Independent Statistics and Analysis
U.S. Energy Information Administration

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MEMORANDUM FOR: Angelina LaRose
Assistant Administrator for Energy Analysis

FROM: Jim Diefenderfer
Director, Office of Long-Term Energy Modeling

Subject: Summary of Petroleum and Natural Gas Long-Term Modeling Team Working Group Meeting held on November 4, 2024

This memorandum summarizes the presentation given during the *Annual Energy Outlook 2025* (AEO2025) Petroleum, Natural Gas, Biofuel, and Hydrogen Second Working Group meeting and the resulting discussions that took place.

The presentation slides are available in a separate document on our website. All slides, charts, and discussions for AEO2025 were preliminary and, therefore, should not be quoted or cited. We will release final AEO2025 materials in 2025 with the product release.

Mindi Farber-DeAnda introduced the presentation and the team of modelers who have been working on five of the modules over the year and a half since we released AEO2023. She reviewed the modules that make up the National Energy Modeling System (NEMS), noting the three new modules introduced for AEO2025: the Hydrocarbon Supply Module; the Carbon Capture, Allocation, Transportation, and Sequestration Module; and the Hydrogen Market Module.

Hydrocarbon Supply Module (HSM)

Andrew Smiddy covered enhancements of the HSM compared with the legacy Oil & Gas Supply Module (OGSM).

Model features

- Split decline curves for co-produced commodities
- Geology-specific cost equations
- Methane venting and flaring costs
- Dynamic CO_2 capture from natural gas processing
- Simplified enhanced oil recovery representation
- Federal and non-federal land representation

Preliminary results

We project:

- West Texas Intermediate (WTI) crude oil prices to be similar to AEO2023
- U.S. crude oil production to increase through 2030, then decline gradually to 2023 levels by the end of projection period
- Tight oil to lead growth in U.S. crude oil production in AEO2025
- Permian plays to lead crude oil production throughout the projection period
- U.S. Henry Hub natural gas spot price to increase steadily as highly economic resources deplete and natural gas production moves to less economical formations
- U.S. dry natural gas production to increase through 2030 before leveling off
- Shale gas to lead growth in U.S. dry natural gas production in AEO2025
- U.S. dry natural gas production from oil formations to follow the same trends as crude oil production
- Appalachian Basin to lead shale gas production in AEO2025, with significant production volumes from the Southeast directed to liquified natural gas (LNG)
- Increased natural gas production in Appalachia, which has a high liquids-to-gas ratio, to lead to higher natural gas plant liquids production through the mid-term

Discussion

One attendee asked EIA to explain why oil production drops after 2030. We explained that we project oil production to decline in the Permian Basin, particularly the Wolfcamp play. Attendees were curious about well productivity in the Permian Basin in the 2030s as production declines. We explained that we project wells drilled in the top three Permian plays (Wolfcamp, Spraberry, and Avalon/Bone Springs) to become less productive in the future. We do not change drilling density assumptions; they remain constant over the projection period.

Another attendee asked which plays are included in the *other* category (red area of Slide 8) of crude oil production. We explained that *other* includes the Denver-Julesburg (DJ) Basin, Anadarko, Western Gulf, and other smaller plays.

An attendee asked about the increase or decline in natural gas production. We project the Haynesville play to grow significantly through the early 2030s and then decline and very little growth will occur in the other regions. Another attendee asked why associated gas declines steeply with decreasing crude oil production in AEO2025 on Slide 12, whereas in AEO2023, associated gas increased with flat crude oil production; the split decline curves result in higher natural gas relative to crude oil production. We explained that the assumptions and decline curves are different by region and geology.

Natural Gas Market Module (NGMM)

Stephen York covered key data and model updates for AEO2025:

Model and data updates

- Incorporated data from the *Natural Gas Annual* (2023 annual data)
- Incorporated data from the *Natural Gas Monthly* (complete 2023 history)
- Incorporated historical data for Mexico and Canada through 2023
- Updated pipeline capacity and pipeline projects EIA tracks
- Updated natural gas spot price historical data

- Updated LNG export assumptions for under-construction projects

Preliminary results

We project:

- Overall domestic natural gas consumption to decline in AEO2025, and natural gas production to grow slightly to accommodate the rise in LNG exports
- Natural gas consumption in the electric power sector to decline in AEO2025 due to effects from the Inflation Reduction Act (IRA) and higher natural gas prices
- Net imports from Canada to be higher in AEO2025 compared with AEO2023
- AEO2025 pipeline exports to Mexico to grow in the near term but finish the projection period lower than AEO2023
- LNG exports to be higher in AEO2025 compared with AEO2023, reaching a peak in the mid-2030s

Discussion

One attendee asked why natural gas exports to Mexico are lower. We explained that natural gas production in Mexico is slightly higher, and Mexico's natural gas demand for power and industry are both projected to be lower.

Another attendee questioned where the LNG exports are going. We explained that EIA does not project the destinations for LNG exports. We explained that we model the net present value of LNG exports leaving the United States to ports representative of the Atlantic (Europe) and Pacific (Asia) Basins during LNG capacity expansion decisions, but we do not model specifically where exported LNG is delivered.

One attendee asked how the growth in data centers and AI demand is reflected in the electric power sector and domestic natural gas demand. We explained that several factors are not yet represented in the electric power sector for these results and suggested that he attend the Electricity Working Group meeting on November 12. We directed attendees to visit our AEO working group page to register for all events.

One attendee asked us to explain the High Oil Price case and Low Oil Price case. We explained that global market balances, primarily international supply and demand factors, drive future crude oil prices. To account for these factors, oil prices for the Reference case, High Oil Price case, and Low Oil Price case are exogenous assumptions in our analysis. We have not set those for AEO2025; we're only presenting preliminary Reference case results.

One attendee asked why the Henry Hub price is much higher in 2050 than we projected in AEO2023. We explained that the higher Henry Hub prices are the result of the highly economic resources depleting, forcing production to move to less economical formations.

Liquid Fuels Market Module (LFMM) and International Energy Module (IEM)

Brittany Phalon covered the key data updates for AEO2025, and Peter Colletti and Estella Shi helped answer questions.

Model and data updates

- Updated international crude oil and petroleum product import and export curves
- Updated crude oil price differentials by crude oil type
- Updated pipeline capacity and transport costs
- Updated state and federal fuel taxes
- Incorporated historical and *Short-Term Energy Outlook* (STEO) liquid fuels data
- Incorporated capacity updates for refineries, biofuels, and cogeneration
- Incorporated changes to representation of H_2 production and carbon capture and sequestration (CCS) retrofits for ethanol plants
- Incorporated Renewable Fuel Standard update based on the June 2023 EPA rulemaking
- Updated the Washington Clean Fuel Standard representation

Preliminary results

We project:

- Brent crude oil prices to be lower in the early projection years, then minimal change compared with AEO2023
- Brent-WTI price spread to rise slightly based on STEO forecasts, then remain between $2 per barrel and $3 per barrel throughout the projection period
- Crude oil exports to decline over the projection period and to remain between 25% and 30% of total crude oil production
- Consumption to be met through a combination of domestic production and net imports of both crude oil-based and biofuels-based products
- Total crude oil supply to U.S. refineries to be similar over the projection period and refinery utilization rates to be slightly lower
- Gross exports of refined products to be higher compared with AEO2023 in response to decreasing domestic product demand
- Biofuels supply to receive a small boost due to provisions of the IRA, then stabilize at a higher level than AEO2023
- Renewable diesel supply to continue to outpace biodiesel due to increased current capacity and planned expansion

Discussion

The first question was regarding the feasibility of more than 10 million barrels per day of gross product exports. We explained that we do believe this level is possible and that investments will be made in U.S. infrastructure to support those levels in the 2040s.

Another attendee asked if our module accounts for changes in refinery capacity due to conversions and shutdowns. Our current LFMM does not account for changes in refinery capacity and instead considers

changes in refinery utilization. Our efforts to redesign LFMM will include refinery capacity accounting in the new Fuel Liquids EXchange (FLEX) module we intend to roll out for AEO2026.

Another attendee asked which petroleum products are exported more over time. We explained that, given assumptions regarding the market penetration of electric vehicles, motor gasoline blendstocks for oxygenate blending (BOBs) are likely to grow the most. This expectation could change, however, in response to changes in domestic demand.

One attendee asked what causes the stagnation in biofuel supply growth after 2030. We explained that ethanol constitutes most of the biofuel supply. Ethanol is blended with motor gasoline, and we project motor gasoline demand to decrease through the projection period. In addition, the Renewable Fuel Standard sunsets in 2027, and we cannot confidently assume credits will increase in the later years.

Hydrogen Market Module

Stephen York reviewed key components of the new Hydrogen Market Module (HMM) (introduced on June 12). Nicholas Skarzynski and Brittany Phalon helped answer questions.

Model features

- Three H_2 production pathways represented:
  - Grid-based electrolysis
  - Steam methane reforming (SMR)
  - SMR with carbon capture and sequestration (CCS)
- Production technology options allow HMM to analyze the mid- to long-term impacts of current policies, laws, and regulations governing hydrogen markets
  - Section 45V H_2 production tax credits from the IRA
  - Section 45Q tax credits for capturing CO_2
- H_2 consumption in the industrial, electric power, refining, and transportation sectors
- H_2 supply modeled by HMM is termed marketed hydrogen
- Section 45V tax credits played a major role in HMM granularity and scope

Preliminary results

We project:

- Most H_2 to be produced via SMR; SMR with carbon capture and electrolyzer production will taper off in response to credits sunsetting
- Average H_2 spot price to increase through the projection period, trending with natural gas prices
- Majority of electrolyzer production to be produced using the 45V credit, if available
- Electrolyzers to be generally most economical in the Southeast due to cheap electricity prices
- Hydrogen demand to mostly come from the industrial and refining sectors
- West South Central to be the largest demand region for H_2 by far

Discussion

One attendee asked why electrolysis-based H_2 does not show up until 2033 in the projection. We explained that when Henry Hub natural gas spot prices are low, SMRs are popular; once the prices exceed $5 per million British thermal units, electrolyzers become more economical by comparison. In addition, learning reduces the capital costs of the electrolyzers over time, improving their competitiveness by 2033.

Attendees asked how we modeled DOE's H_2 hubs and its $1 per kilogram clean H_2 target. We explained that we do not model H_2 hubs exogenously or endogenously. We only consider projects under construction or reaching final investment decision (FID). Our new model does not assume that DOE's $1 per kilogram clean H_2 target is necessarily met by producers. Our H_2 prices are solved endogenously to calculate marginal costs.

Another attendee asked if the projection for H_2 production included electricity generated by nuclear power plants. We answered that the Greenhouse gases, Regulated Emissions, and Energy Use in Technologies (GREET) model treats nuclear generation as zero-emissions, but the IRA and HMM specifically require nuclear to be incremental, not a new facility, to qualify for credits. We do not model any production pathways where H_2 and nuclear generation are co-located.

An attendee asked about our source for the cost numbers for SMR with CCS and the level of carbon capture (90% or 99%). We answered that all of our cost assumptions come from the National Renewable Energy Laboratory's reports on H2A Lite and H2A models. We assume the carbon capture rate is somewhere between 90%–99%.

An attendee asked what drives the growth in H_2 demand. We responded that most of the growth comes from industry and refining. H_2 demand in these sectors is sensitive to changes in the macroeconomy. Current industrial H_2 demand is only for feedstocks, not heat. Our Macroeconomic Activity Module projects the value of agricultural chemicals to be produced each year, and the Industrial Demand Module determines the amount of H_2 needed to produce those chemicals (for example, fertilizer). Another attendee asked for more clarification: does H_2 demand relate dynamically to LFMM (that is, refinery demand) in our modeling? We explained that refineries use H_2 for hydrotreaters/crackers to upgrade petroleum products to meet specifications. Refinery H_2 demand and prices do not change much over time.

An attendee asked why H_2 production declines due to phasing out Section 45V when project investments have already been made and no more H_2 credits are distributed. Another commented that Sections 45Q and 45V do not appear to make much of a difference. We answered that once Section 45V phases out, if the marginal cost of producing H_2 exceeds the benefit it gets from producing electricity (as the grid electricity must be purchased), HMM stops utilization of electrolyzers where it is too expensive to produce H_2 in most hours. They will generally continue to operate in curtailed hours when the price of electricity is cheap. We reiterated that the presentation includes preliminary results that will change by the time we release AEO2025.

Other attendees asked for more details on the demand sectors in each region (specifically South Atlantic) presented on Slide 43. We explained that we don't have more specific details at this point in the process.

Attendees

Guests (via Teams)	*Affiliation*
Mariannne Mintz	Argonne National Lab
Alyssa Leibold	Bureau of Labor Statistics
Mark Jensen	Bureau of Ocean Energy Management (BOEM)
Charles Paris	BOEM
Doo Hyun Chung	Chevron
Robin Lynch	Chevron
John Martini	Chevron
Kevin Medeiros	Chevron
Kiran Mishra-Jha	Chevron
Lecie Tucker	Chevron
Bobby Wright	Chevron
Phillip Brown	Congressional Research Service
Megan Mahajan	Energy Innovation
Charles Sheppard	EOG Resources
Bryan Chapman	ExxonMobil
Ken Ditzel	FTI Consulting
Charles Azih	Gas Supply Consulting
Ram Dharmarajan	GTI Energy
Srijana Rai	GTI Energy
Shadi Salahshoor	GTI Energy
Shilpa Kokate	Hitachi Energy
Boddu Venkatesh	ICF
Harry Vidas	ICF
Michael Istre	INGAA Foundation
Scott Yager	INGAA Foundation
Marshall Carolus	INTEK Inc
Hitesh Mohan	INTEK Inc
Christopher Smith	Interstate Natural Gas Association of America
John Meyer	Leidos
Kenneth Walsh	Leidos
Douglas Hengel	LNG Allies
Michael Verney	McDaniel & Associates
Indra Bhattacharya	National Energy Technology Laboratory (NETL)
Luciane Cunha	NETL
Kristen Fauria	NETL
Sally Homsy	NETL
Sangbum lee	NETL

James Slutz	National Petroleum Council
Wesley Cole	National Renewable Energy Laboratory (NREL)
Keith Wipke	NREL
Cory Forgrave	Office of Natural Resource Revenue
Samaneh Babaee	OnLocation, Inc.
Hao Deng	OnLocation, Inc.
Amogh Prabhu	OnLocation, Inc.
Sharon Showalter	OnLocation, Inc.
Peter Whitman	Onlocation, Inc.
Frances Wood	OnLocation, Inc.
Richard Fullenbaum	RFF Consulting LLC
Hannah Kolus	Rhodium Group
Anna van Brummen	Rhodium Group
Candise Henry	RTI International
Joshua Junge	Sargent & Lundy
Betty Pun	Sustainability and Strategy
Ernest Carter	U.S. Department of Agriculture
Barry Basile	U.S. Department of Energy (DOE)
James Easton	DOE
Andrew Foss	DOE
Jordan Kislear	DOE
Brian Lavoie	DOE
Brandon McMurtry	DOE
Russell Ogle	DOE
Pavan Ravulaparthy	DOE
Rachel Reolfi	DOE
Isabella Ruble	DOE
Peri Ulrey	DOE
Henry Kotanjyan	U.S. Department of State
Jameel Alsalam	U.S. Environmental Protection Agency (EPA)
Jordan Galloway	EPA
Sumitrra Ganguli	EPA
Christopher Ramig	EPA
Natasha Vatalaro	EPA
Lester Wyborny	EPA
Xiaobing Zhao	EPA
Wyatt Thompson	University of Missouri
Jarrett Whistance	University of Missouri

EIA participants (via Teams)

Greg Adams
Tuncay Alparslan
Jeffrey Bennett
Rosalyn Berry
Erin Boedecker
Emily Burke
Zachary Chairez
Singfoong Cheah
William Chime
Michael Cole
Peter Colletti
Matthew Corne
Jim Diefenderfer
Michael Dwyer
Mindi Farber-DeAnda (presenter)
David Fritsch
Peter Gross
Christina Jenq
Ari Kahan
Mala Kline
Michael Kopalek
Angelina LaRose
Katie Lewis
Vikram Linga
Laura Martin
Chris Namovicz
Boon Teck Ong
Britany Phalon (presenter)
Corrina Ricker
Merek Roman
Mark Schipper
Estella Shi
Nicholas Skarzynski
Matthew Skelton
Andrew Smiddy (presenter)
William Sommer
Manussawee Sukunta
Rubaiyat Tasnim
Ed Thomas
Neil Wagner
Mary Webber
Josh Whitlinger
Stephen York (presenter)