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Applying EIA's National Energy Modeling System to US Coal Projections: Strengths and Weaknesses for BLM's Programmatic Environmental Impact Statement

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Key Points

- The need to address greenhouse gas (GHG) emissions, particularly from coal, has heightened a conversation among policymakers and various organizations regarding the modeling used to project future energy demand and emissions for the Bureau of Land Management's (BLM's) coal programmatic environmental impact statement.
- The Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) is the foremost governmental energy and emissions modeling system. NEMS outputs will likely serve as a large component of BLM's analysis of future coal supply scenarios.
- While NEMS is a nuanced and important model for energy and climate research, policymakers should weigh a variety of scenarios beyond the Annual Energy Outlook (AEO) reference case when the NEMS design is inadequate, such as: carbon pricing scenarios, extension of the Clean Power Plan, and the low technology cost scenario, as well as pertinent additional models such as ICF International's Integrated Planning Model (IPM).

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- A series of reasonably likely scenarios will apply additional pressure on future coal generation beyond the Clean Power Plan. Most significantly, if the United States is to achieve its climate commitments, increased policy pressure will likely fall on the electricity sector, thereby reducing coal generation beyond the 2016 NEMS output.
- Scenarios also should be modeled where coal production could increase, such as if a technology breakthrough makes widespread carbon capture and sequestration (CCS) economically feasible.
- To address scenarios that are not modeled by the 2016 AEO, the Department of the Interior (DOI) and BLM should develop a series of additional model runs that more fully capture foreseeable climate-related policy.

Summary

This policy brief explores the strengths and weakness of the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS), paying special attention to its application in long-term policymaking. The goal of the paper is to provide insight into how NEMS can contribute to the Bureau of Land Management's (BLM's) programmatic environmental impact statement (PEIS) for federal coal leasing. Broadly, the research suggests two conclusions: that while NEMS is a nuanced and important model for energy and climate research, policymakers should weigh a variety of new and existing scenarios beyond the reference case, as well as other model input, when preparing the Environmental Impact Statement. The paper also suggests a series of potential scenarios that could likely put further downward pressure on coal-powered electricity generation, which should be considered by policymakers in developing the Reasonable Foreseeable Development Scenario, alternative actions, and proposed action.

1. Introduction to the Issue and Context of Study

In January 2016 Secretary of the Interior Sally Jewell issued a secretarial order announcing a moratorium on new federal coal leases in order to comprehensively review the Bureau of Land Management's (BLM's) leasing program (DOI 2016a). Noting that the federal coal program had not been overhauled in over 30 years, Secretary Jewell highlighted the need to provide taxpayer fairness and account for climate impacts of fuel production and use (DOI 2016b).

The Department of the Interior's (DOI's) decision to suspend new coal leasing for an estimated three years follows a series of critical reports, most notably a Government Accountability Office report that raised concerns about royalty payments, bonding, and single bidder auctions (GAO 2013). Previous reforms in the 1970s and 1980s attempted to address similar concerns but were largely unsuccessful. Thus the price that industry pays to mine federal coal has not been changed in several decades (Hein and Howard 2015), and as a result, "The program [coal leasing] has been structured in a way that misaligns incentives going back decades, resulting in a distorted coal market with an artificially low price for federal coal and low government revenue from the leasing program" (CEA 2016).

The current moratorium, however, has an added wrinkle—dealing with the externalities associated with climate change, particularly since coal emits large amounts of greenhouse gases (GHGs) per ton burned. Through its current review, BLM aims to bring its 30-year-old leasing policy more in line with global, federal, and regional efforts to reduce GHG emissions.

Addressing GHG emissions has heightened a conversation among policymakers and outside organizations regarding the modeling used to project future energy demand and GHG emissions. BLM needs such a model or models to examine questions such as the following (Howard 2016): How does an expansion or contraction of coal capacity (by offering, renewing, or withholding coal leases for bidding) impact various sectors of the economy? How do the fiscal terms, location, or timing of leases affect various market and economy-wide outcomes? How do different leasing policies affect overall greenhouse gas emissions?

We begin with the hypothesis that in relation to the coal programmatic environmental impact statement (PEIS), the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) could serve as a central component of BLM's analysis of future coal supply scenarios and thus their role in providing energy resources from federal lands.[1] We say this because many federal government agencies, including BLM, have used NEMS to address questions about the effects of policies on the energy sectors and the economy, recently serving as the model underlying Clean Power Plan projections. NEMS is the foremost US governmental energy and emissions modeling system, with its underlying data, modeling structures, economic snapshots, and projections being widely read and followed, particularly through its Annual Energy Outlook (AEO).

Creating energy and emissions projections, particularly 25 years into the future, is complex, and like most models, NEMS has strengths and weaknesses. This policy brief discusses these strengths and weaknesses, paying particular attention to policymakers' application for the coal PEIS. The goal of this paper is twofold. First, we want to provide clarity on the use of NEMS going forward, its important role in providing long-term projections, and how policymakers can better interpret and use NEMS output in conjunction with other energy projections, forecasting input, empirical data, and potential policy changes. Second, the paper analyzes recent AEO side cases and other scenarios as a way of assessing how future coal demand could trend in comparison with the 2016 reference case.

2. Specific Modeling Needs

In March 2016 DOI published a formal notice of intent in the *Federal Register* announcing the programmatic review; six public comment sessions were then held between May and June (BLM 2016). DOI is now in the process of preparing a draft environmental impact

[1] When we refer to BLM in our report, we sometimes mean DOI more generally or parts of DOI that would participate in an analysis but are not part of BLM.

statement (EIS). As part of the draft EIS, BLM will prepare a Reasonably Foreseeable Development Scenario (RFDS) for federal coal production and provide an analysis of potential alternatives for policy action, including a “no action” alternative. BLM will also likely include a proposed action, outlining its recommendation for reform. Following a comment period on the draft EIS, BLM will then release a final EIS, including a final proposed action. The RFDS and development of alternatives are where the energy and emissions modeling primarily come into play during the draft EIS process.

To forecast the demand and supply of federal coal, BLM will be concerned with a number of inputs related to electricity demand, coal substitutes, and commodities prices, among other factors. BLM will also need a model capable of analyzing the impact of proposed regulations and leasing policies and differentiating between effects on federal and private coal lands.

BLM’s RFDS for the Powder River Basin (PRB), which includes development of the Wright Area Leases, provides a look at the standard RFDS and EIS process (BLM 2009). BLM chose to forecast an upper and lower bound for coal production in the PRB to bracket the most likely levels of production. For these projections, the PRB was divided into five subregions: three in Wyoming and two in Montana. Each subregion had its own forecast through 2020.

To develop the forecast BLM relied on historic production levels collected from a variety of publicly available sources. BLM then incorporated future projections from a handful of regional models, including those of Hill and Associates, Platts, and Global Insight, as well as from industry data and interviews (BLM 2009). Its analysis also included an evaluation of new rail lines and transport options.

A review of the 1985 Final EIS Supplement, which modified the 1979 Final EIS, illustrates BLM’s historic approach to modeling federal coal production writ large. For that review, BLM worked with the Department of Energy and EIA to develop forecasts through 2000. Specifically, the EIS states that BLM “generally starts with EIA’s Annual Energy Outlook’s base [reference] cases but usually makes changes to analyze issues of particular concern for the western region.” The report also identifies the National Coal Model (NCM) as a primary tool, modified to specify regional coal demand, industry input, and field staff input (BLM 1985).

The historic use of EIA’s national models as well as a variety of regional energy forecasting models in a recent coal EIS is important for the RFDS and alternative analysis components of the current EIS. This history underscores the common sentiment that BLM’s analysis will likely feature NEMS and that the analysis should incorporate more than one model output. It also raises another issue discussed in this paper: Is the NEMS reference case an appropriate baseline for BLM’s analysis? On a broader level, BLM must first select which model to use as the primary hub and also which models to use for complementary analyses.

In 2016 Peter Howard of NYU’s Institute for Policy Integrity published an analysis of BLM’s modeling choices. He finds NEMS to be a strong modeling choice for BLM if EIA is willing to make some key modifications for the coal PEIS and future coal analysis that BLM requires. Howard identifies specific issues for NEMS to meet BLM’s modeling needs. First, NEMS does not model royalty rates or minimum bids. Second, the model cannot account for substitution among mines on federal, state, and private lands or among regions (with a qualification noted below). As such, NEMS cannot model the impact of changes to leasing policies (Howard 2016).

Other capacity expansion models already used by federal agencies and cited by Howard include the Bureau of Ocean Energy Management's (BOEM's) Revised Market Simulation Module (MarketSim) and ICF International's Integrated Planning Model (IPM). MarketSim is a simple partial-equilibrium model of national energy markets that, compared with other models, is easy to understand. Its simplicity, however, results in a failure to capture important nuances that the energy market faces in reality. ICF's IPM is a linear programming model that is able to find the optimal path "that minimizes the present value of cost streams to expand capacity and control emissions to meet demand, regulatory and system requirements" (Howard 2016). Its coal module is highly disaggregate, and differentiates between federal and non-federal coal (Vulcan 2016). Because of a recent study ICF performed for Vulcan (Vulcan 2016) on the impact of federal coal leasing decisions and IPM's ability to have such policies apply only to federal coal, Howard (2016) concludes that IPM is the only model already tailored to conduct BLM's analysis needs. But a strike against IPM is that the model is confidential and proprietary. NEMS, in contrast, is fully documented and available for use by anyone. In addition, its size and comprehensiveness make NEMS better equipped to provide detail about coal substitutes, consumer behavior, and the macroeconomy. Howard (2016) emphasizes the need for BLM to use a model (or multiple models) allowing for "sensitivity analyses over key parameters, like the price of natural gas," and to disclose the model's limitations.

In the following section, we discuss how NEMS's strengths and weaknesses could be best used and complemented by other model choices.

3. NEMS's Strengths and Weaknesses

To understand the usefulness of NEMS for policymaking, it is essential to understand what NEMS is and is not, its strengths and limitations.

NEMS is an energy-economy simulation modeling system of US energy markets, currently projecting through 2040. NEMS projects the production, consumption, imports, exports, conversion, and prices of all types of energy. It includes a macroeconomic model to set population growth, unemployment, and other features of the broader economy. But it focuses on all the major energy producing and consuming sectors. Whereas many economic models use demand and supply curves to find equilibrium prices, NEMS is basically a technology model, containing many different production and consumption technologies, along with their costs, capacities, and other factors that would underlie the building of supply and demand curves but are explicit in NEMS. Inclusion of these details allows one to swap in new technologies to see what will happen and makes NEMS much more transparent than models that embed technologies in supply curves.

NEMS is also a deterministic simulation model, which means that it has no representation of uncertainties about future prices and other factors, although it does include "learning by doing" factors, which represent reductions in costs or increases in performance of a set of technologies over time. Uncertainties in NEMS are addressed through specifications of scenarios embodying various assumptions about future prices (such as on oil), technologies, costs, and other factors. To run the model, users have to specify various parameters addressing macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, technology characteristics, and demographics. In some cases, exogenous decisions are made that are not subject to economic forces, such as the amount of nuclear capacity to be built or retired. Ultimately, NEMS produces a general equilibrium solution for energy supply and demand (meaning that prices adjust to bring supply and demand in US energy markets into balance on an annual basis).

When using NEMS for policy analysis, one first examines the "reference case," which takes existing policies at the federal and state level as given. Then various model assumptions or policies can be added or altered as appropriate to create a scenario that is called a "side case." Comparing the time path of variables between the side case and the reference case provides insights into how the changes to policy or assumptions affect the entire economic system, particularly the energy sectors. Each year EIA releases a reference case and side cases. Most recently, EIA has decided to alternate "light" and "heavy" side cases each year. Thus for 2017, which is a "light" year, only six standard side cases are planned so far, labeled as high/low oil prices, high/low natural gas prices, and high/low macroeconomic growth.

In examining NEMS's general strengths and weaknesses, it must be asked, "compared with what?" Any one model cannot do all things and answer all questions put to it equally well. Many competing models are available, although none with the resources, history, and particular place in government policymaking of NEMS. Beyond the energy systems models mentioned in the discussion above based on Howard (2016), there are other classes called computable general equilibrium (CGE) and dynamic stochastic general equilibrium (DSGE) models. Both of these solve explicitly for price paths that are compatible with production and investment decisions, but they do so by dramatically simplifying the representations of supply and demand. Even the large CGE models may feature only a single oil and gas sector. Such models are of little help to DOI. The DSGEs are capable of embedding uncertainty about the future directly into the model, so price volatility, risk aversion, and other elements can be represented. Like the CGE models, however, these improvements come at the cost of detail on any one sector.

We turn now to specific strengths and weaknesses. First, EIA is the model of a neutral agency interested in informing public policy. EIA does not have a political agenda. Its reference case, which is always defined to include only current policies and not to speculate that proposed policies will get passed, reflects this culture and mandate. EIA's decision not to speculate about future policies for its reference case is viewed as a strength by some and a weakness by others. This "freeze" on current policies is particularly important for policymakers to understand and something we would like to call attention to, particularly given the large effect new policies or policy assumptions can have on outputs. Modelers like this decision because the baseline policy situation is very clear, and the case can then be used as the counterfactual in policy analyses. Critics, however, lament that the model is not forward looking enough.

Second, NEMS is comprehensive in its coverage of energy markets and their underlying technologies and resource bases. For instance, few other models will include natural gas liquids, be divided into so many geographic regions, or represent state-level renewable portfolio standards (RPS) programs as thoroughly as NEMS. NEMS is a behemoth, with EIA spending over $5 million per year making model improvements and running the reference case model and another large amount of money generating data that go into the model.

But this comprehensiveness comes at the cost of having outputs that can be hard to interpret, and it is costly and time-consuming to make changes and updates to the model. This is why NEMS sometimes is relatively slow to incorporate the latest data and new thinking about how to model various phenomena. Moreover, NEMS's comprehensiveness and complexity often mean that changes to one part of the model necessitate changes to other parts, presenting coordination challenges and contributing to further delays. Tension has arisen in the modeling community over photovoltaic (PV) penetration, when PV hardware rapidly dropped in price and it was alleged that EIA was slow to recognize this fact in NEMS.

On the other hand, knowing this limitation, EIA makes deliberate attempts to update the model every year after seeking input from experts about problems they have with the model. This opening to public comment also has its strengths and weaknesses for the model's credibility. Unlike private modelers, NEMS staff hold webinars and working group meetings to take advice and vet possible changes. Gathering extensive stakeholder input slows the pace of model changes and data updates but also helps ensure that changes are well justified. Finally, NEMS aims to be transparent by thoroughly documenting and publicizing its inputs, outputs, and modeling routines. Transparency, in the form of public availability and understandability, is critical for widespread use of the model by agencies such as BLM and the broader public. Yet transparency also subjects the model to more scrutiny than other models.

Given these points, optimism about policies to promote renewables, as an example, will not be found in a NEMS reference case. Rather, one should examine NEMS's side cases, which include policies that are not current. This is particularly an issue for renewables where tax credits and other subsidies usually have sunset provisions attached to them, which EIA will faithfully model as sunsetting, even though these policies are usually renewed. Thus if one believes the federal investment tax credit (ITC) and production tax credit (PTC) will be renewed, a NEMS side case (if available) may be a better choice to model implications of additional policy changes than the NEMS reference case. While the NEMS model is criticized for underestimating the penetration rates of renewable energy sources and missing major market swings, such as the recent oil glut, as we show below, NEMS is quite sensitive to policy changes.

Another feature of NEMS related to its comprehensiveness is its "time step" of one year. That is, EIA made a decision to make the NEMS project year to year (rather than, say, month to month like another EIA model). Given that decision, NEMS relies on annual data and information in the literature based on analyses of these data to populate and help design the model. Most energy models use an annual time step like NEMS does. While many economic phenomena can be reasonably captured with such a time step, the impacts of volatile movements in price (such as that of oil, which is exogenous to the model) cannot be captured, although year-to-year changes in price levels, however measured, can be reflected in the following AEO.

A common weakness among all energy systems models, including NEMS, is that they are not set up to provide welfare measures associated with policy changes. Such welfare measures would include, for instance, changes in consumer and producer surplus associated with the policy changes and any nonmarket values for changes in public/environmental goods. Rather, NEMS is designed to produce changes in many components that would enter into such calculations, such as changes in electricity or natural gas prices and quantities of electricity generated, but it mainly targets changes in gross domestic product (GDP) as its metric of national benefits. For a variety of reasons, GDP is a poor measure of social welfare. Having made this criticism, however, Krupnick et al. (2010) show how NEMS outputs can be manipulated to obtain welfare measures under certain conditions and do produce such estimates. This effort is aided by NEMS, including changes to CO_2 and SO_2 emissions as output variables, although it focuses on several sectors rather than offering a life cycle accounting of such emissions associated with any policy change (Krupnick et al. 2010).

A final but important shortcoming for the coal PEIS analysis is that NEMS does not differentiate between coal mines on federal and private land. This is possibly a fundamental problem given that DOI's reforms could potentially have opposite impacts on production, lowering production on federal land and raising it on private land. Nevertheless, NEMS models regional subsections, and to the extent that any of these regions substantially overlap federal holdings, this issue could be mitigated. Indeed, the most important federal holdings—in the PRB in Wyoming—are captured by two Wyoming regions defined in NEMS. Thus, NEMS could be run with policy applied exclusively to federal lands in the PRB, permitting substitution to private lands around the country, with the caveat that some of these lands also contain federal holdings. This simplification may be reasonable for BLM in some cases, but the results would not reflect policy applied to all federal lands. To the extent that BLM needs to understand the dynamic substitution relationship within regions, across coal regions, and even at the mine level (with respect to surface versus underground coal, for example) in order to best develop production and emissions forecasts, it will need to use other models.

A promising model is ICF's IPM model, which the US Environmental Protection Agency (EPA) regularly uses for regulatory purposes. Vulcan Philanthropy's research shows that IPM has the ability to differentiate between federal and private coal. Importantly, this work and the Council of Economic Advisers' June release conclude that reduced production on federal lands will partially shift to private lands (Vulcan Philanthropy 2016; CEA 2016). Understanding the specific impacts of substitution to the economy and emissions under various policy scenarios will be essential for BLM's analysis. EIA potentially could include ICF output as exogenous inputs to NEMS to address this concern. However, EIA rules out the major model updates it would need to make to develop supply relationships unique to federal holdings

4. NEMS Data and Model Updates over Time

It is clear that NEMS has a well-institutionalized annual process for updating its model and data. It is also clear that EIA staff have been working on the renewables part of the electricity module recently (EIA 2016a). One way of understanding this process is to seek out cost and modeling changes one at a time and try to sort them out. But ultimately, what we care about is the implications of such changes for penetration of various fuels and generation technologies, such as solar generation as a percentage of total generation. An enlightening way to show this is to compare the forecasts for fuel and generation penetration that come out of the AEO reference cases each year. This is not a perfect approach, because many things besides costs and technologies are changing each year that can affect penetration rates. Nevertheless, these comparisons are revealing.

Specifically, Figures 1, 2, 3, and 4 illustrate the evolution of NEMS reference case projections for total US electricity, coal-fired, solar, and wind generation from the 2010–16 AEOs. All figures are in billion kilowatt hours (bkWh).

Figure 1 shows a slightly decreasing trend for total electricity generation over time. However, the change is modest despite new assumptions about the macro market, commodity prices, electricity technology, and policies such as the Clean Power Plan. This figure suggests that total electricity consumption is not heavily affected by changes in policy or specific fuel uses.

Figure 2 depicts rapidly changing projections for coal generation. The initial downward trend is predictably from the new abundance of low-price natural gas that appeared on the market during the period. The large downward jump in AEO 2016 is largely due to the effect of the Clean Power Plan. In contrast to Figure 1, Figure 2 shows that NEMS fuel-specific projections can be significantly affected by changes to policy assumptions. In addition to the sizable step down in AEO 2016, we question whether the coal module is capturing all coal retirements that may result from forthcoming EPA regulations, which would further reduce coal generation (EIA 2016b).

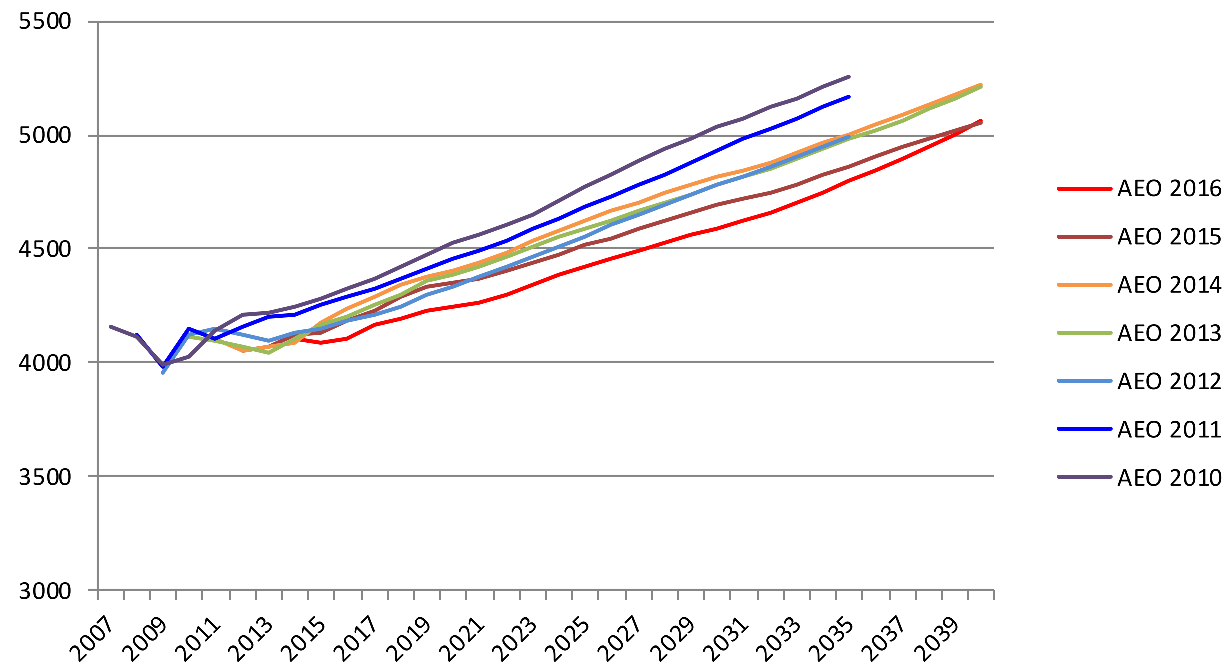
Figures 3 and 4 illustrate how solar PV and wind generation projections, respectively, have changed over time. The large shift in both generation levels in the 2016 reference case reinforces the same point as Figure 2—that policy assumptions, including tax benefits, create large swings in fuel-specific generation even if the total generation figures shift only modestly.

Comparing projections from AEO 2015, AEO 2016 without the Clean Power Plan, and AEO 2016, we can generalize some broad effects of policy impacts on PV and wind. A primary difference between the 2015 reference case and the non–Clean Power Plan 2016 case is the extension of production and investment tax credits for solar and wind. Realistically, we can attribute some of the near-term change to the taxes' positive impact on renewable generation.

Comparing reference case 2016 to the non–Clean Power Plan 2016 case shows the effect of the Clean Power Plan on PV and wind penetration. Both benefit significantly; however, PV has a greater positive difference between the two cases. Interestingly, PV continues to increase post-2030 (post-Clean Power Plan) in the 2016 reference case, whereas wind energy rises sharply through 2022 and then plateaus. Because PV rises in both the 2016 reference case and non–Clean Power Plan case, and taxes sunset in the early 2020s, we can infer that the increasing PV generation can be largely attributed to significant cost decreases within NEMS's solar module.

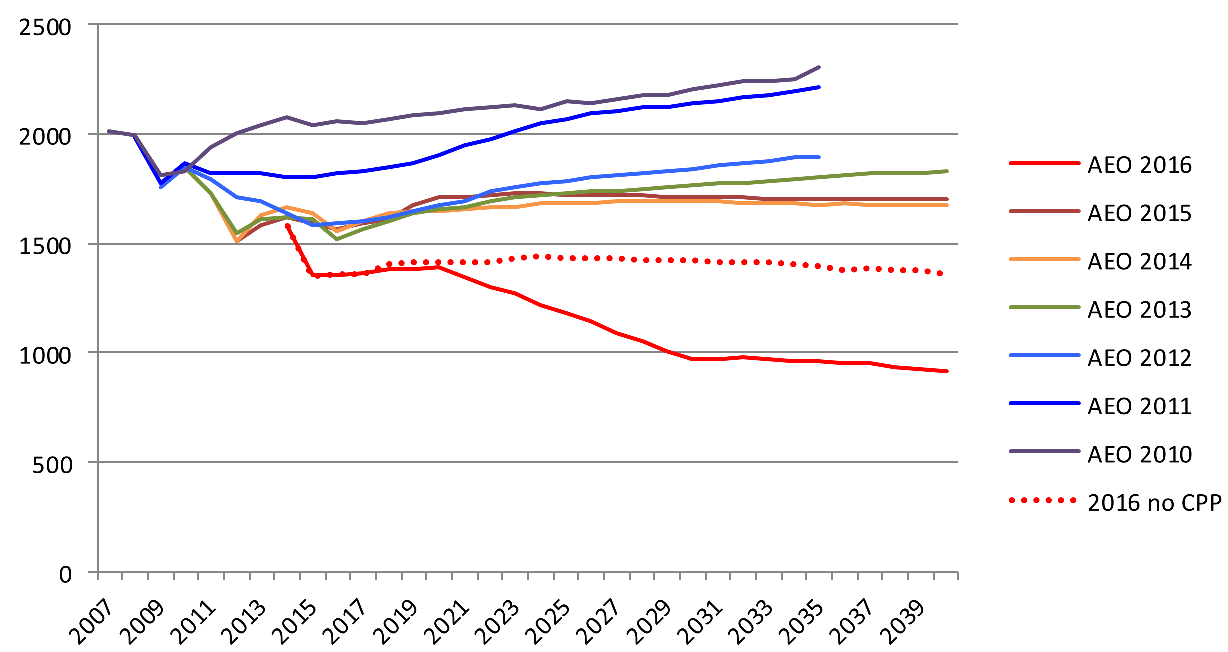
This common theme of policies driving fuel selection is important for policymakers to remember, particularly in light of the fact that NEMS does not, nor should it be expected to, model all future scenarios. Therefore, it is up to policymakers to consider how policies outside of the NEMS side cases should be evaluated within the PEIS process. One interesting omission to note, given the growing salience and prevalence of climate policy, is that EIA chose a carbon tax for a side case in 2014 but not thereafter.

Figure 1. Total US Electricity Generation Projections from AEO 2010–16 (bkWh)



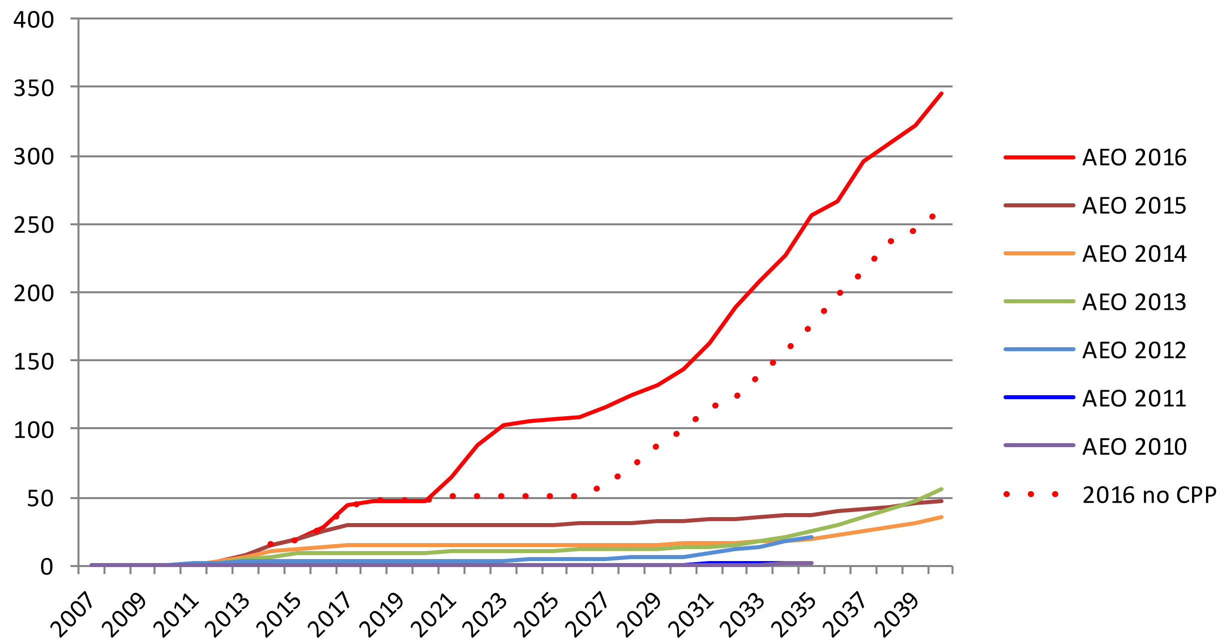
Source: EIA Online Interactive Data Browser

Figure 2. Total Coal Electricity Generation Projections from AEO 2010–16 (bkWh)



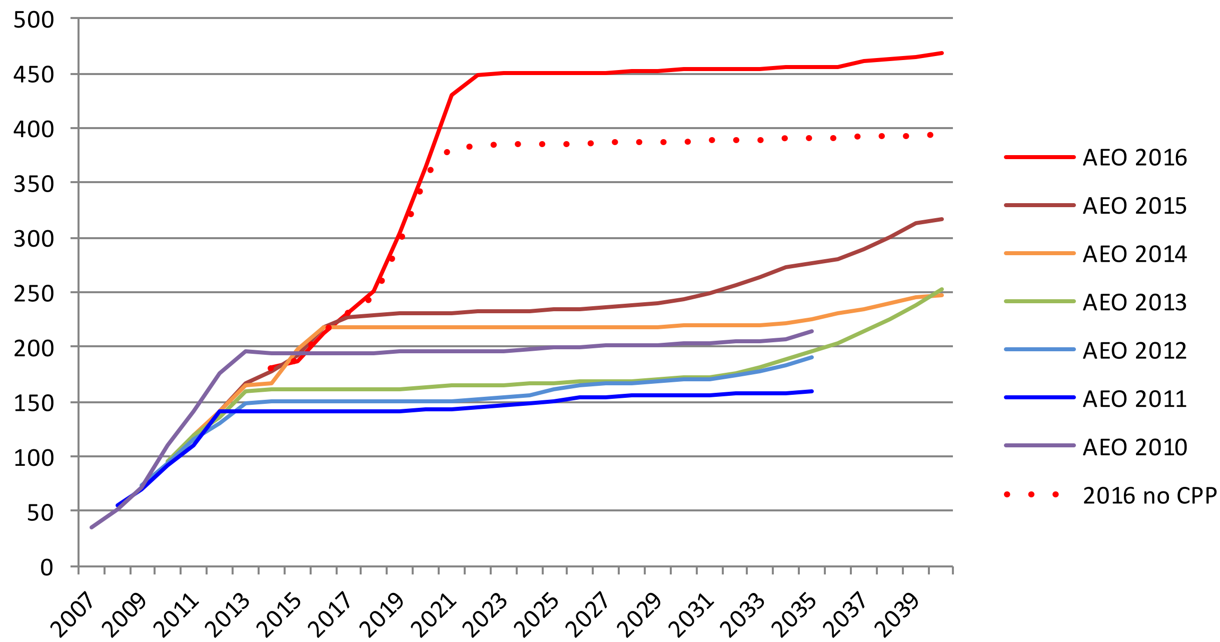
Source: EIA Online Interactive Data Browser

FIGURE 3. SOLAR PV ELECTRICITY GENERATION PROJECTIONS FROM AEO 2010–16 (BKWH)



Source: EIA Online Interactive Data Browser

FIGURE 4. WIND ELECTRICITY GENERATION PROJECTIONS FROM AEO 2010–16 (BKWH)



Source: EIA Online Interactive Data Browser

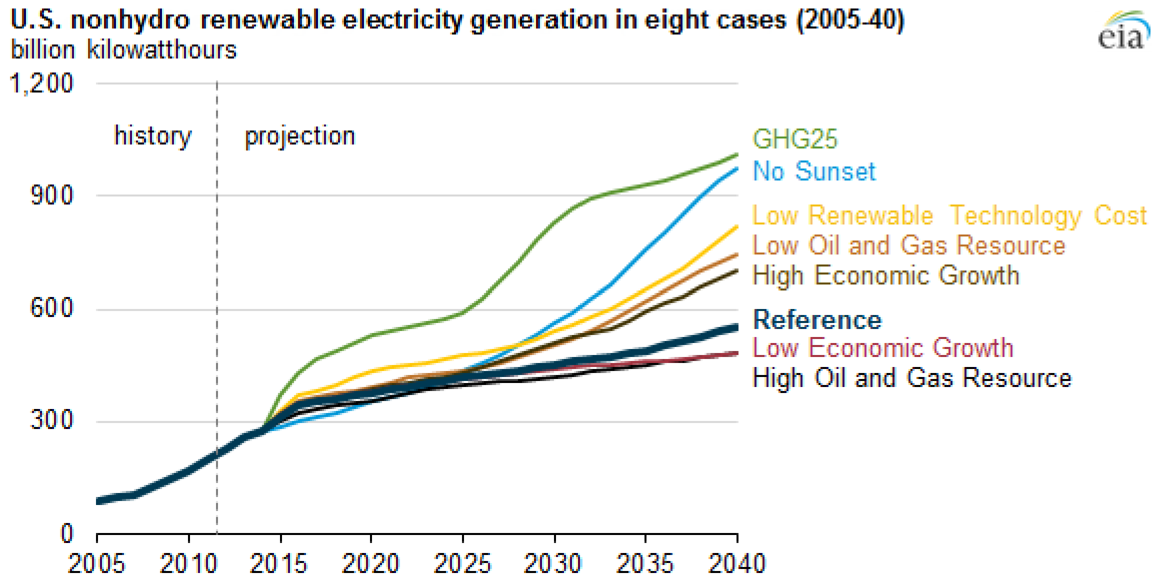
5. Uncertainties about Policies and Future State of the World Represented with Side Cases

As noted above, EIA's response to the deterministic setup of NEMS and to its dictum of not modeling policies unless they are in place is to run side cases for alternative assumptions about highly uncertain variables, such as future oil prices, or about policies that might be in place in the future, including the extension of existing policies. Figure 5 illustrates some side cases and how they can affect renewables penetration. Note the thick dark line for the reference case for nonhydroelectric renewables. The projection begins in 2014 at about 350 billion kWh, rising to more than 500 billion kWh by 2040. Figure 5 shows side cases for uncertain oil prices, uncertain macroeconomic growth, uncertain recoverable resources, and most relevant, faster renewables cost reductions. EIA also ran a side case for a $25 per-ton carbon tax increasing over time (GHG25) and a case where wind and solar subsidies extend over the modeling period to 2040 (No Sunset). Note that the carbon tax has greater impacts on renewables penetration than the other side cases modeled in AEO 2014.

Specifically, the cases modeled in AEO 2014 include the following, which correspond with cases in Figure 5 below:

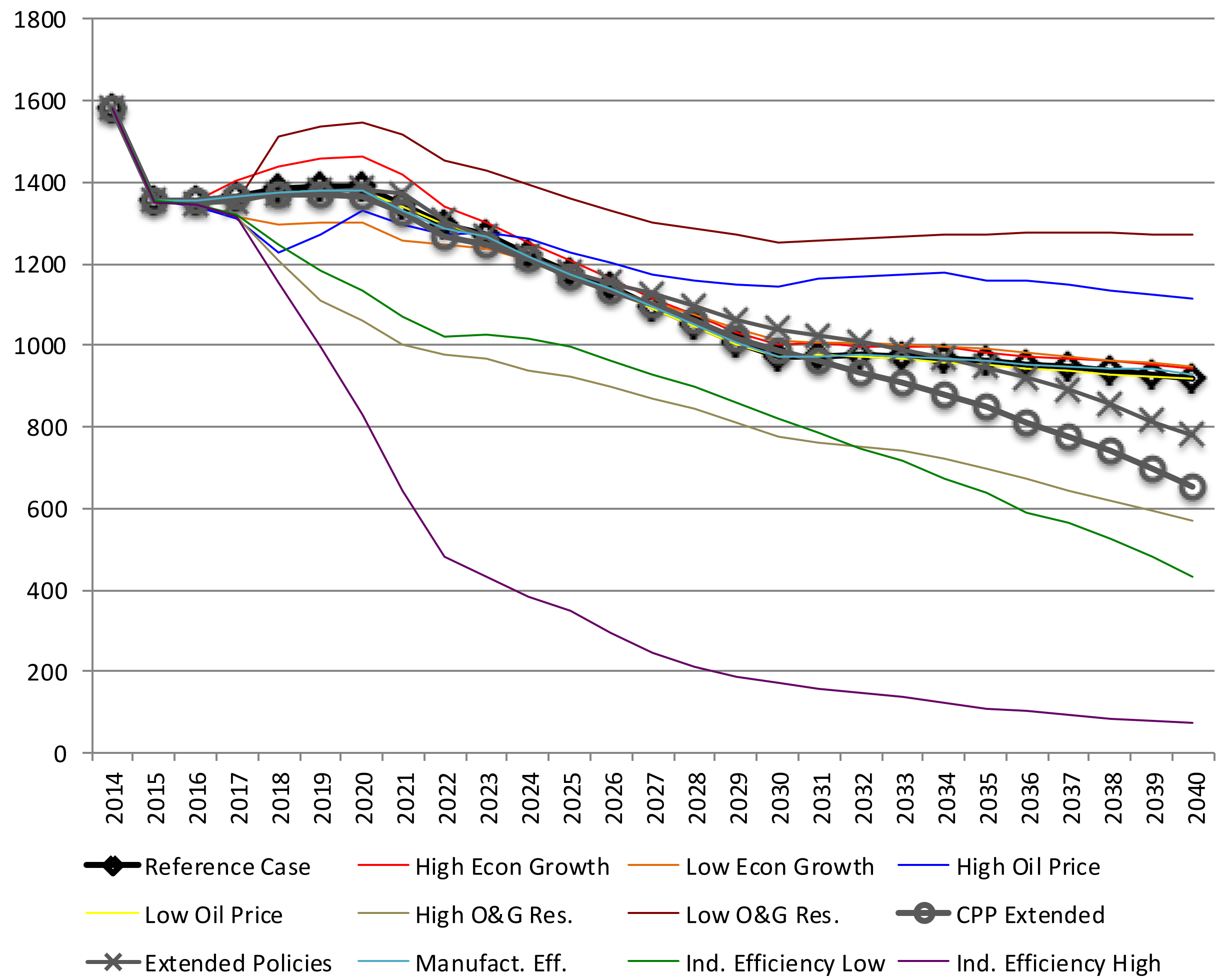
- **Reference Case:** Assumes no changes in policy or law. Laws with an expiration date are assumed to expire as scheduled.
- **Side Cases**
    - **Low Economic Growth:** Real GDP grows at an average annual rate lower than the Reference case. (All other energy market and policy assumptions remain the same as Reference.)
    - **High Economic Growth:** Real GDP grows at an average annual rate higher than the Reference. (Again, all other energy market and policy assumptions remain the same as Reference.)
    - **Low Oil and Gas Resource:** Estimated ultimate recovery (EUR) per shale gas, tight gas, and tight oil well is lower than in the Reference.
    - **High Oil and Gas Resource:** EUR per shale gas, tight gas, and tight oil well is higher than in the Reference. Tight oil resources are added and well spacing is closer than in the Reference.
    - **Low Renewable Technology Cost:** Capital costs for new nonhydropower renewable generating technologies are reduced in each year relative to costs in the Reference case.
    - **No Sunset:** Assumes extension of all existing tax credits and policies that contain sunset provisions, except those requiring extensive regulatory analysis or those requiring additional funding (such as the loan guarantee programs). Also assumes extension of ethanol and biodiesel subsidies.
    - **GHG25:** Applies a price of carbon dioxide emissions starting at $25 per metric ton and rising at five percent per year through the projection period.

FIGURE 5. US NONHYDROPOWER RENEWABLE ELECTRICITY GENERATION IN EIGHT CASES FROM 2005 TO 2040 (AEO 2014, CITED IN EIA 2016C)



To provide an additional look at coal generation and the impact of side cases, we analyze 12 side cases listed in AEO 2016, depicted in Figure 6. The primary takeaway from Figure 6 is that most side cases modeled by AEO 2016 project reduced coal supply through 2040 compared with the reference case. These side cases include the extension of the Clean Power Plan and of other policies, including tax credits, and increased industrial efficiency. The industrial efficiency side cases use a CO_2 fee as a proxy for demand side efficiency. For our analysis, these two side cases provide insight into the magnitude of impact that a carbon fee would have on coal generation. In both the low and high case, coal decreases substantially from the reference case. However, the industrial efficiency high case approximates the social cost of carbon more closely and drives coal generation to near zero. Only two side cases—High Oil Price and Low Oil and Gas Resource and Technology Case—markedly increase coal demand.

FIGURE 6. COAL ELECTRICITY GENERATION UNDER 12 CASES FROM 2014 TO 2040 (BKWH)



Source: EIA Online Interactive Data Browser

6. Additional Scenarios to Consider

As discussed above, outside of side cases, NEMS does not account for future policy or other changes, regardless of their likelihood. Because of this limitation, it is important for BLM to consider how potential policy decisions and other economic shifts could impact coal supply decision-making, particularly in a climate-constrained market. Following are several scenarios that highlight the importance of examining issues beyond those in NEMS side cases and that could likely apply further downward pressure on future coal supply.

6.1. Future Shifts in Renewables Policy

Figures 3 and 4 (above) show the evolution of AEO solar and wind projections. The progression illustrates the refinement of the NEMS model, including renewables cost updates but also the impact that new policies have on generation. Note, as an example, 2016's reference case, which includes the Clean Power Plan. As a result of the Clean Power Plan, AEO 2016 projections in Figure 2 show a drastic drop in coal generation, while Figures 3 and 4 show rapid increases in solar and wind generation projections. While not all the change can be attributed to the Clean Power Plan through our analysis, it is arguably a driving force. Importantly, the Clean Power Plan's sudden impact on coal, PV, and wind generation in AEO 2016 generation projections highlights EIA's policy of not accounting for future policies in the reference case and minimal policy-based side cases.

Realistically, given the recent expansion of local, state, federal, and international clean energy policies and the growing public salience of climate change, a variety of policy extensions and future policies could reasonably reduce coal supply and demand. These include but are not limited to an extension of the Clean Power Plan over time, extension or expansion of state RPS programs, extension of the ITC or other supporting tax incentives, increased public and utility financial incentives, and through research and development (R&D) support, further reductions in solar and wind generation costs.

6.2. National or Regional Carbon Pricing

Figure 5, from the 2014 AEO, includes a carbon price for GHG emissions. The price starts at $25 per metric ton and rises over the time period shown. The illustration highlights the significant effects that a carbon price would have on electricity generation sources. Over the reference case, nonhydropower renewables generation rise by roughly 100 percent by 2040.

Interestingly, despite the expansion of climate policy over the ensuing years, EIA did not include a carbon tax in either AEO 2015 or 2016 side cases. However, the industrial efficiency side cases in Figure 6 use a carbon fee as a proxy for demand side efficiency. The applied carbon fee drives coal down significantly, especially in the 'high' case, which more accurately reflects the social cost of carbon (SCC).

Despite not explicitly modeling for a carbon fee in recent AEOs, BLM should consider a scenario with a broad-based carbon tax, for instance, one based on the SCC (about $42/ton CO_2) as one bounding scenario for the RFDS. BLM should also note that a carbon tax need not necessarily be a nation-wide tax. The expansion of the Regional Greenhouse Gas Initiative or California's Cap and Trade program, via the Western Climate Initiative, are two prime examples of regional carbon pricing policies.

A carbon price scenario could be run through NEMS, as seen in the 2014 AEO. Other models could also be consulted, including Resources for the Future's Haiku model, which has previously been used to analyze the impact of carbon pricing and more recently the Clean Power Plan.

6.3. Future Shifts in Renewable Costs

Renewable energy sources face major barriers to increasing penetration in the electricity market. Key among these concerns is reliability of renewable sources due to intermittency of supply. Maintaining reliability of the grid's supply to meet fluctuations in demand often determines the economic dispatch of energy sources. With the rapid innovation in policy incentives, finance systems, as well as storage and integration technology there are a number of variables that NEMS does not explicitly capture that could shift the cost and ability to integrate renewable sources onto the grid. Such rapid increases in the share of renewable generation in the electricity sector will contribute to further downward pressure on coal. Note, however, that NEMS includes a learning by doing algorithm that pushes costs down over time, depending on previous penetration rates.

6.3.1. Financial Innovations Such as Solar Leasing, PPAs, and Community-Shared Solar

Improved technology and market maturation have driven significant growth in PV capacity over the past decade. Instability of future pricing schemes for solar distributed generation causes market uncertainty that depresses consumer demand, and impedes solar penetration. In fact, much of the growth in PV stems from favorable public policies such as the ITC, local rebate programs, and net metering payment systems. According to the solar industry, the extension of the ITC will result in over 72 GW of PV installations between 2016 and 2020 (SEIA 2016). In addition, due to federal financial incentives, over the past few years private companies, cities and utility companies have been experimenting with innovative financial programs that reduce costs and help bring additional certainty to investments in distributed generation. A few of these financial innovations include solar leasing ("Rent your Roof" programs) and community ("shared") solar programs through the use of long-term Power Purchasing Agreements (PPAs).

Under the solar leasing program solar contractors enter into long-term energy supply contracts with the utility. Contractors finance, install, own, and maintain solar PV systems on residential and small commercial rooftops at no cost to the resident. In exchange for leasing their roof, the owner of the building receives a reduction on their monthly bill. The contractor then sells the electrical output to the utility under a PPA, just like in the wholesale market (CPS Energy 2015). Such systems ensure the solar industry stability against potential government reductions to current rebates.

In community solar programs, households can buy solar power without having an array installed on their roof. Instead, households that previously did not have access to solar power can now subscribe to a portion of a nearby solar farm and generate credits on their monthly bills for the power produced by those panels (Motyka 2016).

Such innovations in solar financing could allow for the expansion of solar generation to middle and low-income customers. With no out of pocket cost to the customer, households, and small businesses, that otherwise would be unable to afford rooftop solar could reap the benefits of distributed generation. As an example, GTM Research projects community solar will grow 59 percent annually, reaching close to a half-gigawatt annual market, through 2020 (Honeyman 2015). In addition, different utility business models are driving a large share of these innovative program designs. Electric cooperatives (private, not-for-profit businesses governed by consumer-members) are at the forefront of community solar development, administering over two-thirds of current programs, and investor-owned utilities (IOUs) account for over half of community solar capacity (Motyka 2016).

Currently, EIA estimates cost curves for each technology and assumes financing as part of the cost. Thus, some financial innovations in the solar industry may be captured in the current cost function. However, it is unlikely that more recent innovations, particularly more nascent markets like community solar, are fully factored in; thereby, suggesting that some future PV capacity may not be currently estimated by NEMS.

As evidence, a June 2016 article by the EIA broke down the effect of recent modeling updates on utility solar versus residential and commercial solar within NEMS (EIA 2016e). It shows that residential and commercial markets are more heavily affected by cost reductions than the ITC or Clean Power Plan, and it also suggests small changes in cost can have large impacts on generation, as the projects sit largely on the margin. Therefore, evolving PV applications that reduce cost even modestly could shift substantial generation to solar PV.

6.3.2. Rapid Changes Involving New Grid Storage Technology

Improvements in grid storage technology have the potential to increase intermittent renewable generation. In February 2016, Duke Energy, the largest utility in the United States, installed a hybrid energy storage system at one of its substations that combines batteries (made by Aquion Energy) and ultracapacitors (from Maxwell Technologies) (Martin 2016). The batteries store energy over longer periods and allow for maintaining solar power access to the grid when the sun goes down and electricity demand rises. Cost is critical for meaningful deployment of electric storage to occur. Compared with the lithium-ion batteries, the Aquion batteries reduce the cost of storage from around $450 to under $350 per kilowatt-hour of capacity (Martin 2016). In the Duke Energy case, the less expensive Aquion battery combined with ultracapacitors reduced the installation cost by around 10 to 15 percent (Martin 2016). According to GTM Research, annual US energy storage systems for renewable integration will pass 1GW in 2019 and by 2020 will be a 1.7 GW market with a value around $2.5 billion (Munsell 2016).

However, a recent paper by Josh Linn and Jhih-Shyang Shih shows that the effect of increased storage may be ambiguous in terms of net emissions reductions (Linn and Shih 2016). They cite the relative price responsiveness of coal, gas, solar, and wind in their explanation. The interaction with climate policy, like carbon pricing, is also important to understand. Presently, EIA does not include energy storage within its model, but it is working to incorporate that in the near term. Ideally, future iterations of NEMS projections will account for storage, likely increasing wind penetration.

6.3.3. Employment of a Network of High-Voltage Direct-Current Transmission Lines

Another area of grid technology with potential to increase penetration of renewables is moving from a regionally divided electricity sector to a national system enabled by a high-voltage direct-current (DC) transmission system (MacDonald et al. 2016). HVDC helps to protect a transmission system from disturbances resulting from rapid changes in power sources such as solar and wind. In May 2016, MacDonald et al. published a study in *Nature* that found by making this switch the US power sector can reduce carbon dioxide emissions by up to 80 percent relative to 1990 levels. Furthermore, the study shows that these reductions would not require a change in current technology or electrical storage ability. HVDC enables power transmission between unsynchronized alternating current (AC) systems. With significant variation in costs based on the particulars of each project and with most providers of HVDC systems refusing to disclose cost details for proprietary reasons, it is difficult to compare its economic advantage to other technologies that increase renewable penetration. The fact remains that transitions to these "transmission super highways" would help address the reliability concerns of intermittent renewable sources, potentially causing a major boost to renewables (Mahan 2013).

6.3.4. Consultation of Outside resources for Faster Updates on Cost Declines for Renewables

While EIA can and has incorporated more accurate cost decline estimates for renewables, they have traditionally lagged real world conditions. Therefore, policymakers should consult outside resources, including industry professionals, like BLM has done with the coal industry in recent EISs.

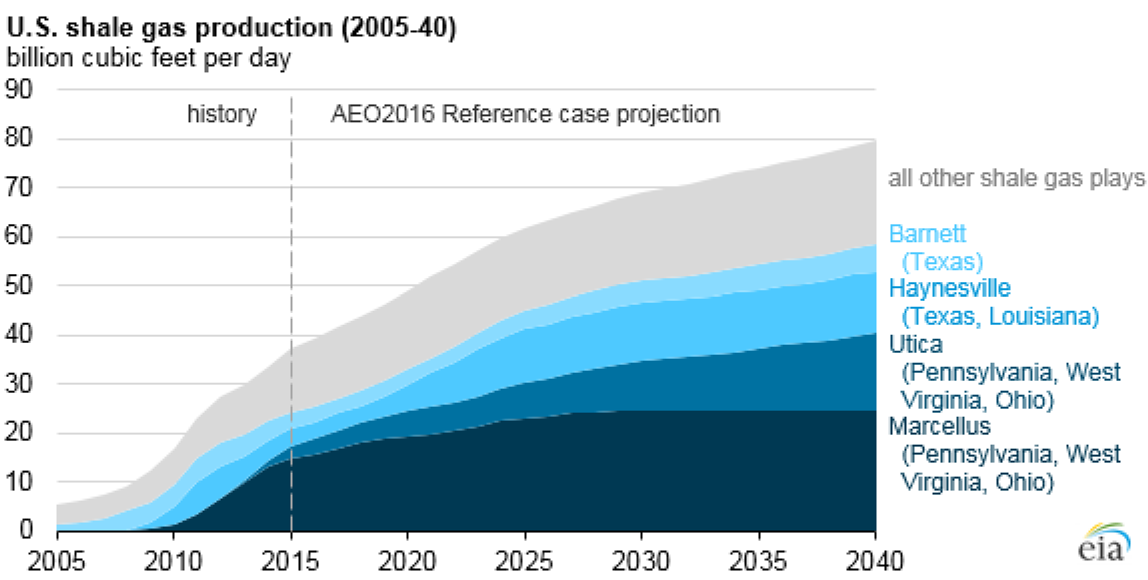
7. Other Coal Substitutes: Natural Gas, Nuclear, and Hydroelectric Power

BLM could also consider scenarios that involve changes in the competitiveness of nonrenewable substitutes.

7.1. Natural Gas

Natural gas electricity generation has expanded rapidly in recently years, competing against renewables and coal for market share and hastening the early retirement of coal plants. In 2016 natural gas passed coal in terms of net electricity generation for the first time. The expansion is not expected to stop soon. As an example, in May 2016 EIA forecast that nearly 19 GWs of new gas-fired generation (mostly shale) capacity to come on line by 2019. Furthermore, based on the 2016 reference case, EIA expects shale gas production to increase by 100 percent through 2040 (see Figure 7). BLM might consider a side case for even more optimistic natural gas production (and low prices), which EIA is indeed planning for AEO2017.

FIGURE 7. US SHALE GAS PRODUCTION



Source: EIA 2016c.

BLM could also consider using EIA's side case of Low Oil and Gas Resource and Technology—the lone case that greatly reduces natural gas production and becomes more favorable for coal. Most experts expect that natural gas will continue to win market share from coal based on low prices. Of course, a carbon tax or cap and trade program would decrease gas's competitiveness against renewables; but at the same time, gas would have an even larger competitive advantage over coal (assuming fugitive emissions from natural gas are low).

7.2. Nuclear

Nuclear power is a competitor to coal as a reliable, base-load power source. It is also the main carbon-free generation source in the United States, currently producing 63% of carbon-free electricity (WNA 2016). Despite some clear advantages, nuclear energy in a post-Fukushima era remains highly contentious. Some argue that nuclear generation is a vital component of the clean energy economy. Others shun nuclear due to concerns about accidents, long-term storage of wastes, and concerns about terrorism.

EIA took an interesting step in AEO 2016 and froze nuclear generation levels through 2040. Its decision makes our analysis somewhat limited, especially with the public discussion of early retirements within the existing nuclear fleet. We can foresee scenarios where nuclear generation could increase or decrease in the longer term with somewhat similar likelihood.

On the one hand, low-cost gas or successful advocates could drive early retirements, as with Diablo Canyon or Vermont Yankee. From an analytic perspective, we would then need to assess what fuel will replace this lost nuclear generation. Substitution patterns will largely be based on the state or region where the nuclear plant is located. AEO 2014 sheds light on this discussion via the accelerated nuclear retirement case. Under those assumptions nuclear electricity is replaced by roughly 75% natural gas and 25% renewable energy; coal comprises a negligible amount (AEO 2014).

On the other hand, the success of small modular reactors and associated approval processes, plant extensions, increased efficiency, or a carbon policy could contribute to revitalizing the nuclear industry. Currently, however, only two new nuclear plants are scheduled to come online.

It is beyond the scope of this work to provide further data-based analysis of the nuclear sector. Given that the United States is the world's largest producer of nuclear power, with 99 nuclear reactors that produced 798 billion kWh in 2015 (WNA 2016), we encourage EIA and BLM to consider scenarios that reflect nuclear growth and retraction, paying particular attention to which fuel is likely to replace lost generation in those scenarios.

7.3. Hydroelectric Power

Hydroelectric power has been a stable contributor to carbon-free power in the United States. Most areas that would support hydropower expansion would likely generate strong public opposition. However, several provinces in Canada, such as Ontario, have ample untapped hydrological resources and are eager to sell this power to the United States. Under the Clean Power Plan, states are able to use Canadian hydro to meet their responsibilities. Thus hydroelectric resources providing electricity from Canada could be modeled as part of a scenario pushing harder on coal. Note that at this point in time, NEMS does not model Canadian electricity imports by type, nor assumes any increase in hydroelectric and transmission resources to serve U.S. markets.

8. Conclusions and Recommendations

Having reviewed a series of recent AEOs and related literature, we find that the AEO 2016 reference case is not sufficient for reflecting future trends in coal, solar, and wind generation. Part of the reason for this is simply philosophical. No model can predict or even claim to predict the far future. Models like NEMS are useful for asking “what if” questions and getting a sense of what can happen in the near future, all else equal. But when agencies need to gauge the impact of prospective policies, they should build a wide range of future scenarios and use them to project how their proposed policy changes will fare given each potential scenario. Thus just using a reference case from any model for the RFDS is not recommended practice. Another point specific to NEMS is that the reference case should not be taken as representing the highest-likelihood future. It is just one possible future scenario, and it is a conservative view in the sense that no further policy changes are included, whereas new policies are sure to be legislated and implemented in the future.

In addition, and somewhat more controversial, the reference case is quite likely to provide for too much coal use compared with certain scenarios that we deem more probable. For instance, it is widely believed that current measures such as the Clean Power Plan will be insufficient to meet US targets for greenhouse gas reductions (C2ES 2016). While many sectors of the US economy remain unregulated for CO_2 and methane, many of the cheapest reductions will probably still come from the electric power industry. Thus future climate policies are expected to work additionally against coal generation and for renewables. Having said this, there may well be scenarios that would increase coal use over the reference case, such as a big increase in worldwide coal demand or a breakthrough in carbon capture and sequestration. BLM should consider modeling reasonable scenarios like these for its RFDS, just as it should model carbon taxes or other policies that will further move the economy away from fossil fuels.

To be specific about recommendations for BLM, we suggest that the agency go through a scenario specification process—something already done by many companies, such as Shell Oil (Shell 2016) —and then use one or more of the existing available energy system models, such as NEMS, to work through the implications of these scenarios for *baseline coal projections.* The NEMS reference case is a good candidate for one of the scenarios because it offers projections free from new policies. BLM might also specify policies affecting electrical generators on CO_2 reductions—one that is a moderate but further extension of the Clean Power Plan and state RPS policies, and another that would be more stringent—as well as a scenario that is more optimistic for coal production. Using NEMS for all scenarios would provide a consistency advantage, although BLM might need to employ private contractors for this exercise, as EIA plans to go “light” with side cases for AEO 2017 (EIA 2016d).

With RFDS specified, BLM would then be ready for policy analysis. If NEMS can be modified to account for federal coal (or a judgment is made that its specification of federal coal lands in Wyoming is good enough), and if the coal module is sensitive enough to model increases in royalty rates and other possible policy options, then NEMS could be used for these exercises as well, with the policy changes applied to each of the above specified scenarios. Other models such as IPM could be used for policy analysis in addition to or instead of NEMS, so long as the NEMS scenario baselines could be reflected in the baselines of the other model's runs.

9. Future Research Needs

BLM's PEIS process will need baseline coal projections, which can come from NEMS or other models. NEMS is favored because it is well documented and reviewed, and it has recently undergone a series of updates. However, in order for energy and climate researchers and policy professionals to better use NEMS output, we encourage additional quantitative NEMS-based analysis that seeks to clarify primary drivers within the model and significant future inputs. This analysis would best be accomplished by looking both retrospectively at EIA's model runs and into the future via alternative assumptions beyond EIA's standard side cases. We particularly draw attention to climate pricing, both regional and national, which was modeled by EIA in 2014 but not explicitly since then.

We believe that modeling additional scenarios, as outlined above, is a fundamental step for BLM in the development of its RFDS and policy alternatives. We also encourage the economics and modeling communities to explore these issues within NEMS. As an open source model, it could be used in a series of insightful projects related to the effect of climate policies, notably a carbon tax, and energy-based trajectories that would meet national climate goals. Importantly, the results from an outside study would contribute to conversations beyond the coal PEIS.

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