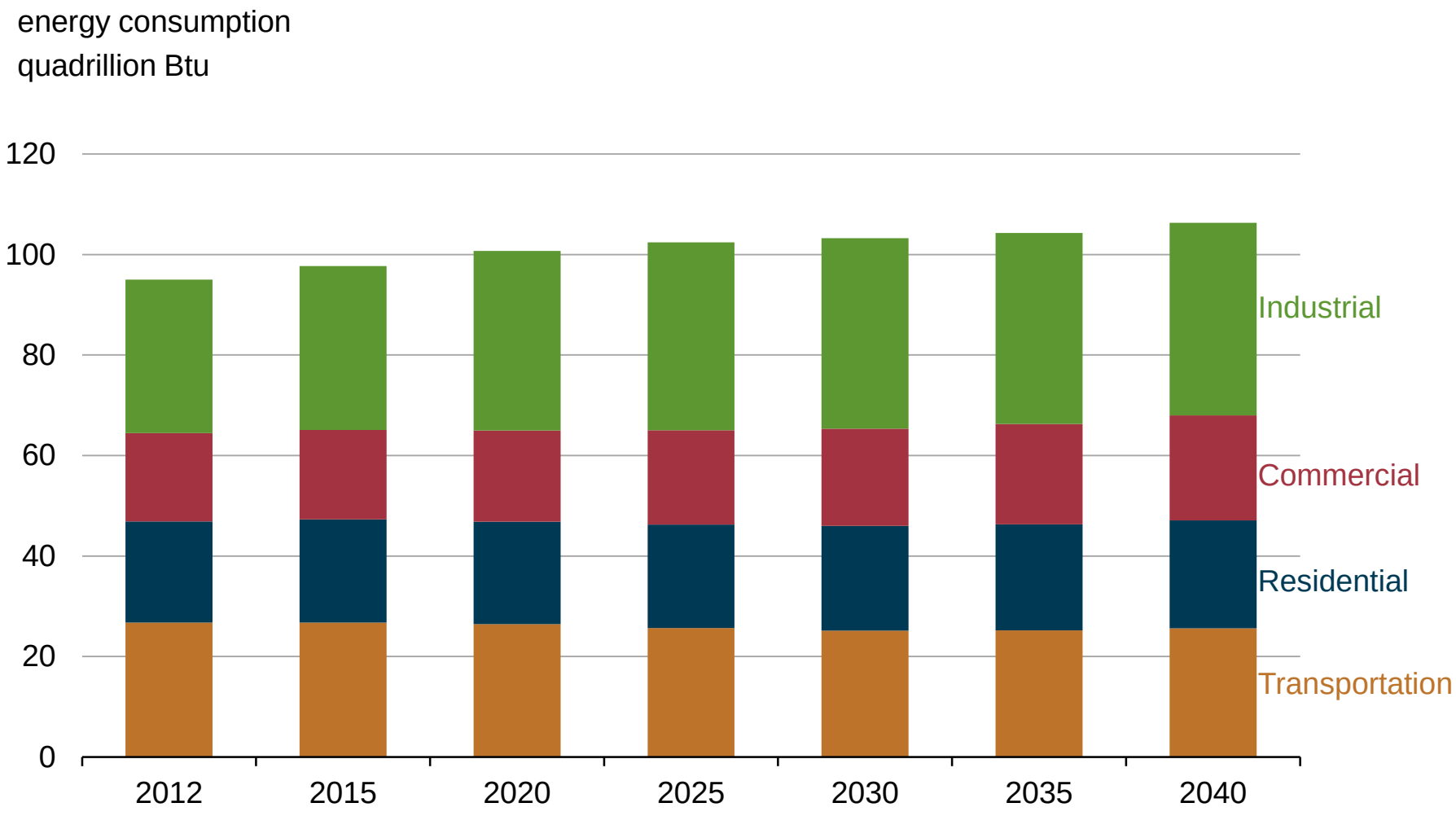
Typical production calendar for full *AEO* report

- Meet with Administrator/Deputy Administrator on scope and format (April to May)
- Update NEMS modules (April to September)
- Derive world oil price assumptions using international models (March to June)
- Complete, review, and finalize macroeconomic projection (May to September)
- Develop *AEO* Reference case runs (June to October)
- Hold working group meetings with internal and external parties on assumptions (July) and preliminary *AEO* reference case results (August to September)
- Provide briefings to Administrator/Deputy Administrator on selected issues and preliminary *AEO* reference case (September to October)
- Develop *AEO* Alternative Cases (October to December)
- Provide *AEO* Reference case briefing to Secretary (late November)
- Publish Early Release *AEO* reference case press conference (early December)
- Complete *AEO* report text and other materials for publication (December to April)
- Release web version of *AEO* (April)
- Release hardcopy version of *AEO* (April to May)
- Complete *AEO* assumption report (April to May)
- Complete NEMS documentation (May to August)

NEMS transparency

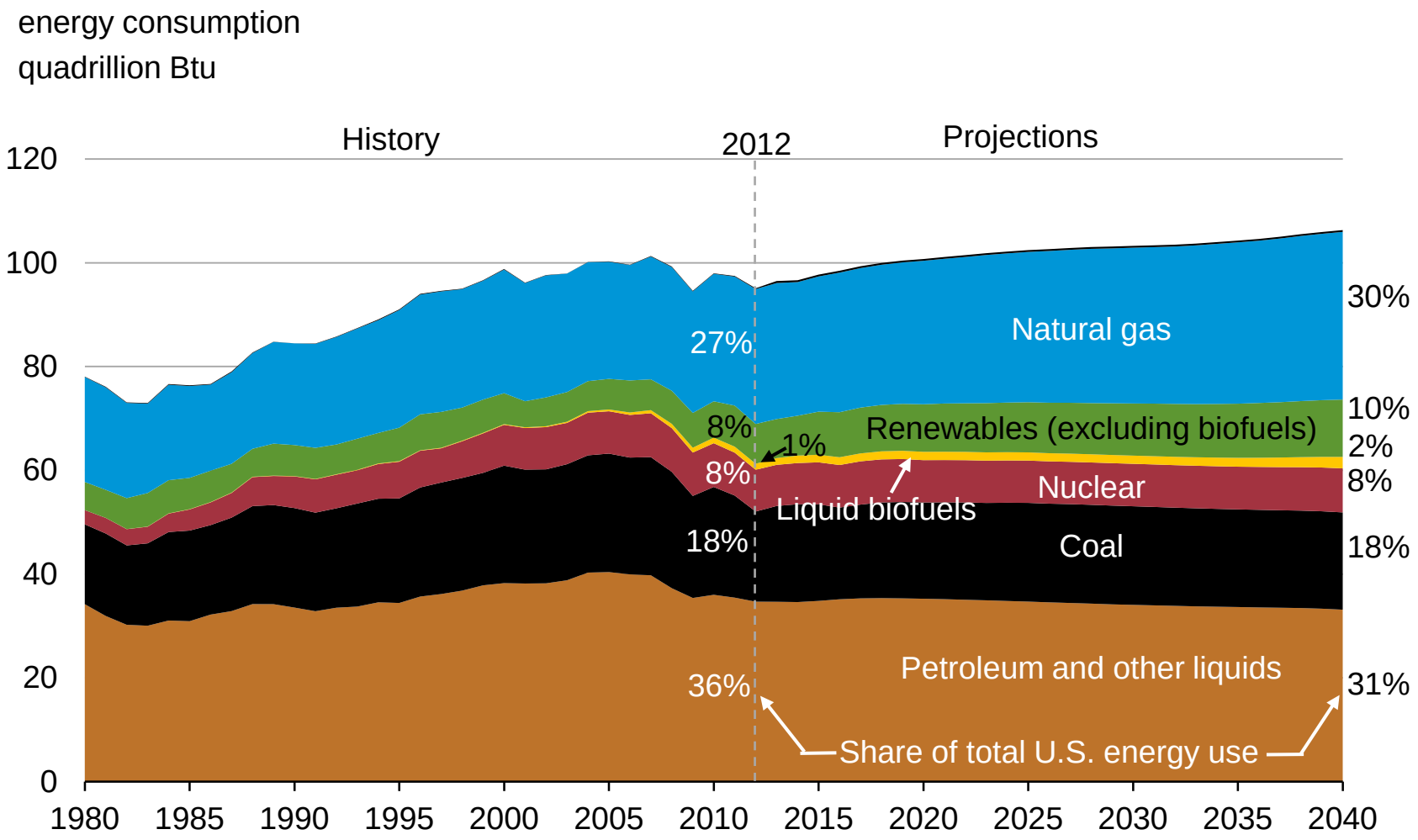
- Transparency is an essential component of government energy models. Two characteristics that often drive *transparency* are availability and *usability*
- NEMS is available and used by DOE Labs, a few universities, a few nongovernmental organizations, and some private companies (often on behalf of trade associations)
- Detailed model documentation is available on the EIA web site (to meet EIA model documentation standards)
- Single-Run "archive" of NEMS available for each *AEO* and published study (also required by EIA archival standard)
- However, *usability* is not as easily achieved
  - NEMS is rather difficult to operate and requires substantial resources to use effectively
  - NEMS uses a number of proprietary software packages whose cost put it out of reach for the casual user

Primary energy use by end-use sector in selected years in the Reference case, 2012-2040



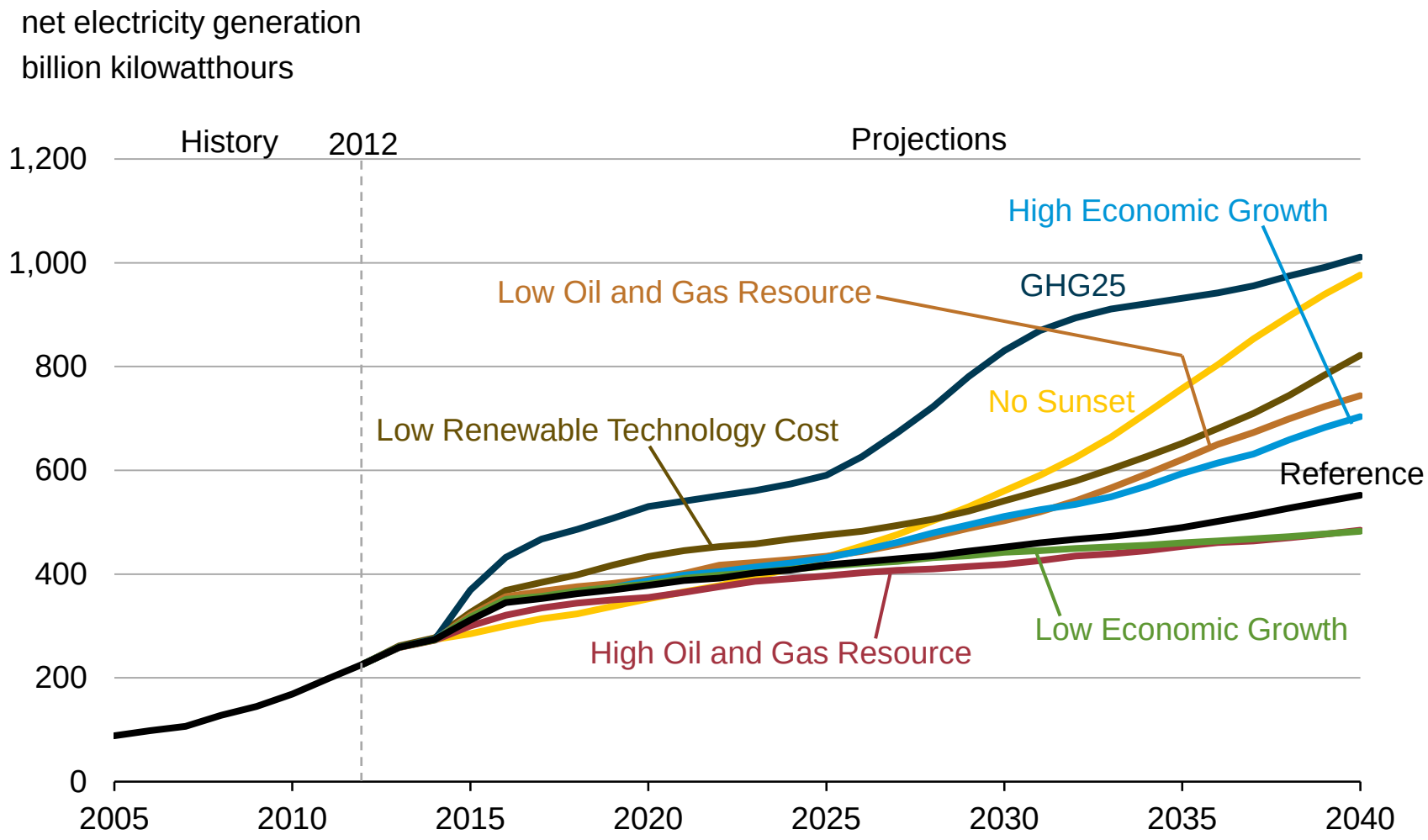
Source: EIA, Annual Energy Outlook 2014

Primary energy use by fuel in the Reference case, 1980-2040



Source: EIA, Annual Energy Outlook 2014

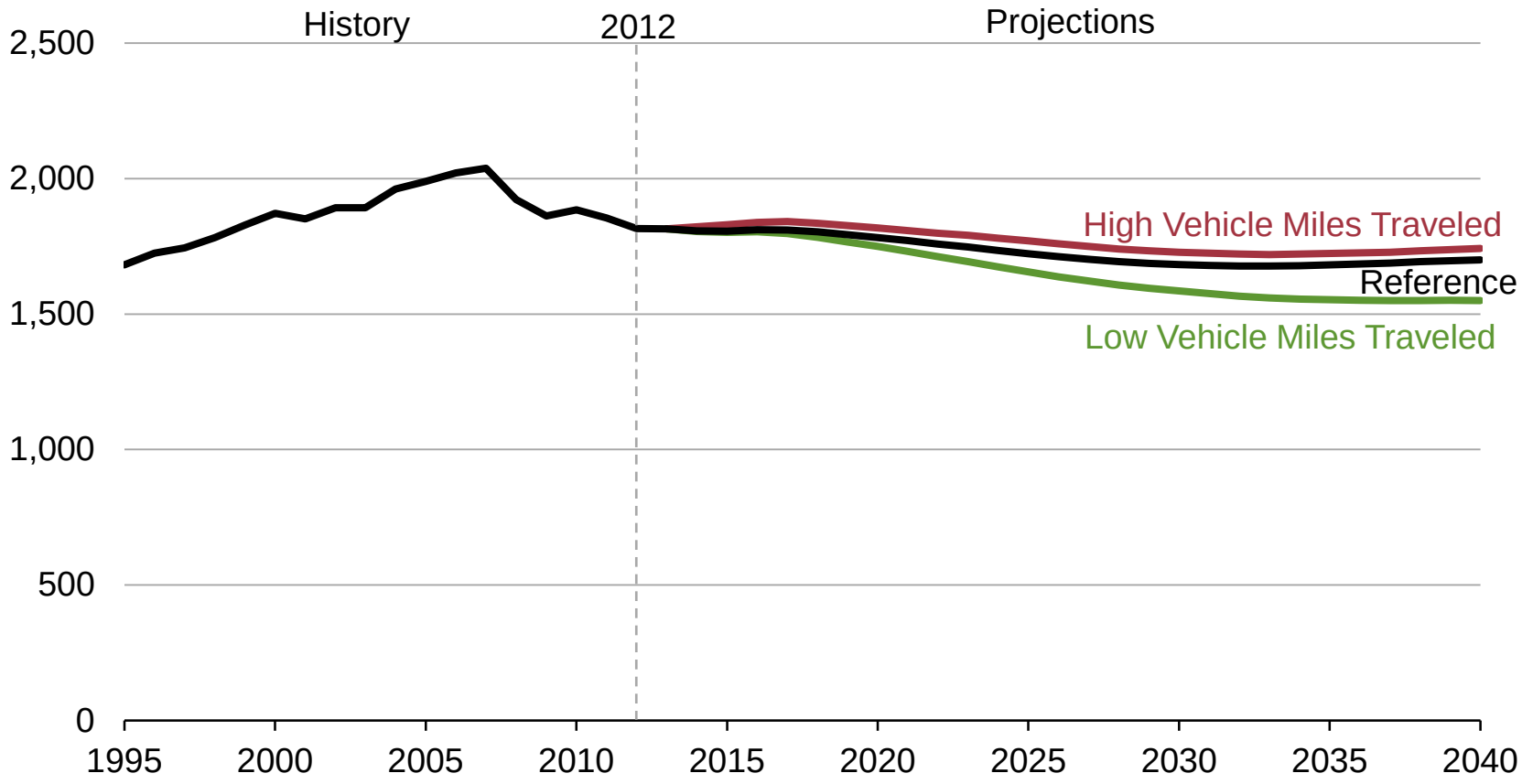
Nonhydropower renewable electricity generation in eight cases, 2005-2040



Source: EIA, Annual Energy Outlook 2014

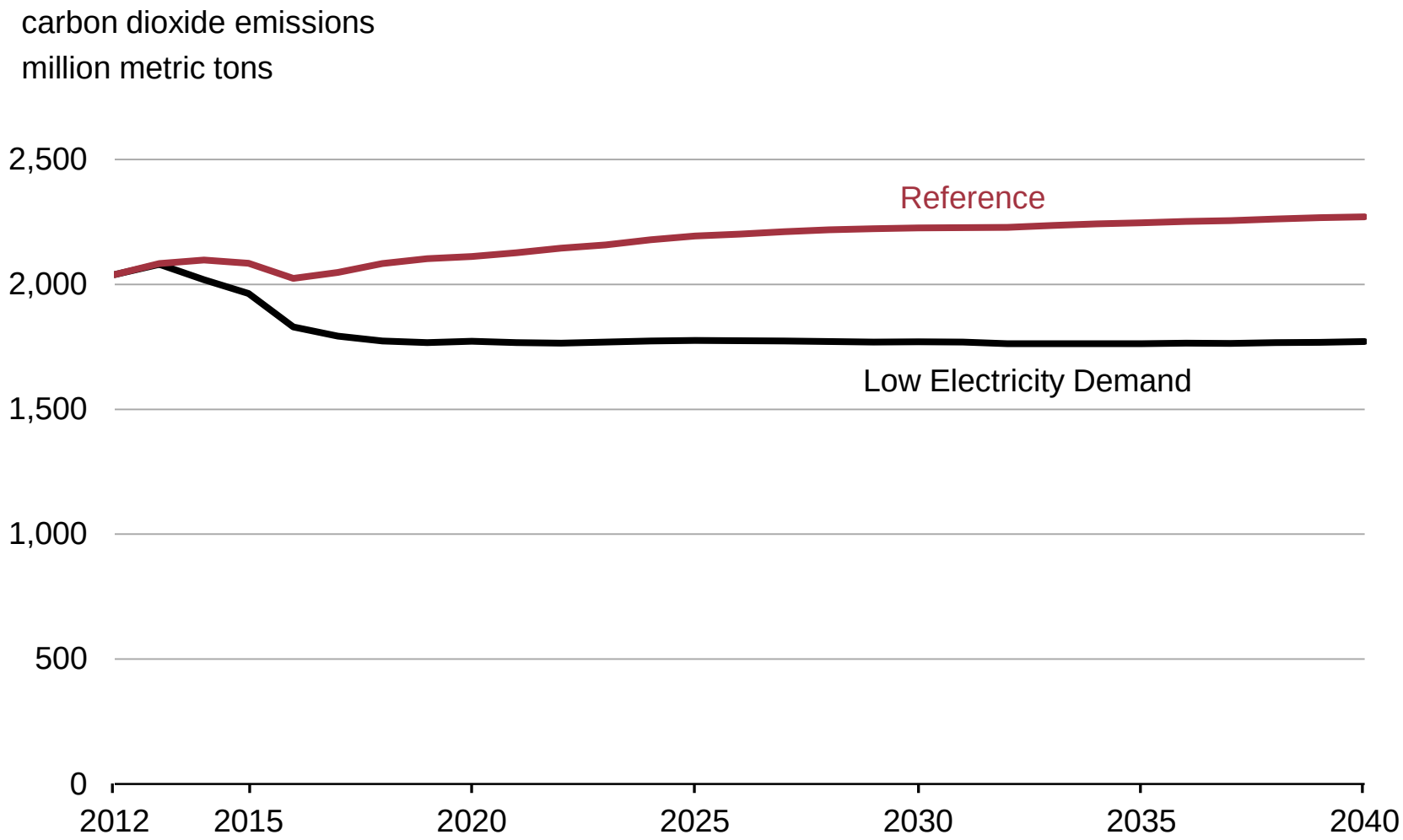
U.S. carbon dioxide emissions in the transportation sector in three cases, 1995-2040

carbon dioxide emissions
million metric tons



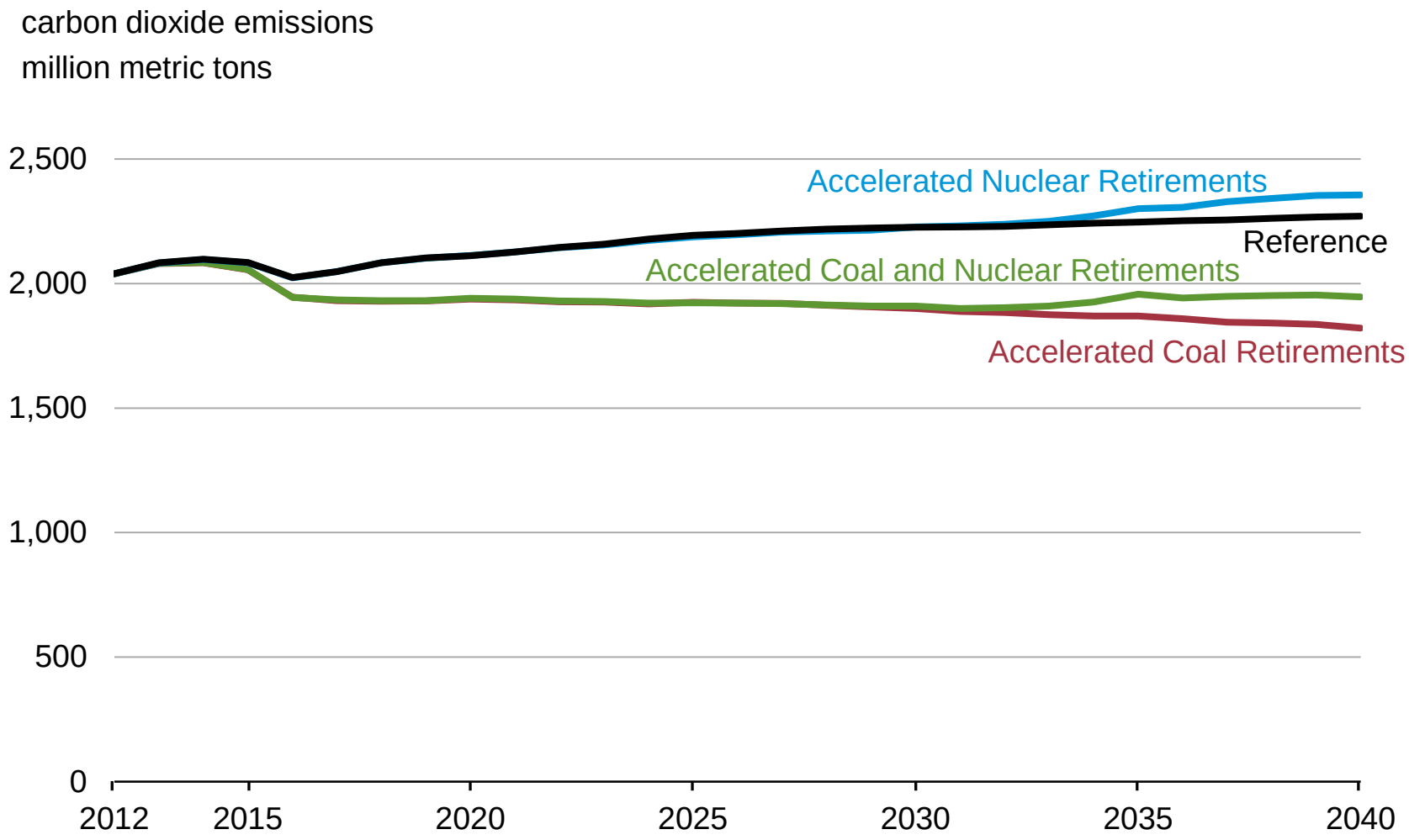
Source: EIA, Annual Energy Outlook 2014

Carbon dioxide emissions in the electric power sector in two cases, 2012-2040



Source: EIA, Annual Energy Outlook 2014

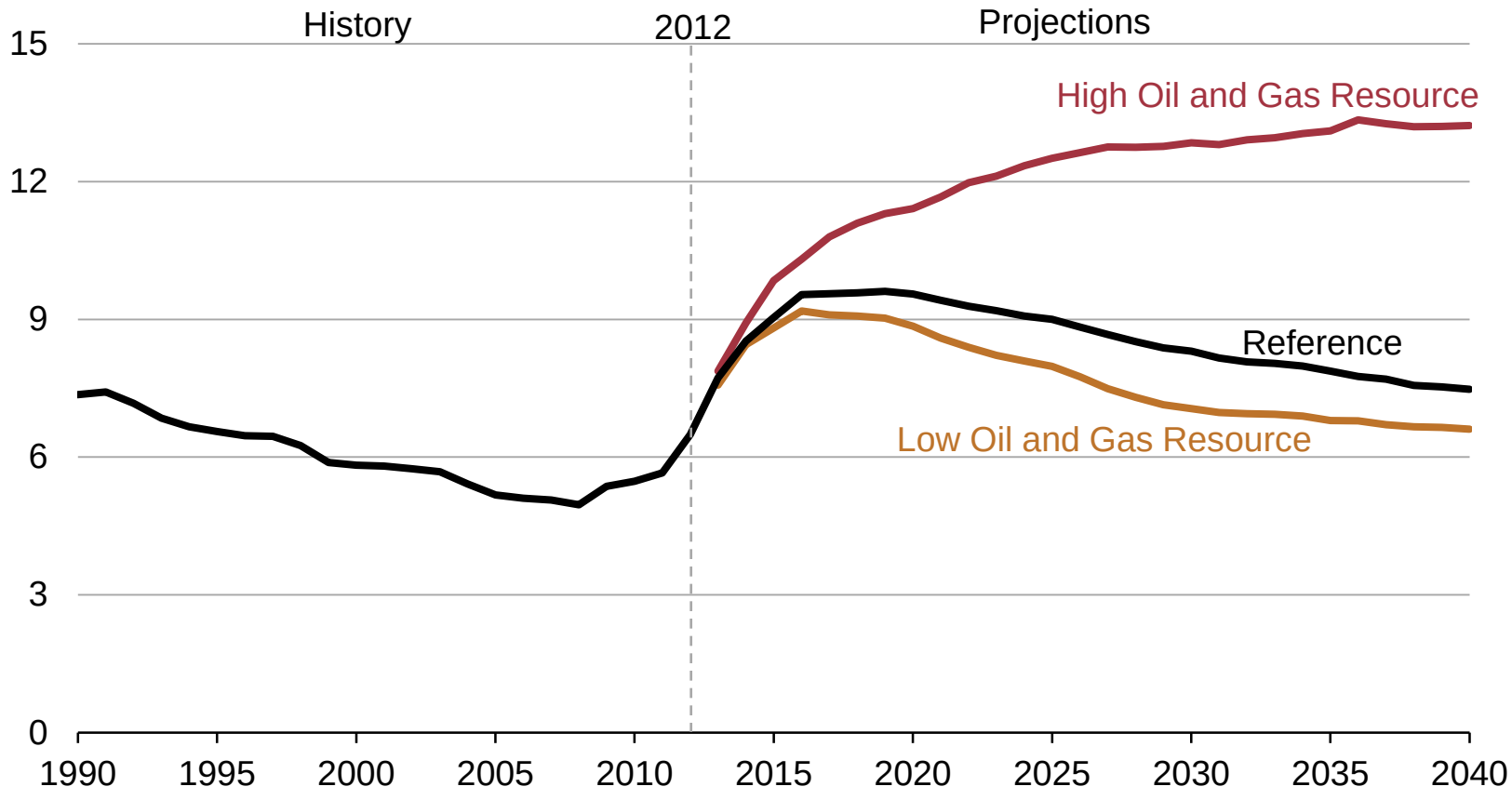
Electric power sector carbon dioxide emissions in four cases, 2012-2040



Source: EIA, Annual Energy Outlook 2014

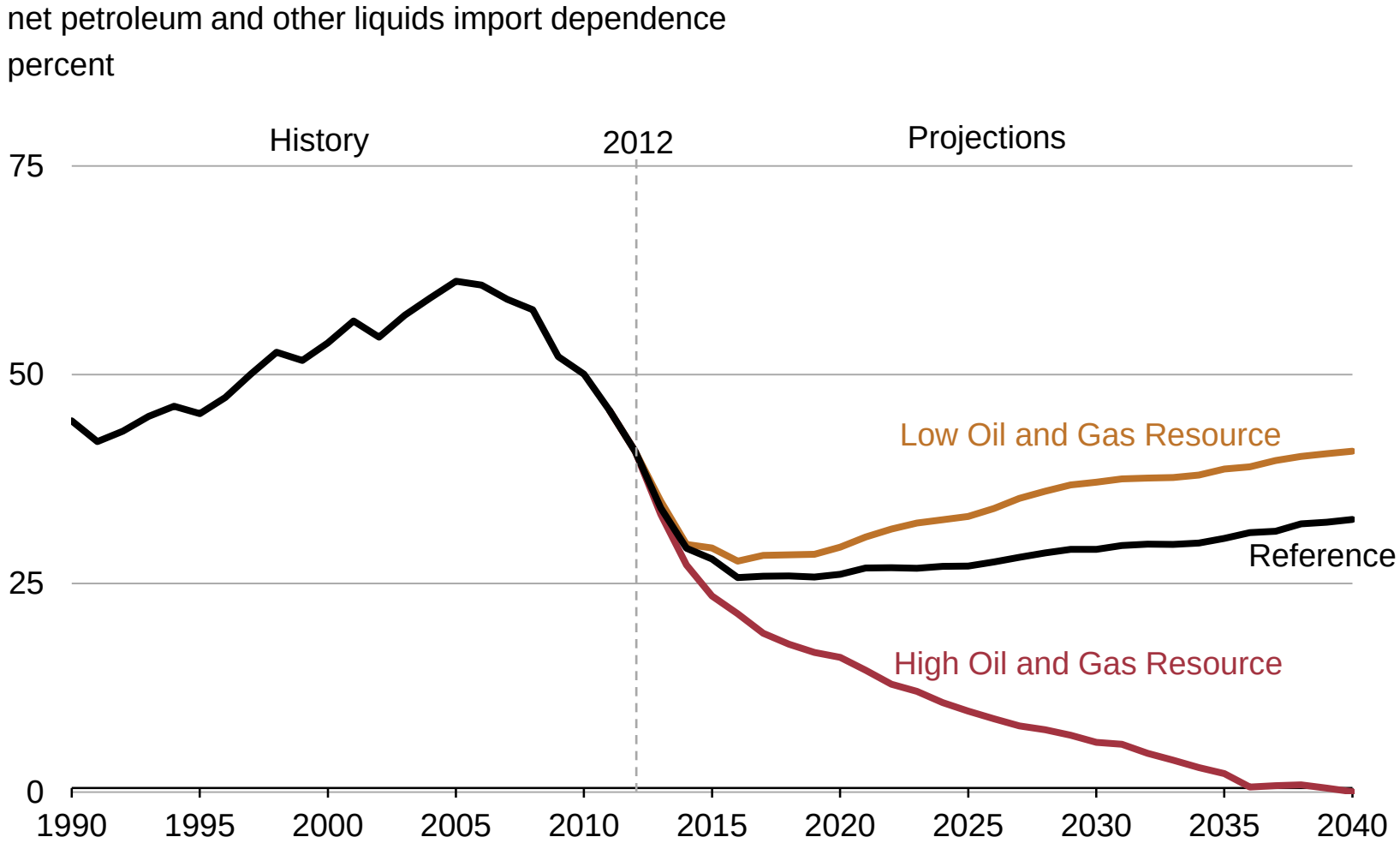
Total U.S. crude oil production in three cases, 1990-2040

crude oil production
million barrels per day



Source: EIA, Annual Energy Outlook 2014

Net import share of U.S. petroleum and other liquids consumption in three cases, 1990-2040



Source: EIA, Annual Energy Outlook 2014