

# Update to industrial drivers in the AEO2015 as a result of new input-output data

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May 4, 2015

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## Introduction

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The *Annual Energy Outlook 2015 (AEO2015)* industrial economic projections include a major historical/baseline update from the 2002 BEA Input-Output (IO) tables to the 2007 BEA IO tables[1] and, using a new statistical methodology[2], are able to use aggregate industry information up to 2013; effectively, these changes added more than a full decade of new information. Other changes contributed to new results in *AEO2015* industrial shipments including, but not limited to, updating energy prices and resources, Gross Domestic Product (GDP) and trade trends and structure[3], and the industrial capacity stock.

This paper will discuss major methodological changes for macroeconomic modeling of the industrial sector from the *AEO2014* to the *AEO2015*, highlighting how industrial sector output (agriculture, mining, construction, and manufacturing) and explanatory GDP components, also called final demand categories[4,5], affect the projection of industrial output. It will focus on how BEA's IO table updates, combined with greater use of available data, have changed the relationship between final demand and supply chain requirements and industry output across various aggregates of the industrial sector.

Keywords: industrial, input-output, modeling, shipments, final demand, supply chain

JEL Codes: L6, L7, C67, L16, Q00

## Background

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The National Energy Modeling System (NEMS) is a long-term forecasting and analysis tool that projects energy supply, demand, prices, and environmental emissions, by region[6], given assumptions about the state of the economy, international markets, and energy policies. The Macroeconomic Activity Module (MAM) provides the energy supply, demand, and conversion modules of the NEMS with economic driver variables. The MAM comprises four sets of models: IHS's model of the U.S. economy, IHS's industry model of output and employment, and U.S. Energy Information Administration's (EIA) commercial building floorspace and regional models. Except for the commercial floorspace and regional models, EIA uses derivations of IHS's models tailored to provide the detail required by the NEMS modeling system.

EIA's Industrial Output Model matches shipments by industry for the manufacturing sectors and revenue for the non-manufacturing sectors, defined using the North American Industry Classification System (NAICS) 2007[7]. The final demand categories (consumption, investment, government spending, exports, and imports) are calculated in the U.S. Macroeconomic Model and a detailed input-output (I/O) procedure and an econometric block is utilized to model output and employment. The input-output operation proceeds in two steps. First, the components of GDP, also called final demand categories, from the U.S. Macroeconomic Model are translated into industrial deliveries using a 'bridge matrix', constructed from the 2007 input-output table[8]. For the *AEO2015*, the standard model known as the RAS algorithm[9,10] was implemented to perform an I/O extension from the 2007 baseline to 2013

using the BEA Intermediate Demand Tables[8]. The bridge matrix is then static from 2014 until the end of the forecast period.

Once final demands are estimated, the industrial output required to produce the bill of goods for final use is calculated using the inter-industry matrix, representing the domestic supply chain. Following standard I/O conventions, it is assumed that the technology of production as reflected by the matrix of direct input coefficients remains relatively stable over time. This inter-industry matrix also uses 2007 baseline values extended to 2013 using RAS[8,9,10] for the *AEO2015*. The RAS method accounts for the effects of absorption, commodity substitutions, and production process changes with aggregate data sets available more frequently. For projecting forward, production processes are assumed to be linear and exhibit constant returns to scale with no possibility for substitution among inputs. However, these restrictions apply for the I/O calculation only and do not apply to the subsequent econometrics, which supply final shipments by industry. Ultimately, 132 industries satisfy 59 macroeconomic final demands.

## Comparing historical aggregate results before and after *AEO2015* updates

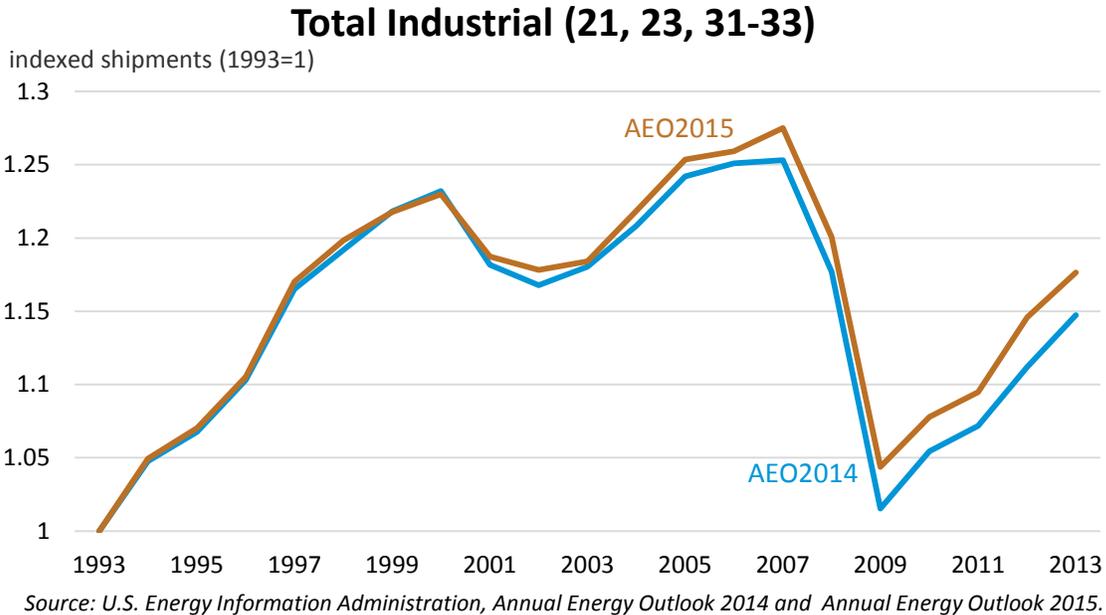
**Table 1. Summary of changed impacts by major driver categories by industry group; notably increased influence (+), no significant change (blank), or notably decreased influence (-).**

Industry group	Domestic consumption	Trade	Investment	Government	Supply chain
Chemicals	+	+			+
Primary metals	-		-	-	+
Non-metallic minerals	+			-	+
Paper	+		-	-	
Food	-	+		-	+
Metal-Based Durables (MBDs)			+		+
Non-manufacturing*, non-services	+			+	+

\*excluding energy product extraction since these are modeled separately

## Industrial sector

Figure 1. Indexed<sup>a</sup> industrial sector shipments for the historical period for two AEOs, including NAICS codes in parenthesis

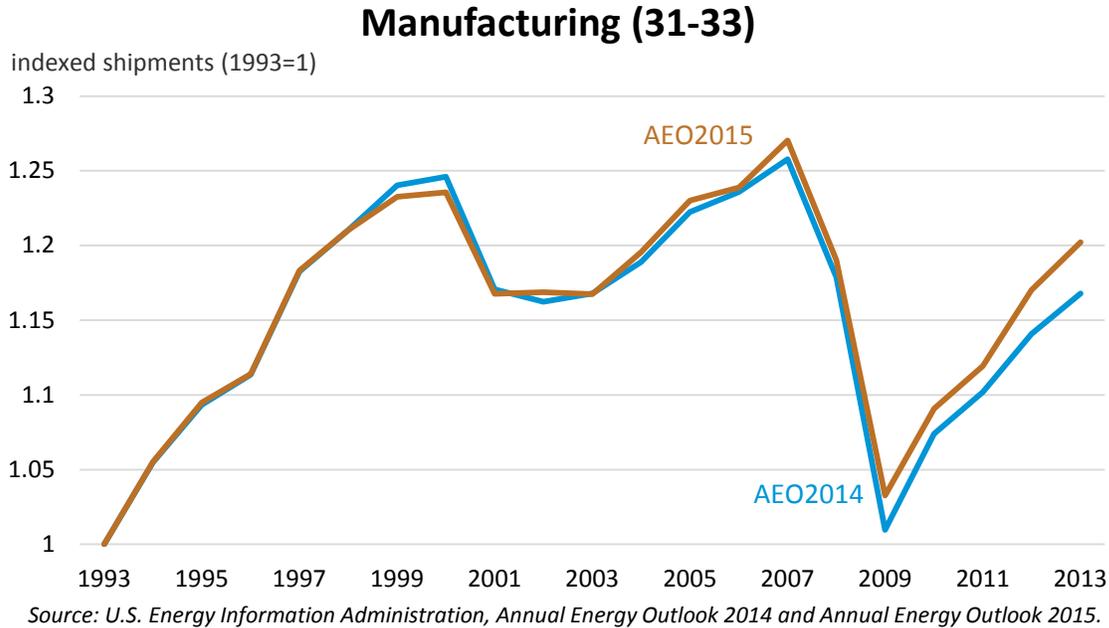


The industrial sector, which includes agriculture, construction, mining, and manufacturing, accounted for approximately 22% of U.S. primary energy use in 2013 [11]. The new data included in the *AEO2015* update the drivers and links within the sector, showing the greatest impacts from trade. *AEO2014* reflected 2002 trade relationships among individual industries, so when net exports changed, impacts on industrial shipments were lower.

<sup>a</sup> Shipments are measured in billion dollars, but the dollar year changed from 2005\$ in the AEO2014 to 2009\$ in the AEO2015. To allow direct comparison of the two AEOs these data are indexed to a start year of 1993 for this paper.

## Manufacturing sector

Figure 2. Indexed manufacturing sector shipments for the historical period for two AEOs, including NAICS codes in parenthesis



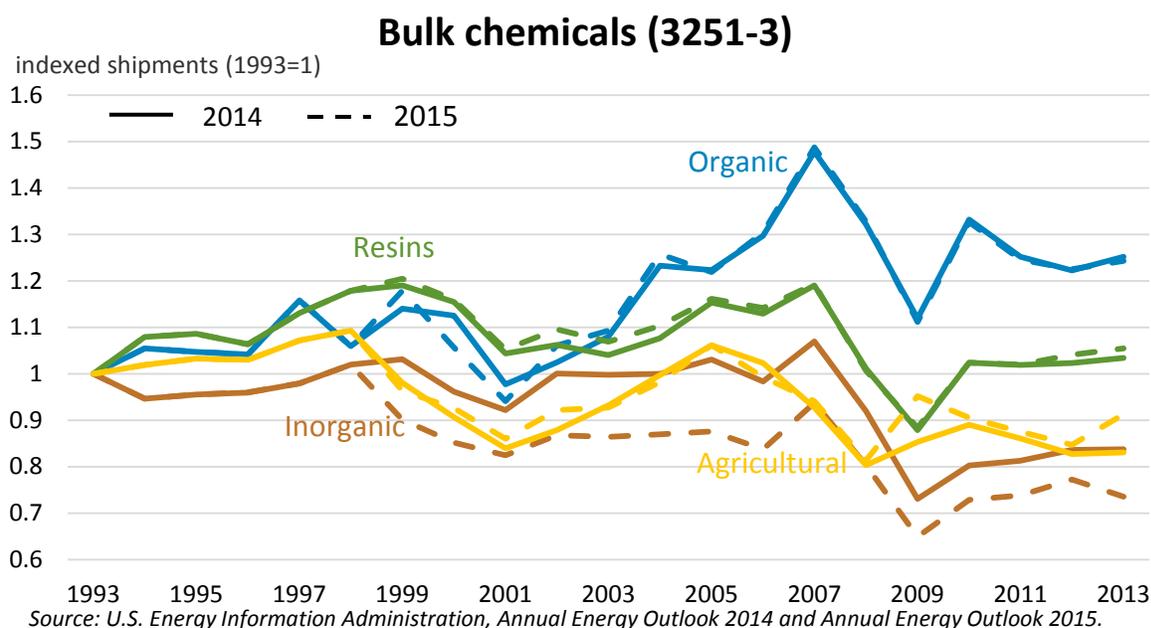
Manufacturing industries are those that use processes and assembly production to make goods, both final for the consumer and intermediate for combination with other components within manufacturing. Of the manufacturing industries, the largest users of energy, called energy-intensive industries, are also responsible for many of the goods traded by the United States. These “heavy”, exporting (and importing) industries are often grouped together as “energy-intensive, trade-exposed”, or EITE, and typically include: food, paper, chemicals, petroleum and coal products (primarily refining), primary metals, and non-metallic minerals (also called “stone, clay and glass” or “SCG”). This group of industries is responsible for a large portion of the change in industrial projections from year to year because of the importance of trade influences and links to investment behavior.

The following sections provide analysis of changes in historical information for the most influential industries within the U.S. industrial sector and drivers used to estimate future industrial production in detail for the AEO.

## Chemical industry results

### Bulk chemicals

Figure 3. Indexed bulk chemical industries shipments for the historical period for two AEOs, including NAICS codes in parenthesis



Industries included in this subsector in order of output (with *AEO2015* shipments for 2013 in billion 2009\$) are: organic chemicals (\$137), resins and synthetic fibers (\$81), inorganic chemicals (\$36), and agricultural chemicals (\$34). For the *AEO2015*, trade and domestic goods consumption final demand influences increases for bulk chemicals, with the impact of some detailed trade categories, such as industrial supplies[12], increasing and others, such as inventories, decreasing. There is also greater effects in the inter-industry matrix, with the weight of some inputs decreasing, and others increasing, notably the increased impact of services and fossil fuels industries' needs.

#### *Organic*

For organic chemicals, trade and domestic consumer influences are approximately 25% higher in the *AEO2015* demand matrix than in the matrix used in *AEO2014*, and inventories no longer show influence. Industrial supplies are still the most important demand driver for this industry, and the inter-industry matrix shows much greater linkage across the domestic supply chain, especially requirements from other EITE industries.

#### *Inorganic*

In the inorganic chemicals industry, trade influences are nearly four times higher in the *AEO2015* demand matrix than in the matrix used in *AEO2014*, and inventories also no longer show influence. Again, an overwhelming shift toward inter-industry requirements from EITE industries is notable. This industry also had historical revisions clearly visible in the difference in the tan lines in Figure 3.

**Resins**

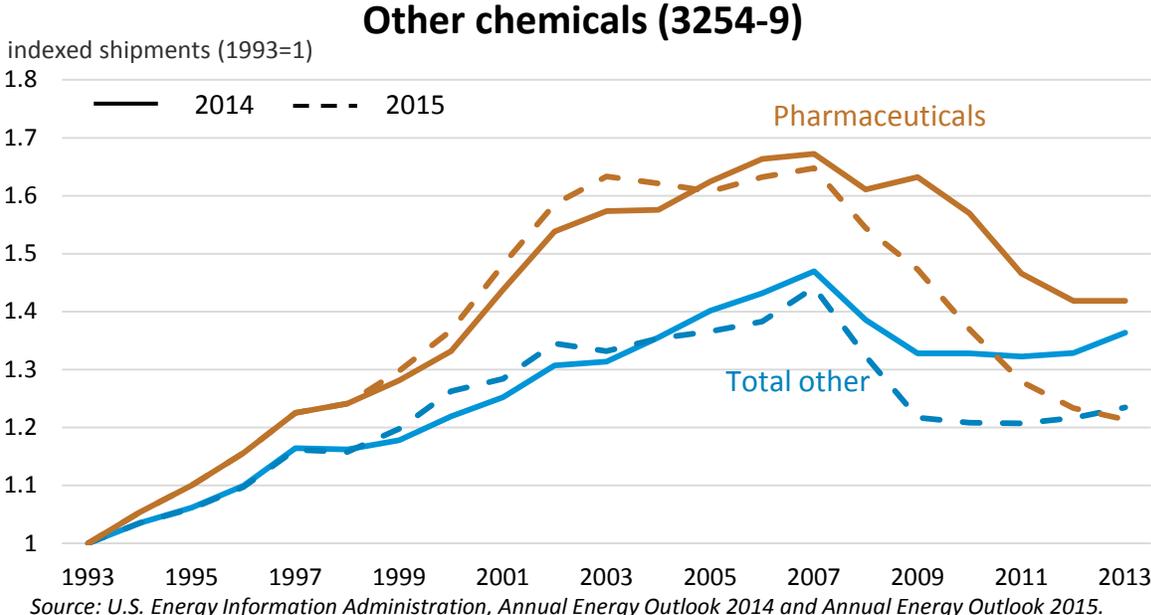
For the resins industry, trade and domestic consumer influences increased in the AEO2015 demand matrix from the matrix used in AEO2014, and the influence of specific trade categories is updated. The importance of certain industries changed for the AEO2015 inter-industry matrix and intensity of the impact for most supply-chain relationships increased. This industry also had smaller historical revisions visible in the smaller difference in the green lines in Figure 3.

**Agricultural chemicals**

The AEO2015 final demand drivers in agricultural chemicals show a shift in the primary import category and a slightly reduced impact of exports compared to AEO2014. For the inter-industry matrix there is a greater influence from agriculture industry needs.

**Other chemicals**

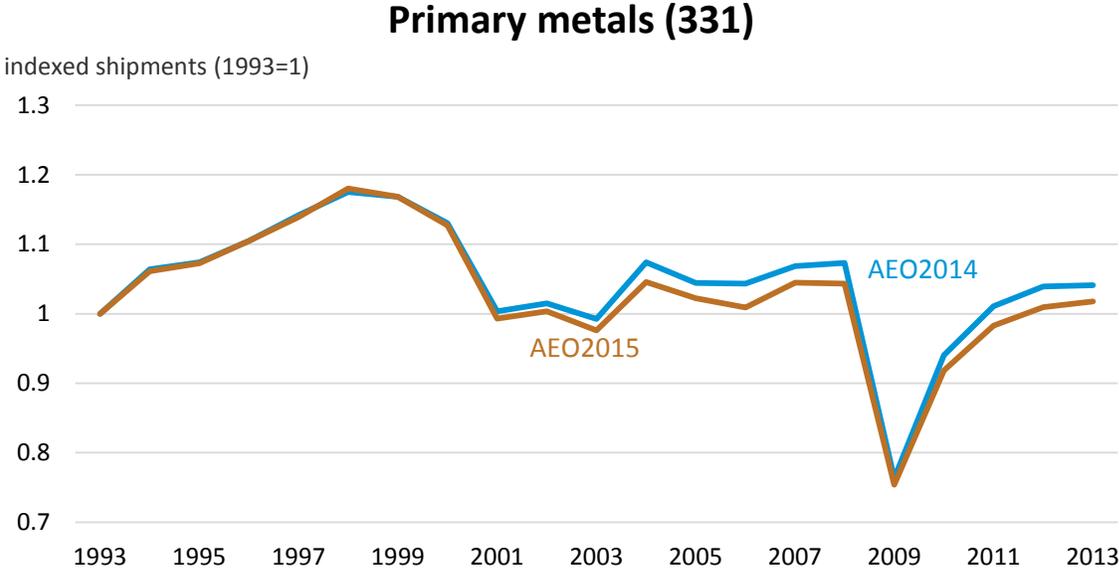
**Figure 4. Indexed other chemical industries shipments for the historical period for two AEOs, including NAICS codes in parenthesis**



For other chemical final demand drivers, domestic consumption of pharmaceuticals and medicine has its own category; otherwise this subsector’s largest influences are from trade in non-automotive consumer goods, trade of industrial supplies, and domestic consumption of nondurable goods. In the inter-industry matrix, medical and household application industries’ needs are the biggest drivers. For the pharmaceutical industry there is some reordering of influences from AEO2014 to AEO2015 in both matrices.

# Primary metals industry results

Figure 5. Indexed primary metals industries shipments for the historical period for two AEOs, including NAICS codes in parenthesis



Source: U.S. Energy Information Administration, Annual Energy Outlook 2014 and Annual Energy Outlook 2015.

Industries included in this subsector in order of output (with AEO2015 shipments for 2013 in billion 2009\$) are: iron and steel (\$105), nonenergy-intensive primary metals (\$78), and aluminum (\$34). The biggest final demand driver for this subsector is the trade of industrial supplies, which did not change in AEO2015. The overall demand matrix influence of domestic consumption decreased slightly for AEO2015, while the impact of investment was down significantly from AEO2014. The AEO2015 inter-industry matrix shows new inputs to the subsector and intensification of intrasector inputs compared to AEO2014.

### Iron and steel

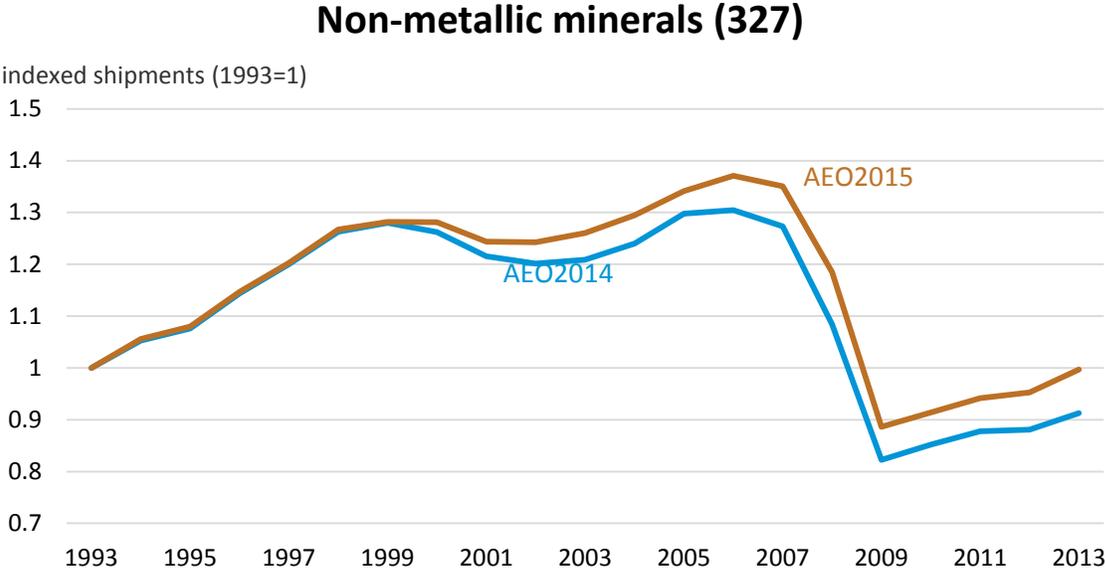
For AEO2015, the trade of industrial supplies remains vital to the iron and steel industry demand matrix and MBD industries' requirements remain extremely important to the supply chain.

### Aluminum

Trade of industrial supplies also continues to be key to the aluminum industry demand matrix for AEO2015. Although MBDs remain important to the supply chain, beverage production is actually the most important driver of output domestically for the AEO2015 whereas in the AEO2014 beverage production had less influence than some MBDs.

# Non-metallic minerals industry results

Figure 6. Indexed non-metallic minerals industries shipments for the historical period for two AEOs, including NAICS codes in parenthesis



Source: U.S. Energy Information Administration, Annual Energy Outlook 2014 and Annual Energy Outlook 2015.

Industries included in this subsector in order of output (with AEO2015 shipments for 2013 in billion 2009\$) are: other SCG (\$77), glass (\$21), and cement (\$7). One major change for AEO2015 was the explicit account for glass and cement in both matrices, rather than just a single non-metallic minerals category, which makes it difficult to quantify differences directly. The most important final demand drivers for this subsector are trade of industrial supplies and durable household goods[12], with domestic consumption influences also strong, which is similar to the AEO2014. Construction is a more influential driver in the supply chain than for the AEO2014.

### Glass

In the AEO2015 final demand representation of the glass and glass products, industry trade of industrial supplies is significant, with beverage production and MBDs industries’ needs most important to the supply chain.

### Cement

The AEO2015 cement industry final demand representation has a large influence from trade of industrial supplies, but the domestic concrete industry (part of “other SCG”) is the primary supply chain, which is included in the inter-industry matrix.

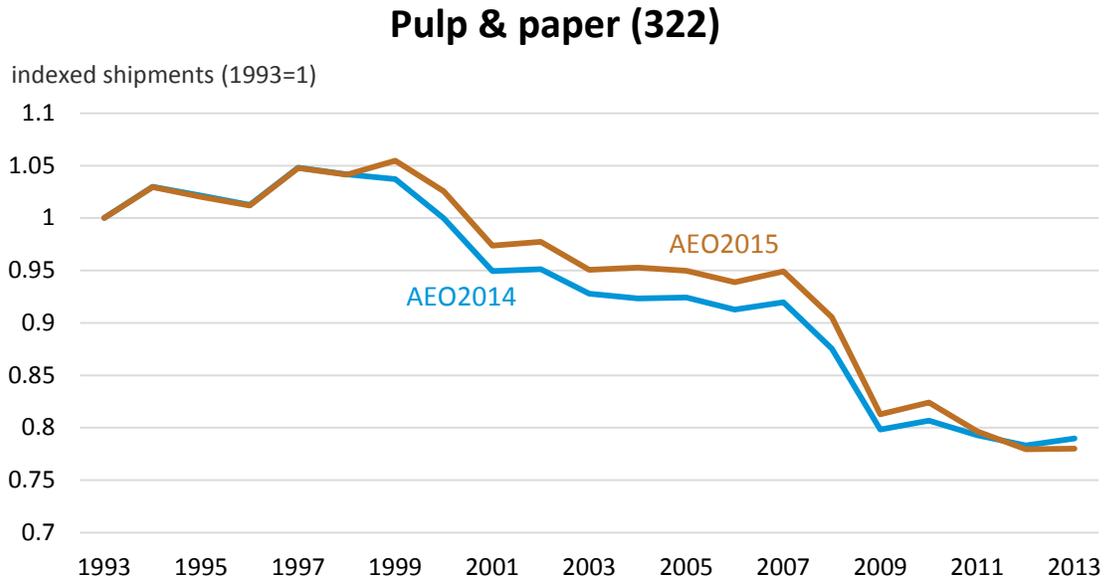
### Other

The primary final demand drivers for this group of industries in AEO2015 are trade of industrial supplies and domestic consumption on household durables. Construction industry requirements plus re-input to

glass and cement make up the bulk of the supply chain, but other industry requirements include chemicals, for example mineral pigments, or MBDs, for example ceramic components.

## Paper industry results

**Figure 7. Indexed paper industry shipments for the historical period for two AEOs, including NAICS codes in parenthesis**

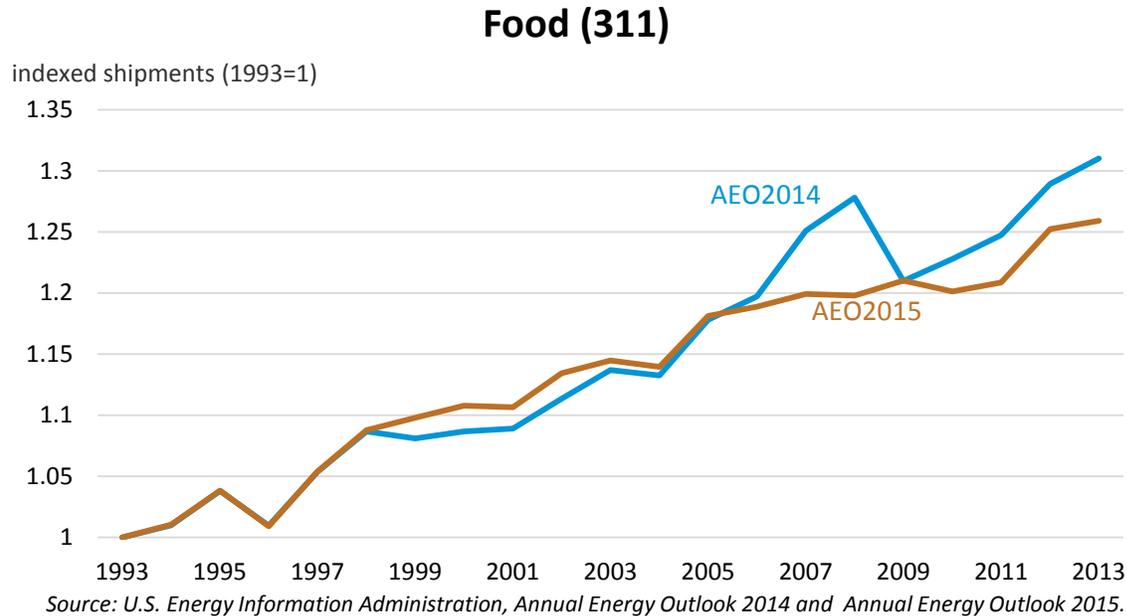


Source: U.S. Energy Information Administration, *Annual Energy Outlook 2014* and *Annual Energy Outlook 2015*.

Paper industry *AEO2015* shipments for 2013 in billion 2009\$ are \$152. Domestic consumption influences increased slightly overall for the *AEO2015*, but trade is still the largest final demand driver for this industry, with new detailed trade categories having impacts, such as non-automotive consumer goods. Shifts occurred in the *AEO2015* inter-industry matrix away from domestic mills toward paperboard (more commonly known as cardboard) and services industries' requirements.

## Food industry results

**Figure 8. Indexed food manufacturing industry shipments for the historical period for two AEOs, including NAICS codes in parenthesis**



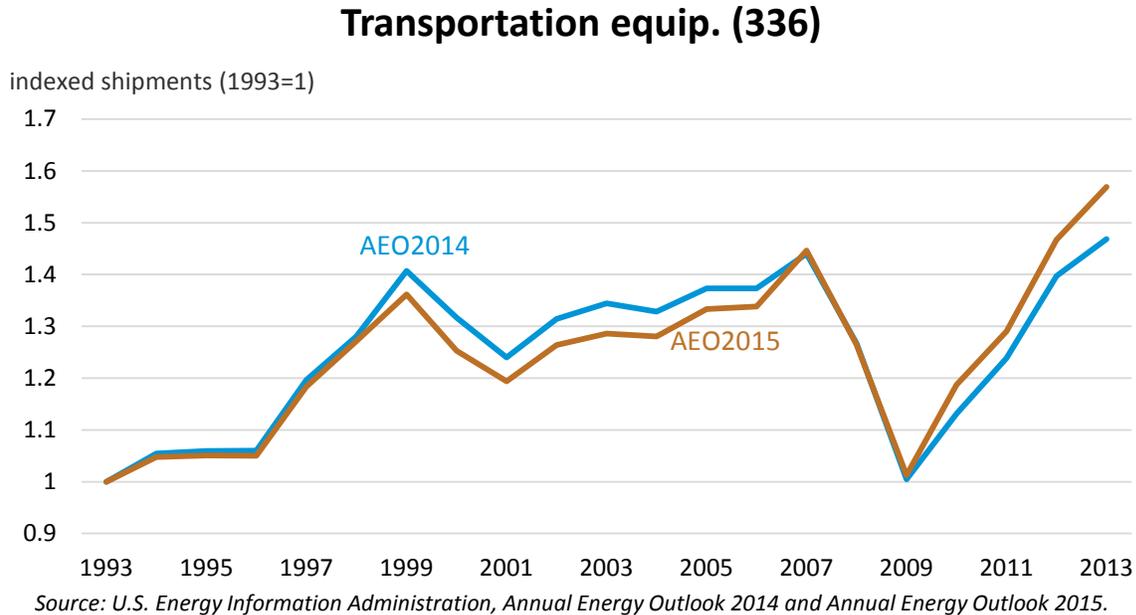
Food industry *AEO2015* shipments for 2013 in billion 2009\$ are \$638. Domestic consumption and investment final demand influences are slightly lower and trade influences are higher for the *AEO2015*, specifically in direct trade of food, feed, and beverage[12]. There is a lower impact of fossil fuel inputs in the supply chain with increased impact for agricultural inputs compared to *AEO2014*.

## Metal-Based Durables (MBDs) industries results

Industries included in this subsector in order of output (with *AEO2015* shipments for 2013 in billion 2009\$) are: transportation equipment (\$850), computers and electronic equipment (\$440), machinery (\$358), fabricated metal products (\$335), and electrical equipment and appliances (\$111). The biggest final demand drivers for this diverse subsector are trade and investment in equipment and durables goods, such as vehicles, aircraft, and computers, domestic consumption of these goods, and the trade of non-automotive consumer goods. Much of the supply chain mix for these industries is linked to each other, such as fabricated metal items used to make vehicles. Detailed information below outlines how this subsector's industries' relationships changed from *AEO2014*.

## Transportation equipment

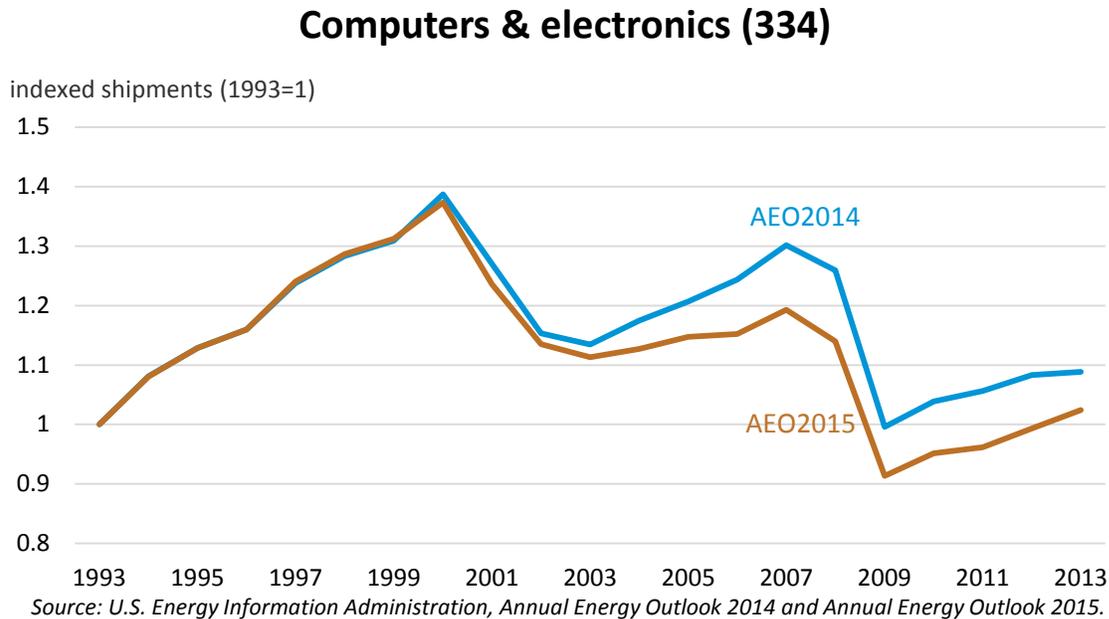
Figure 9. Indexed transportation equipment industry shipments for the historical period for two AEOs, including NAICS codes in parenthesis



Transportation equipment industry final demand influences for the *AEO2015* are completely different from *AEO2014*, with investment in non-residential transportation equipment and trade of motor vehicles and parts and aircraft having the greatest influence in the demand matrix. Inputs in the supply chain have changed as well, with material inputs reordered relative to *AEO2014* reflecting technological changes (for example, light-weighting using plastics instead of metals [13]).

## Computers and electronics

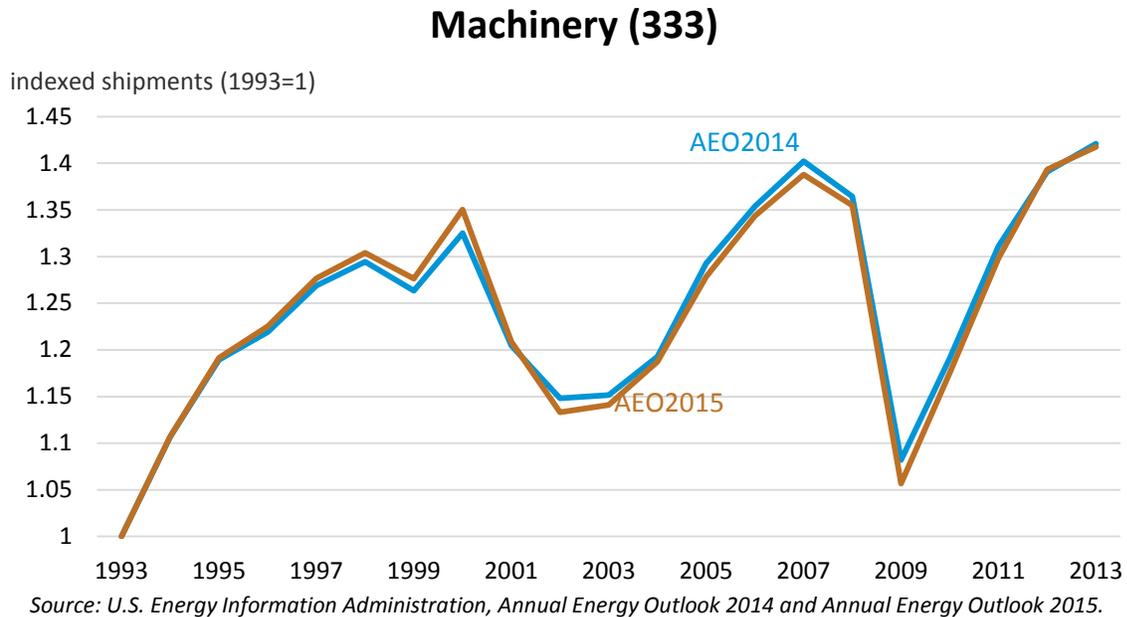
Figure 10. Indexed computer and electronics industry shipments for the historical period for two AEOs, including NAICS codes in parenthesis



Trade categories did not have an influence in *AEO2014*, but there is a strong trade influence in the demand matrix relative to domestic consumption for the computers and electronics industry. This industry also saw reordering in the inter-industry matrix reflecting technological change. Additionally, this industry had historical data revisions.

## Machinery

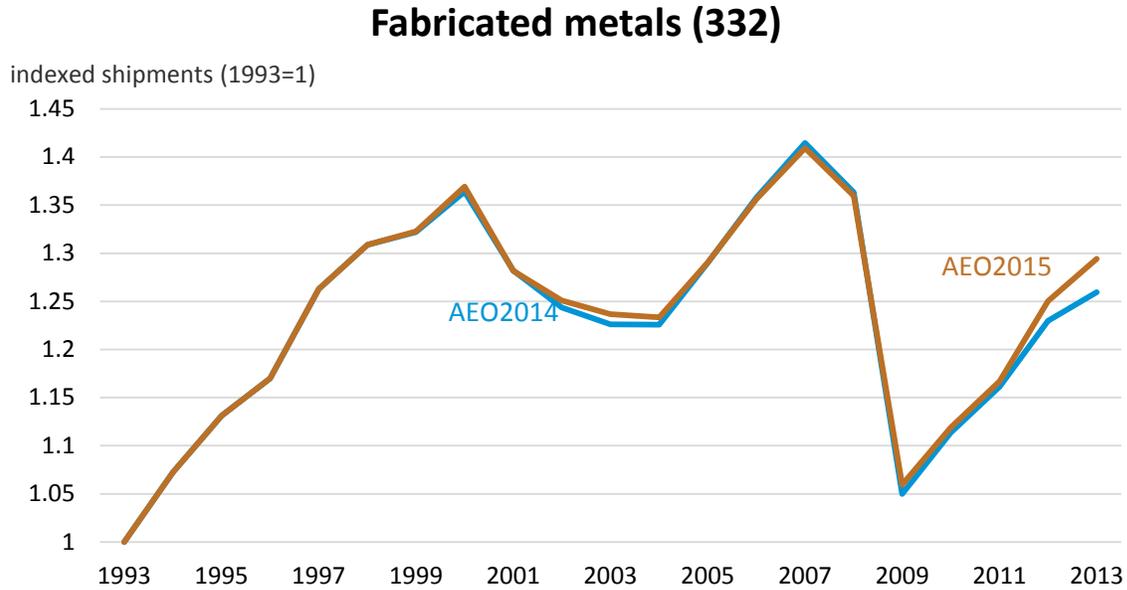
Figure 11. Indexed machinery industry shipments for the historical period for two AEOs, including NAICS codes in parenthesis



The largest final demand drivers for this industry are trade of capital goods[12], investment (particularly in equipment), with a much smaller contribution from domestic consumption of equipment. The supply chain for this industry is driven by other industries with high machinery requirements, such as agriculture or MBDs. These relationships represent a significant reshuffling across the matrices for the various subindustries within machinery, most likely as a result of technological/product-application changes.

## Fabricated metals

Figure 12. Indexed fabricated metals industry shipments for the historical period for two AEOs, including NAICS codes in parenthesis

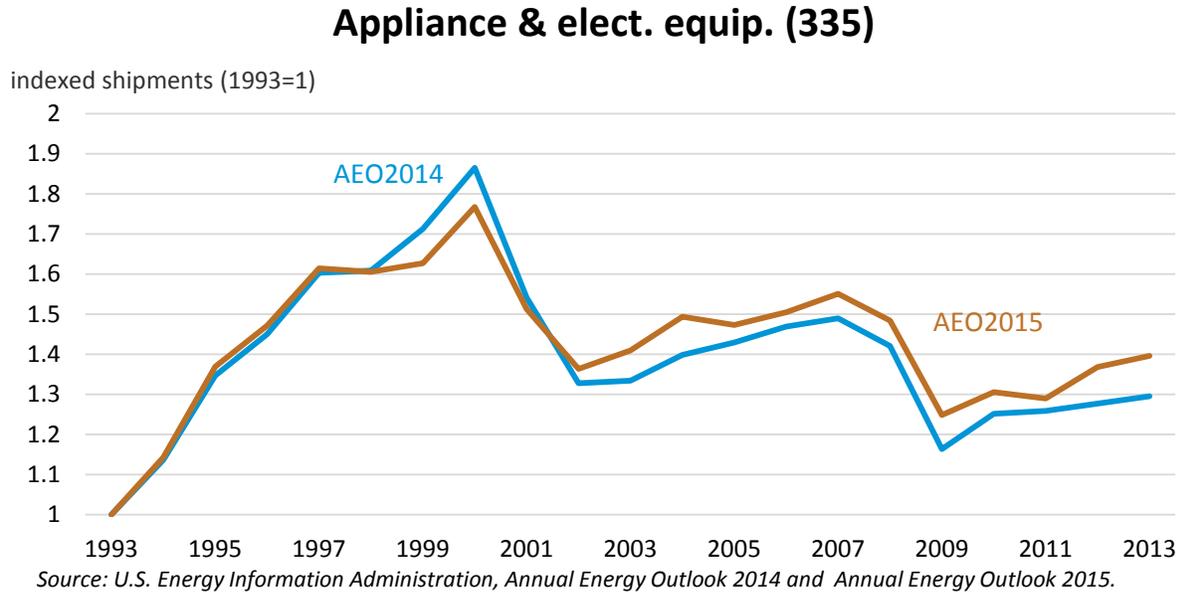


Source: U.S. Energy Information Administration, Annual Energy Outlook 2014 and Annual Energy Outlook 2015.

Final demand drivers include trade of capital goods and the miscellaneous domestic goods consumption category, which picks up the general trend in the domestic consumption category. These effects are stronger and for more generally applicable final demand categories than the previous matrix. The supply chain is driven most heavily by other MBDs, including stronger effects than *AEO2014*, with construction being the next largest consumer, which had not previously been well represented in the inter-industry matrix.

## Electrical equipment and appliances

Figure 13. Indexed electrical equipment and appliances industry shipments for the historical period for two AEOs, including NAICS codes in parenthesis



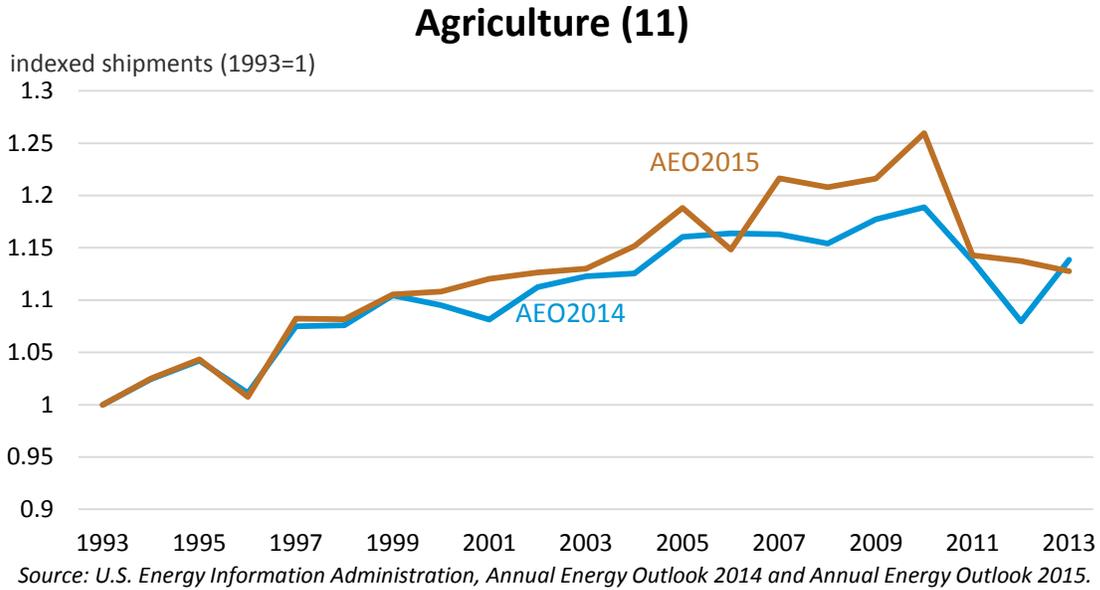
The biggest final demand drivers are trade of capital equipment, domestic consumption of household durables, investment in industrial equipment, and trade in non-auto consumer goods, which specifically includes consumer appliances. The supply chain is primarily inputs to construction (new buildings or renovations specifically drive appliance needs) and MBDs. Influences in both matrices are lower for the *AEO2015* than *AEO2014*, although composition is similar.

## Non-manufacturing industries results

Industries included in this subsector in order of output (with *AEO2015* shipments for 2013 in billion 2009\$) are: construction (\$1120), mining (\$435), and agriculture (\$304). The non-manufacturing sector includes agriculture, mining and construction. These industries differ from manufacturing primarily because of the heavy reliance on mobile equipment and/or the production of goods that are used as raw materials for other industries, for example metal ore or wheat. Given the diversity of industries, this sector is best analyzed as its individual underlying industries.

## Agriculture

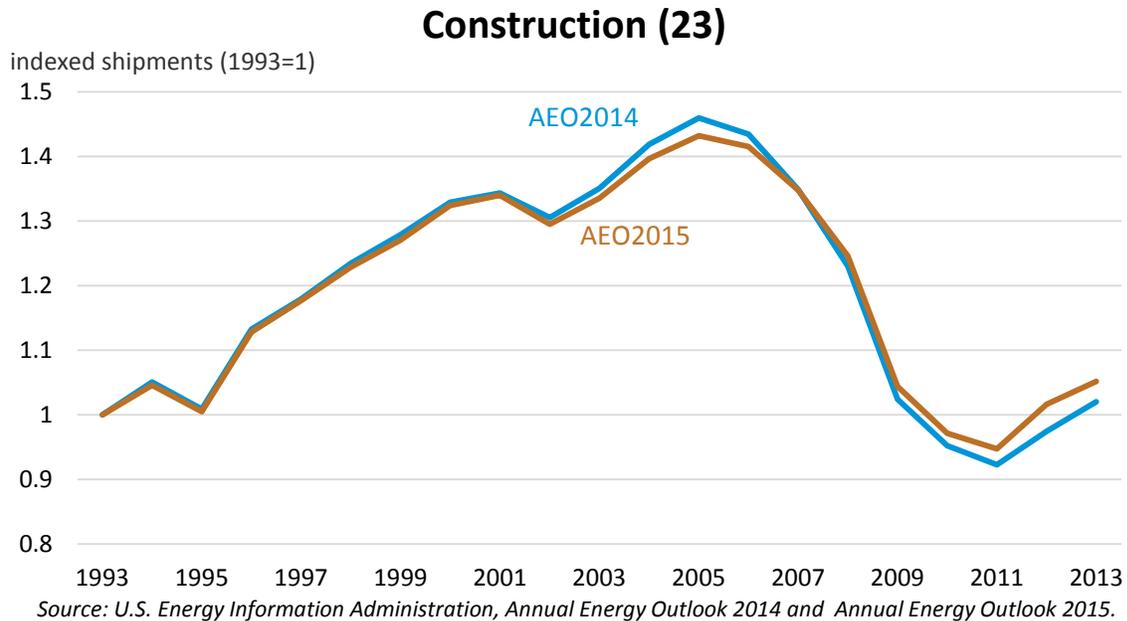
Figure 14. Indexed agriculture industry shipments for the historical period for two AEOs, including NAICS codes in parenthesis



For the AEO2015 final demand matrix trade influences increased slightly, but the primary driver remains the trade of food, feed, and beverage and the domestic food supply chain, represented in the inter-industry matrix. Data for this industry include historical revisions.

## Construction

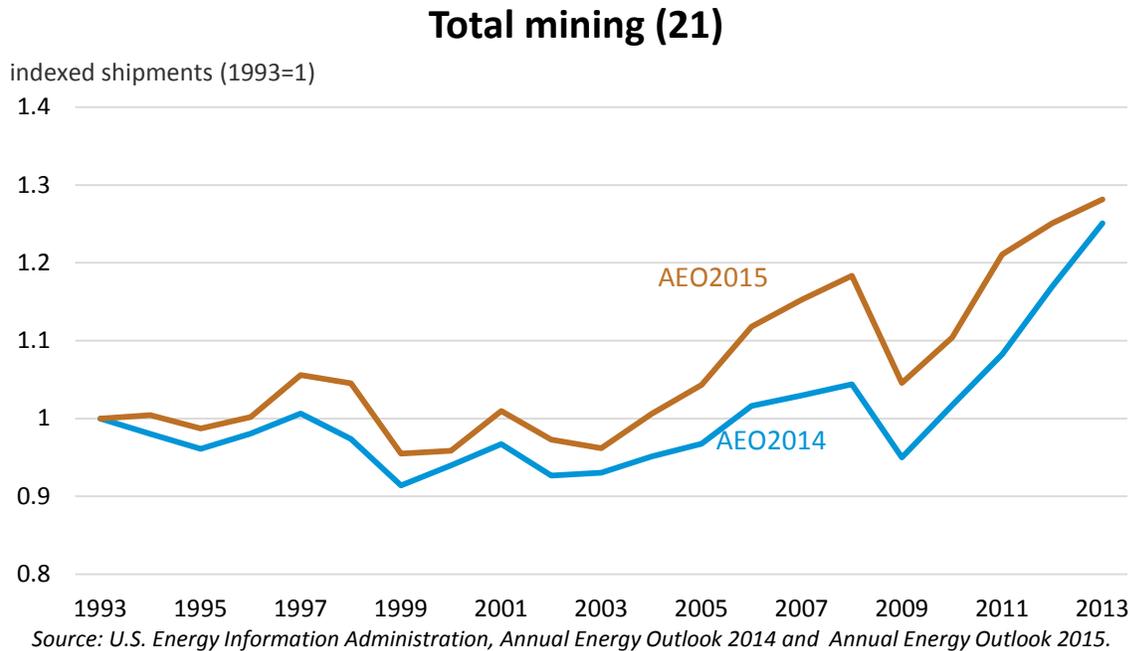
Figure 15. Indexed construction industry shipments for the historical period for two AEOs, including NAICS codes in parenthesis



For the *AEO2015* final demand influences are completely different from the *AEO2014*, with government spending having the greatest increased impact. The residential subindustry has changed because of previous bubble and recession events, the non-residential subindustry was also affected by the recession, and the public/heavy subindustry is now seeing strong influences from resource development. Inputs in the supply chain have changed as well, with material inputs shuffled reflecting technological changes (for example, plastic versus metal plumbing).

## Mining

Figure 16. Indexed mining industry shipments for the historical period for two AEOs, including NAICS codes in parenthesis



Mining shipments results are heavily dominated by NEMS internal energy supply results, but non-metallic mineral and metal ore mining is calculated using the MAM industry model. The primary final demand driver is trade of industrial supplies, and the supply chain is connected to primary metals, chemicals, SCG, and construction requirements in the inter-industry matrix. These relationships are similar to *AEO2014*, but they include greater impacts for each link in *AEO2015*.

## Conclusion

The *AEO2015* update from the 2002 to the 2007 BEA IO tables[1] and further data utilization[2], allowing updates up to 2013, effectively added more than a decade of new information to industrial economic projections. Along with energy, GDP, trade, and capacity stock updates, new results in *AEO2015* industrial shipments show enhanced links throughout the economy. The most notable changes from *AEO2014* to *AEO2015* are greater final demand effects from trade, and to a smaller degree domestic consumption, across various categories, and a more tightly linked supply chain. The historical series detailed here reveal specific areas of change and give insight into how industrial output projections in years after 2014 are estimated in the *AEO2015*.

## Acknowledgements

The author wishes to thank Mohsen Bonakdarpour at IHS, as well as Kay Smith, Paul Otis, Peter Gross, Lynn Westfall and Colleen Blessing at EIA for their review, comments, and feedback.

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