Modeling Long-Term Energy Markets

for

NCAC-USAEE Annual Energy Policy Conference

April 20, 2021| Virtual

by

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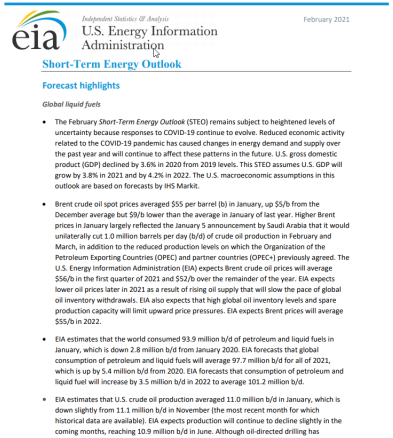
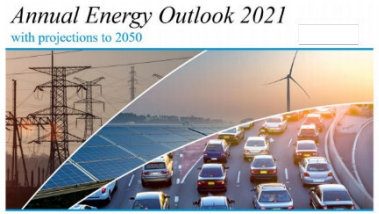
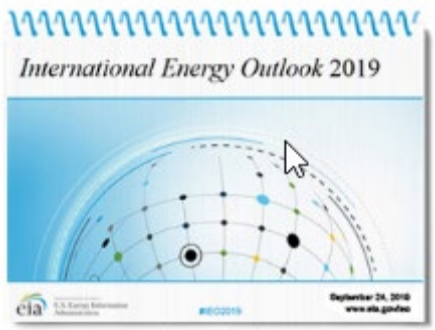
EIA operates three large energy system models

EIA Product	STEO	AEO	IEO
			
Geographic Scope	U.S.	U.S.	World
Projection Period	1-2 years	~25-30 years	~25-30 years
Publication Frequency	Monthly	Annual	Annual
Generating Model	**STIFS**	**NEMS**	**WEPS+**

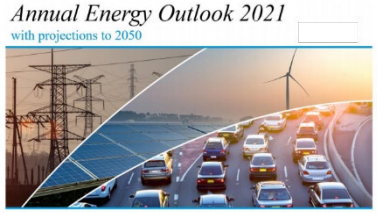
The Reference case is designed to produce a baseline against which to measure changes (e.g., laws, regulations, technology)

- EIA's Reference case is a "no change" baseline
  - Current laws and regulations
  - Only evolutionary technology changes, no technology breakthroughs
- AEO Policy cases layer a policy change on top of Reference
  - Examples: No sunset, extended policies, proposed legislation
  - Difference between policy case and Reference represents impact of policy
  - Many of the uncertainties are highly correlated, and largely cancel in the difference
- AEO side cases provide alternates to test robustness of policy impact
  - Different oil prices, economic growth, or shale resource potential
  - Layering policy on top of the side cases may yield different impacts than in Reference

Why long-term projections ~~might~~ ~~could~~ will be wrong

- Different relative fuel prices
- Faster / slower demand growth
- Changing policies and regulations
- Changing consumer preferences
- Faster / slower technological progress
- Technological breakthroughs

EIA publishes its assumptions and documentation with each edition of the AEO, and biannually publishes a Retrospective Review



About the Annual Energy Outlook

Contact information and staff

Information on Obtaining NEMS

Retrospective Review

NEMS: An Overview (2018)

Previous Editions of the AEO

2020

Documentation and Assumptions

- *Trends and Expectations Surrounding the Outlook for Energy Markets* (August 2020)
- *Annual Energy Outlook 2021* Case Descriptions
- Assumptions report (2021)
- Working Groups
- Model documentation
- Additional AEO Documentation

AEO Retrospective: GDP

Table 3. Real Gross Domestic Product Growth Trends, Projected vs. Actual (Continued)

Projected vs. Historical

(percent difference)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
AEO 1994	0.34	-0.24	-0.30	-0.52	-0.80	-1.04	-1.22	-1.28	-0.99	-0.84	-0.81	-0.88	-0.93	-0.93	-0.85	-0.66	-0.37	-0.39									
AEO 1995		-0.37	-0.58	-0.96	-1.02	-1.21	-1.41	-1.49	-1.17	-0.99	-0.93	-0.97	-1.00	-0.99	-0.93	-0.73	-0.42	-0.44									
AEO 1996			-0.08	-1.03	-1.18	-1.36	-1.57	-1.59	-1.15	-0.95	-0.94	-1.00	-1.02	-1.00	-0.93	-0.73	-0.40	-0.43	-0.41	-0.42	-0.42	-0.45	-0.50				
AEO 1997				-1.63	-2.24	-2.21	-2.17	-2.03	-1.49	-1.23	-1.15	-1.21	-1.23	-1.17	-1.05	-0.82	-0.47	-0.50	-0.47	-0.49	-0.48	-0.51	-0.57				
AEO 1998					-1.05	-1.59	-1.93	-1.93	-1.31	-1.05	-1.02	-1.09	-1.10	-1.06	-0.93	-0.66	-0.25	-0.28	-0.24	-0.26	-0.25	-0.30	-0.38	-0.38	-0.40	-0.46	-0.48
AEO 1999						-1.09	-2.13	-1.95	-1.17	-0.84	-0.79	-0.90	-0.91	-0.84	-0.69	-0.39	0.06	0.04	0.05	0.02	0.01	-0.04	-0.10	-0.10	-0.14	-0.20	-0.21
AEO 2000							-0.96	-1.58	-0.54	-0.27	-0.26	-0.41	-0.48	-0.51	-0.42	-0.15	0.29	0.23	0.22	0.18	0.19	0.18	0.12	0.11	0.07	0.01	-0.01
AEO 2001								1.08	1.97	1.90	1.48	1.00	0.74	0.64	0.69	0.97	1.43	1.33	1.34	1.29	1.28	1.22	1.13	1.12	1.07	0.98	0.94
AEO 2002									0.03	0.24	0.27	-0.04	-0.11	-0.09	0.09	0.55	1.19	1.19	1.29	1.25	1.24	1.19	1.11	1.12	1.10	1.03	1.00
AEO 2003										0.70	0.53	0.22	0.00	0.02	0.25	0.75	1.42	1.40	1.44	1.40	1.39	1.32	1.21	1.20	1.16	1.08	1.07
AEO 2004											-0.57	-0.31	-0.10	0.08	0.37	0.89	1.56	1.42	1.41	1.33	1.33	1.26	1.15	1.14	1.10	1.03	1.00
AEO 2005												0.56	0.31	0.25	0.57	1.07	1.86	1.68	1.65	1.54	1.51	1.45	1.32	1.31	1.27	1.20	1.17
AEO 2006													0.12	0.28	0.61	1.37	2.24	1.93	1.84	1.68	1.61	1.50	1.37	1.39	1.36	1.27	1.23
AEO 2007														0.46	0.52	1.42	2.47	2.07	1.97	1.75	1.64	1.49	1.32	1.32	1.27	1.17	1.15
AEO 2008															0.27	1.00	2.39	1.99	1.93	1.69	1.53	1.32	1.12	1.09	1.00	0.86	0.81
AEO 2009																1.42	0.51	0.28	0.73	0.80	0.87	0.76	0.57	0.60	0.57	0.51	0.52
AEO 2010																	-0.29	-0.88	0.05	0.38	0.49	0.40	0.30	0.41	0.42	0.38	0.43
AEO 2011																		0.08	0.34	0.79	1.11	0.83	0.65	0.70	0.65	0.53	0.50
AEO 2012																			0.21	-0.39	-0.09	0.21	0.25	0.43	0.41	0.25	0.24
AEO 2013																				-0.14	-0.20	-0.01	0.08	0.33	0.40	0.30	0.33
AEO 2014																					0.00	0.14	0.15	0.47	0.48	0.33	0.32
AEO 2015																						-0.33	-0.15	0.17	0.13	0.04	0.11
AEO 2016																							-0.90	-0.28	0.08	0.18	0.22
AEO 2017																								0.36	0.29	-0.05	-0.10
AEO 2018																									-0.17	-0.42	-0.21
AEO 2019																										-0.63	0.32
AEO 2020																											2.44

AEO Retrospective: Natural Gas Production

Table 10. Natural Gas Production, Projected vs. Actual (continued)

Projected vs. Actual

(percent difference)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
AEO 1994	-2.1	-6.1	-4.1	-3.9	-3.5	-3.1	-1.3	-1.3	-1.7	3.1	3.7	7.1	11.5	9.1	5.8	0.9	-2.2	-5.3									
AEO 1995		-2.9	-3.3	-5.0	-3.7	-2.1	0.5	-0.5	-2.1	2.3	2.2	6.2	10.5	9.0	5.3	2.2	-0.2	-2.0									
AEO 1996			1.6	1.6	3.3	3.0	4.0	2.4	0.6	5.5	6.6	12.0	17.7	15.5	12.5	9.7	9.0	7.1	2.0	-0.9	-0.4	-4.2	-7.8				
AEO 1997				1.3	4.2	6.0	7.9	7.1	5.9	12.3	14.7	20.0	25.5	23.9	21.4	17.5	16.3	13.8	7.6	4.1	4.8	1.0	-3.7				
AEO 1998					-0.3	0.2	8.1	5.7	5.0	10.7	12.3	17.3	23.3	22.4	20.3	17.8	17.5	15.9	9.0	5.4	6.2	0.5	-3.6	-1.4	-0.1	-11.7	-19.0
AEO 1999						-1.2	1.6	0.5	1.0	6.9	8.7	13.2	19.5	18.8	16.6	13.4	12.8	11.5	5.5	2.7	3.4	-0.4	-3.6	-0.8	-0.3	-11.5	-19.1
AEO 2000							-2.5	-1.5	-5.9	-2.2	-1.1	3.0	9.1	9.5	8.5	6.3	5.4	5.4	0.1	-2.8	-1.6	-5.3	-7.6	-5.1	-4.4	-15.1	-22.2
AEO 2001								-3.0	-3.7	3.9	6.2	11.1	15.3	14.1	10.8	8.2	8.4	8.6	3.0	0.7	2.5	-1.0	-3.2	0.8	2.4	-8.1	-15.2
AEO 2002									-1.7	3.2	5.7	10.4	14.8	14.9	12.6	10.6	10.6	10.2	5.7	3.0	4.4	0.2	-2.9	0.5	1.5	-9.2	-16.6
AEO 2003										2.3	4.7	8.4	11.6	10.4	6.5	4.6	4.1	2.6	-2.2	-4.7	-4.1	-8.4	-12.1	-10.4	-10.9	-20.4	-26.6
AEO 2004											2.4	4.9	8.5	6.3	3.6	0.3	-1.8	-3.8	-9.2	-12.1	-12.0	-16.7	-20.2	-19.1	-18.1	-25.4	-30.0
AEO 2005												1.7	6.8	4.0	1.2	-1.3	-0.9	-4.2	-8.7	-11.9	-12.9	-17.8	-23.3	-21.8	-19.5	-27.9	-34.5
AEO 2006													0.5	-1.9	-6.6	-8.8	-10.4	-12.8	-17.4	-20.4	-19.1	-23.4	-24.8	-21.1	-20.7	-29.7	-35.9
AEO 2007														0.4	-0.7	-3.7	-5.9	-9.2	-16.1	-19.1	-20.3	-23.6	-27.7	-26.5	-26.5	-34.1	-38.6
AEO 2008															-1.4	-4.9	-6.5	-9.5	-15.9	-19.3	-19.8	-24.6	-28.0	-26.3	-26.9	-36.1	-42.3
AEO 2009																1.6	-0.1	-6.1	-13.5	-18.5	-19.7	-25.3	-29.5	-28.6	-28.8	-37.0	-42.3
AEO 2010																	-0.1	-6.1	-15.0	-19.8	-21.9	-26.5	-28.8	-27.6	-27.7	-35.9	-41.2
AEO 2011																		-0.2	-8.1	-11.5	-10.2	-14.4	-17.2	-15.7	-15.7	-25.1	-31.1
AEO 2012																			0.2	-1.6	-6.0	-10.1	-12.7	-10.0	-9.8	-20.2	-26.4
AEO 2013																				-0.5	-0.8	-7.3	-11.3	-5.7	-5.4	-15.3	-21.8
AEO 2014																					-0.1	-5.6	-9.1	-3.7	-1.8	-11.1	-16.2
AEO 2015																						-0.6	-2.5	2.4	1.2	-9.5	-16.0
AEO 2016																							0.5	2.9	5.0	-5.4	-12.2
AEO 2017																								-0.5	3.7	-4.8	-10.6
AEO 2018																									0.9	-5.3	-7.3
AEO 2019																										-3.7	-4.2
AEO 2020																											0.5
Average Absolute Percent Difference	2.1	4.5	3.0	2.9	3.0	2.6	3.7	2.8	3.1	5.2	6.2	9.6	13.4	11.4	8.9	7.0	6.6	7.5	8.2	8.8	8.9	10.8	13.3	11.5	11.0	18.3	23.0

Sources: Projections: *Annual Energy Outlook*, Reference Case Projections, Various Editions.

Historical Data: U.S. Energy Information Administration open data API (http://www.eia.gov/opendata/) (Washington, DC). Retrieved September 24, 2020. Series: TOTAL.NGPRPUS.A. Shading indicates overestimation (blue) or underestimation (green).

AEO Retrospective: Energy Intensity

Table 23. Energy Intensity, Projected vs. Actual (continued)

Projected vs. Actual

(percent difference)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
AEO 1994	12.8	13.4	12.9	11.8	14.4	17.5	19.4	20.1	23.1	21.9	23.6	24.2	27.0	30.1	28.8	30.0	31.7	29.2									
AEO 1995		11.1	10.5	9.5	11.7	14.7	16.5	17.1	20.0	18.7	20.1	20.4	23.0	26.2	25.3	26.6	28.4	26.1									
AEO 1996			10.1	9.4	11.9	14.6	16.3	16.6	19.2	18.1	20.0	20.7	23.4	26.4	25.4	26.9	28.7	26.4	28.1	33.5	31.2	31.3	35.3				
AEO 1997				6.3	9.7	13.4	15.4	16.0	19.0	18.2	20.0	20.7	23.4	26.5	25.4	26.6	28.4	26.0	27.5	32.7	30.2	30.6	34.6				
AEO 1998					8.4	12.5	15.7	16.7	20.3	19.5	21.3	21.7	24.6	27.9	27.0	28.2	30.0	27.6	29.0	34.1	31.5	31.8	36.0	37.0	38.8	37.0	40.0
AEO 1999						7.4	11.6	13.4	17.1	16.1	17.3	17.3	19.5	22.2	20.8	21.6	23.0	20.1	21.6	26.4	24.2	24.6	28.3	29.3	31.1	29.5	32.1
AEO 2000							8.0	9.9	12.6	12.0	13.7	13.9	16.4	19.5	18.6	19.8	21.3	18.7	20.2	24.9	22.2	22.1	25.5	26.4	27.8	25.8	28.1
AEO 2001								1.7	4.0	3.0	4.4	4.5	6.3	8.4	7.1	7.3	8.0	5.1	5.4	8.5	5.6	5.0	7.6	7.7	8.4	6.4	8.1
AEO 2002									6.5	7.3	9.8	10.3	12.4	14.9	13.3	12.9	13.0	9.5	9.6	13.0	10.2	9.6	12.0	11.8	12.1	9.8	11.4
AEO 2003										4.5	6.3	6.3	8.4	11.1	9.9	10.2	10.8	7.7	8.3	11.8	9.0	8.6	11.3	11.5	12.1	9.9	11.4
AEO 2004											5.3	5.3	7.5	9.8	8.3	8.7	9.4	6.9	7.8	11.5	8.7	8.2	10.7	10.9	11.6	9.4	11.3
AEO 2005												3.5	5.4	7.8	6.4	7.7	8.6	5.8	6.4	9.8	6.7	6.0	8.2	8.1	8.5	6.1	7.4
AEO 2006													4.7	5.8	4.8	4.8	5.5	2.8	3.3	6.9	4.0	3.2	5.3	5.0	4.9	2.4	3.6
AEO 2007														6.1	5.4	5.7	6.3	3.5	3.8	7.3	4.5	4.1	6.3	6.0	6.0	3.5	4.5
AEO 2008															5.6	7.0	6.5	3.2	3.3	6.4	3.3	2.8	5.1	5.0	5.4	3.2	4.4
AEO 2009																5.7	8.7	6.2	6.2	8.9	5.2	3.9	5.5	5.0	4.9	2.0	2.7
AEO 2010																	6.1	4.9	5.6	8.5	5.2	4.6	6.3	5.7	5.5	2.6	3.3
AEO 2011																		2.9	3.4	5.6	2.1	1.4	3.6	3.1	3.1	0.6	1.7
AEO 2012																			5.0	8.2	3.4	1.6	2.5	1.5	1.3	-0.9	0.1
AEO 2013																				5.4	3.1	1.8	3.6	2.9	2.8	0.5	1.5
AEO 2014																					3.0	1.6	3.5	2.9	3.1	0.7	1.7
AEO 2015																						0.1	0.4	0.5	0.5	-1.9	-0.7
AEO 2016																							0.7	1.2	1.5	-1.7	-0.5
AEO 2017																								0.0	0.3	-1.1	0.9
AEO 2018																									0.5	-0.7	0.8
AEO 2019																										0.0	0.2
AEO 2020																											-0.2
Average Absolute Percent Difference	12.8	12.2	11.1	9.3	11.2	13.4	14.7	13.9	15.7	13.9	14.7	14.1	15.5	17.3	15.5	15.6	16.1	12.9	11.5	14.6	11.2	10.1	12.0	9.1	9.1	7.1	7.7

Sources: Projections: *Annual Energy Outlook*, Reference Case Projections, Various Editions.

Historical Data: Bureau of Economic Analysis, US Dept. of Commerce, June 2016. Shading indicates overestimation (blue) or underestimation (green).

* Actual energy intensity is based on BEA data using 2012 chained dollars.

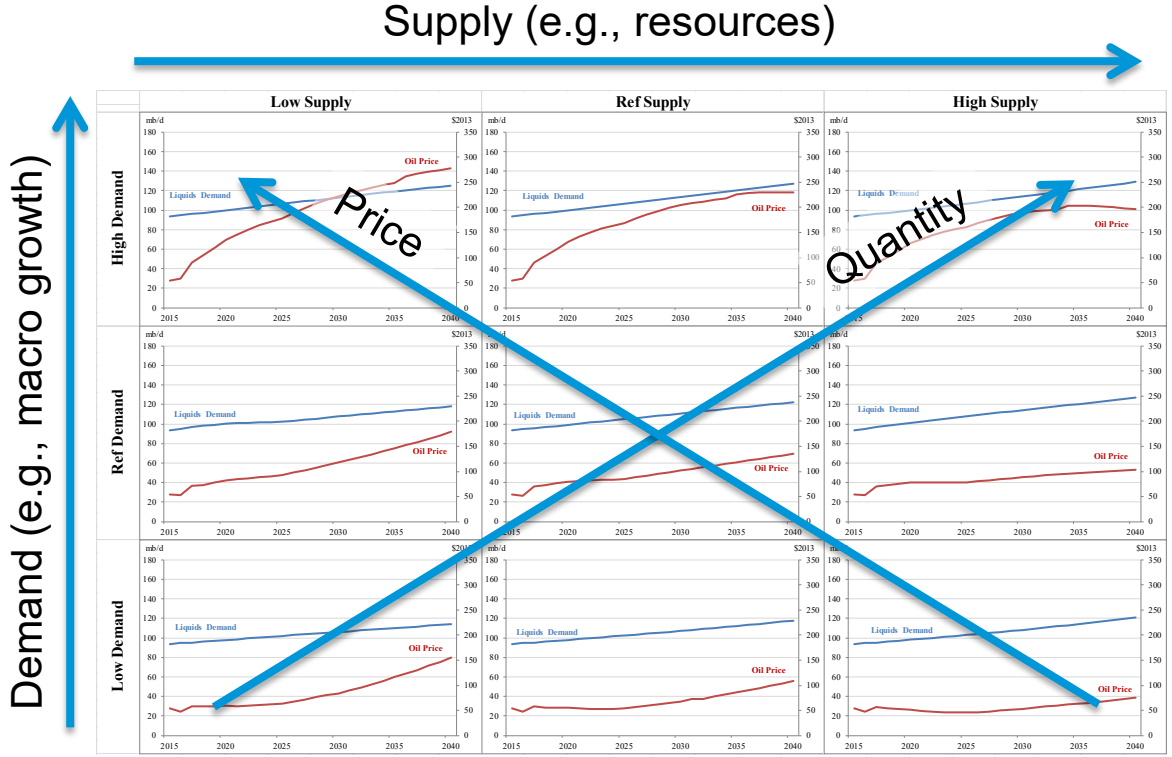
Why should I care about the AEO?

"All models are wrong but some are useful"

– George Box

- Forces internal consistency across energy-economy system
- Represents base case against which inaction can be judged
- Allows for perturbation analysis
  - Sensitivity cases map out dependencies on input assumptions
  - Scenarios describe relative changes that could occur in plausible (internally consistent) alternate futures

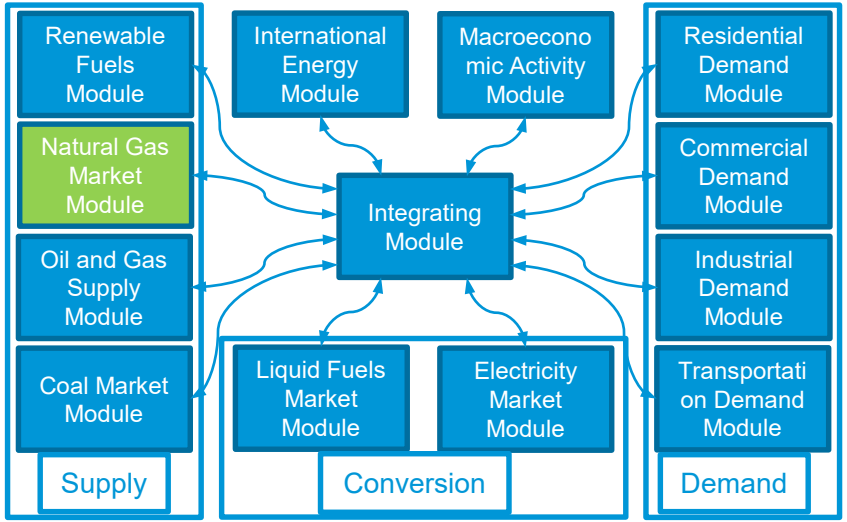
AEO side cases map out the uncertainty space



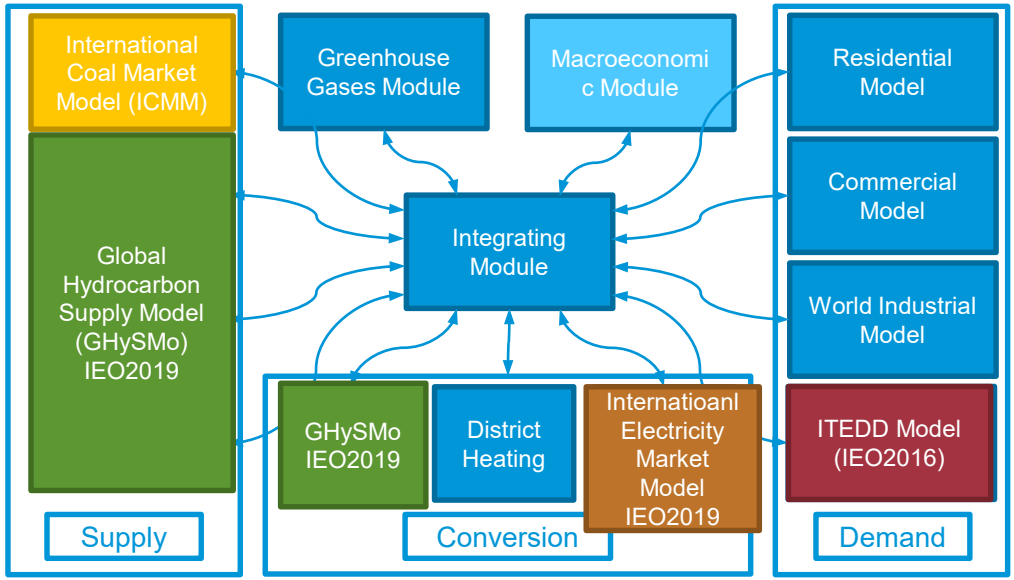
Source: EIA, notional data

Models for AEO and IEO have similar, modular structures, which have been updated to account for market developments

National Energy Modeling System (NEMS)
U.S. model
used in Annual Energy Outlook



World Energy Projection System (WEPS)
16-region global model
used in International Energy Outlook



EIA has recently kicked off a multi-year project to build the next generation of its modeling systems

Phase 1 As-Is Assessment (FY2021)

Goal: Evaluate all of EIA's modeling systems, documenting the current state in order to identify vulnerabilities.

This includes an assessment of software, model and system architecture, and the systems' ability to respond to anticipated market and policy evolutions (i.e. deep decarbonization scenarios).

The As-Is Assessment will help EIA prioritize addressing the vulnerabilities that are identified.

For more information

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

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

International Energy Outlook | www.eia.gov/ieo

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

Today in Energy | www.eia.gov/todayinenergy

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