APRIL 2017

PREPARED FOR **AMERICAN PETROLEUM INSTITUTE**

THE IMPACTS
OF RESTRICTING FOSSIL FUEL ENERGY PRODUCTION

PREPARED BY **ONLOCATION, INC.**
SUITE 300, 501 CHURCH STREET NE | VIENNA, VA 22180

Contacts:

Questions and comments about this report should be directed to:

Lessly Goudarzi, CEO and Founder, OnLocation, Inc.
Frances Wood, Director, OnLocation, Inc.

www.onlocationinc.com

Key Findings

Based on the models used, a U.S. policy of "keep it in the ground" is projected to generate the following impacts relative to a reference case similar to EIA's Annual Energy Outlook 2016 Reference Case. The keep it in the ground scenario includes no new oil and natural gas leases on private, State or federal lands, a ban on hydraulic fracturing, no new or expansions of existing coal mines, and no new energy infrastructure to transport oil and natural gas within and outside of North America.

Difference between KIG and Reference Case	2020	2040
Employment	-4.1 million	-5.9 million
Cumulative GDP (from 2018)	-$823 billion	-$11.8 trillion
Annual energy expenditures per household	+$1,958	+$4,552
US crude oil and NGL production	-6.0 MMbpd	-11.7 MMbpd
US natural gas production	-25 Bcfd	-81 Bcfd
Net liquid petroleum imports	+6.0 MMbpd	+11.1 MMbpd
Crude oil prices (WTI)	+$25 per barrel	+$40 per barrel
Natural gas prices (Henry Hub)	+$8 per MMbtu	+$21 per MMbtu
Retail electricity prices	24.1%	56.4%
Economy wide CO2 emissions	-3.5%	-13.1%

While the outcomes are on the edge of the model's capabilities, they are indicative of the likely pressures that would result from a scenario as extreme as was modeled here. See Caveats and Limitations section for more discussion.

Table of Contents

List of Figures

Executive Summary

Over the last decade, the *Keep It In The Ground* (KIG) effort has evolved from its initial start as a movement to halt oil and gas development on public lands in the US to a climate movement. If successful, efforts to stop the extraction of fossil fuels over the next two decades could have a profound economic impact on the United States. The American Petroleum Institute (API) sponsored this study to spotlight the implications of a future in which *no new fossil fuel production development* occurs.

API commissioned OnLocation, Inc. to perform this study using the National Energy Modeling System (NEMS) that is maintained by the Energy Information Administration (EIA) and used to develop the Annual Energy Outlook (AEO). The AEO 2016 model and input files were used as a starting point and reference case in this analysis. The KIG assumptions provided by API to describe the KIG scenario included:

- No new private, State or Federal oil and natural gas leases
- A complete ban on the use of hydraulic fracturing technology in drilling for oil and gas
- No new coal mines or expansion of existing mines
- No new energy infrastructure (e.g., pipelines)
- Restricting imports/exports to existing trade infrastructure
- No expansion of international gas pipelines into the U.S.

To perform this study, OnLocation made changes to the NEMS model and data inputs to reflect the above assumptions. See Appendix A for a description of this implementation of NEMS. Since OnLocation performed this study and not EIA, all subsequent references to the model and its outputs will be referenced as coming from the KIG-NEMS.

This Executive Summary presents the highlights of the Keep It in The Ground analysis. A more in-depth look at the results of the KIG-NEMS model runs are provided in the body of the report.

	Increase over Ref. Case		
	2020	2030	2040
Increase in Direct Household Energy Expenditures	$783	$938	$1,167
Increase Over Reference Case	16%	21%	26%
Total Increase in Energy Expenditures			
Economy Wide / household	$1,958	$3,128	$4,552
Increase Over Reference Case	19%	29%	39%
Natural Gas : Residential	74%	114%	124%
Motor Gasoline	11%	18%	24%
Average Electricity Price	24%	29%	56%

Figure 1: Potential Household Energy Expenditures and Price Increases Relative to Reference Case

As one would expect, restricting US production of coal, natural gas and oil could drive up the prices of energy for consumers (Figure 1). Direct household energy expenditures (electricity, home heating/cooking and transportation fuels) could increase by $1,167 in 2040. Including "hidden" energy costs in other goods and services, total additional household expenditures due to the KIG scenario could be roughly $4,552.

A primary indicator used to gauge the health of the economy is the gross domestic product (GDP). Higher energy prices and lower domestic energy production lead to a significant drop in US GDP. In real dollar terms, GDP is reduced by $440 billion in 2020 and $850 billion in 2040 (Figure 2). The cumulative loss in GDP is estimated to be $823 billion by 2020 and $11.8 trillion by 2040.

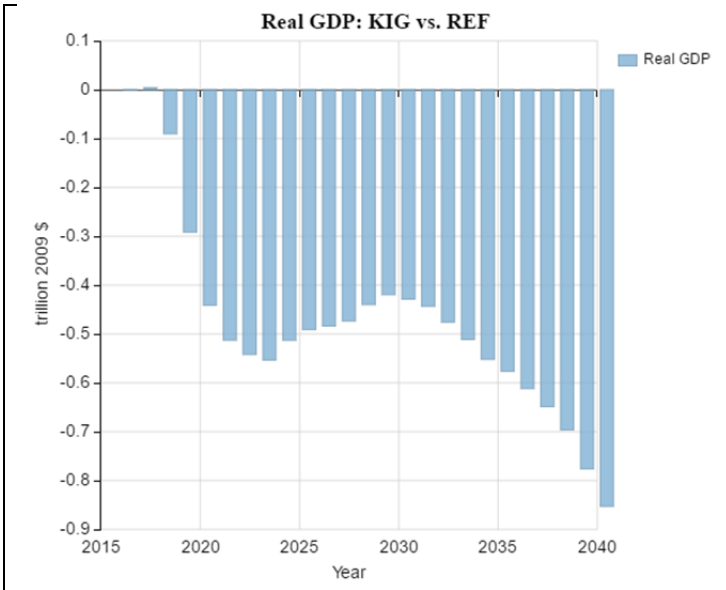

Figure 2: Loss in GDP (2009 Chain weighted dollars)

Lower GDP, higher energy prices and lower domestic production of energy lead to job losses. While the economy continues to grow, albeit at a slower pace, the lower level of economic activity leads to unprecedented job losses. As shown in Figure 3, over the forecast period, job losses range from 3.5 million to 5.9 million raising the unemployment rate to over 7% throughout much of the 2020-2040 period.[1]

[1] Estimates of EMPLOYMENT AND JOBS FORECASTS CORRESPONDING TO TWO "LEAVE IT IN GROUND" SCENARIOS, Prepared for OnLocation, Inc. By Management Information Services, Inc., January 4, 2017

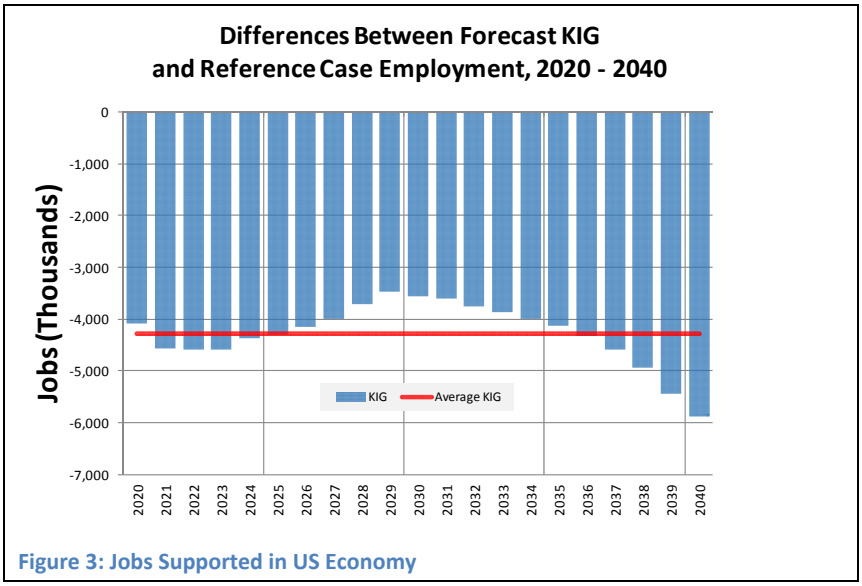

Figure 3: Jobs Supported in US Economy

Restricted production leads to reversals in energy trade trends. As shown in Figure 4, the US goes from a net exporter of energy in the reference case to a net importer in the KIG scenario. Instead of being a net exporter and becoming energy secure, the US becomes a net importer of energy rising to unprecedented levels.

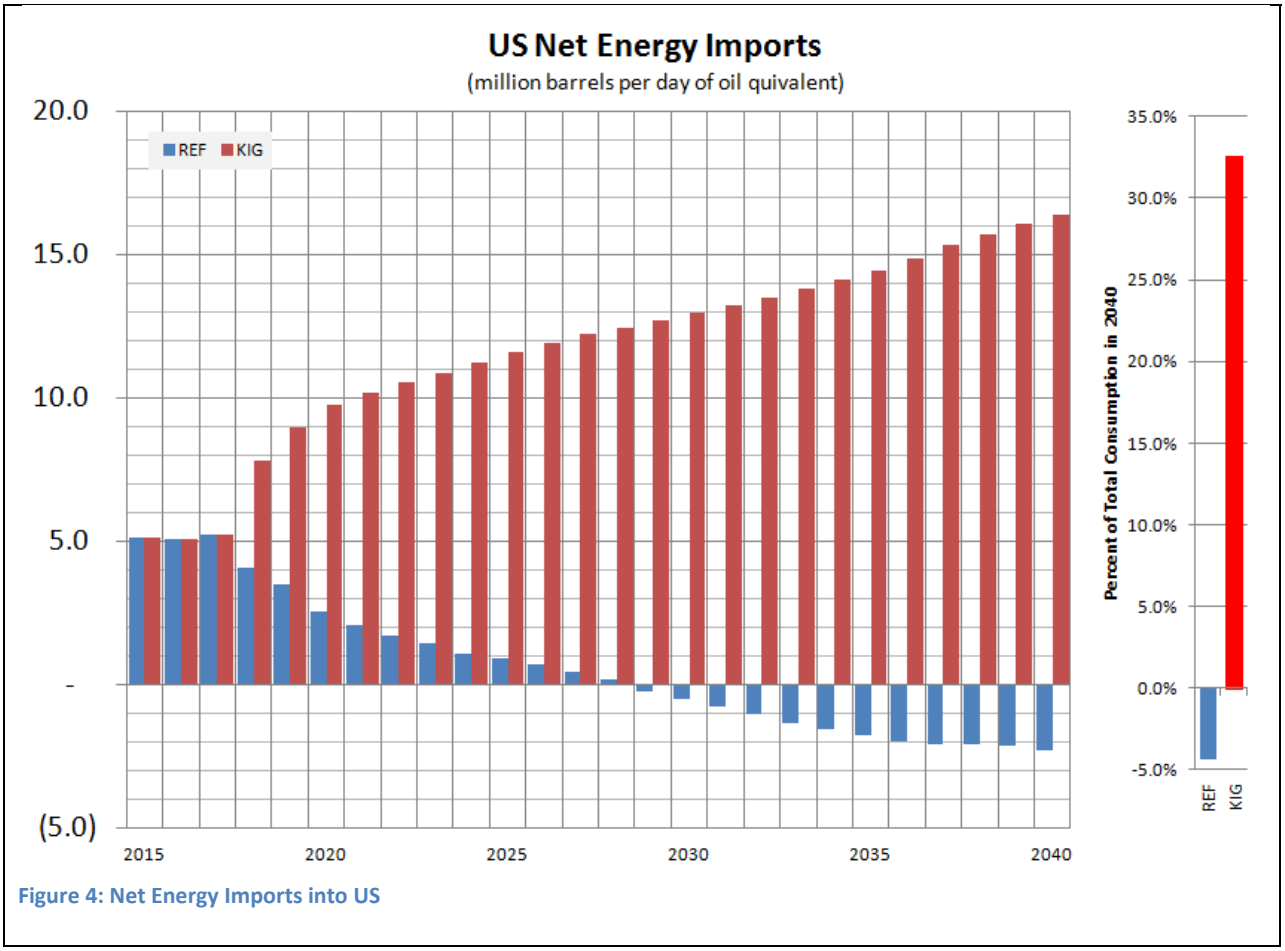

Figure 4: Net Energy Imports into US

As is evident in the model outputs, KIG-NEMS is stretched to respond to the KIG scenarios. Because we are pushing the model significantly, one should view the results as being indicative and directionally accurate but not necessarily a point forecast. The reader should read the Caveats and Limitations section for more discussion.

Background

Over the last decade, the *Keep It In The Ground* (KIG) effort has evolved from its initial start as a movement to halt oil and gas development on public lands in the US to a climate movement. If successful, efforts to stop the extraction of fossil fuels over the next two decades could have a profound economic impact on the United States. The American Petroleum Institute (API) sponsored this study to spotlight the implications of a future in which *no new fossil fuel production development* occurs.

This study seeks to estimate the quantitative impact of the KIG scenario. While there are many energy models that could be employed in investigating a scenario like the KIG scenario (see the following section Approach for more specifics regarding the scenario), API chose to contract with OnLocation who has access and use of the Energy Information Administration's NEMS model. NEMS is used by EIA to project the energy, economic, environmental, and security impacts on the United States of alternative energy policies and different assumptions about energy markets. The projection horizon is approximately 25 years into the future[2]. The projections in Annual Energy Outlook 2016 (AEO2016) are from the present through 2040.

> *This period is one in which technology, demographics, and economic conditions are sufficiently understood to represent energy markets with a reasonable degree of confidence. NEMS provides a consistent framework for representing the complex interactions of the U.S. energy system and its response to a wide variety of alternative assumptions and policies or policy initiatives. As an annual model, NEMS can also be used to examine the impact of new energy programs and policies.* [3]

NEMS projections are not predictions of what will happen, but rather modeled estimates of what may happen given certain assumptions and methodologies. The NEMS model was developed and is maintained by EIA for use in developing annual projections for the "*Annual Energy Outlook*" and for evaluating energy policies based on service requests from Congress and various government agencies who specify the scenarios and assumptions for the analysis.

OnLocation has provided technical support in the design, development and application of the NEMS model since its creation over 20 years ago. Our technical and modeling experts have made major contributions to many of the modules of NEMS. Collectively, the staff of OnLocation has over 100 years of working experience with integrated energy models including NEMS. OnLocation's senior staff and associate consultants have provided insights and solutions to the business and policy challenges of the Department of Energy, Environmental Protection Agency, energy corporations and various non-governmental organizations that support policymakers in Congress and elsewhere. Using NEMS outputs, Management Information Systems, Inc., provided estimates of the employment impacts of the KIG scenario.

[2] Note, the latest release of NEMS goes to 2050 but was not available in time for this study. See AEO2017
[3] See EIA's Overview of NEMS

Approach

To assess the Keep It in The Ground (KIG) future, OnLocation customized a version of EIA's National Energy Modeling System (NEMS) to assess the impact on energy markets and the economy. The state level impact estimated in this study was performed by Management Information Services, Inc. based on NEMS model outputs for the KIG scenario.

OnLocation used EIA's Annual Energy Outlook 2016 Reference Case as the baseline: a business-as-usual trend estimate, given known technological and demographic trends and reflecting existing laws and regulations. The Reference case assumes Clean Power Plan (CPP) compliance through mass-based standards that establish caps on CO_2 emissions from fossil-fired generators covered by the CPP. The KIG scenarios were introduced into the model in 2018 at which point the economic impact becomes immediately visible in the estimates on various economic measures.

For the alternative "Keep It in The Ground" case, OnLocation worked with API staff to identify the specifications for a case that severely limits the expanded production of fossil fuels in the US. These specifications addressed changes to the model or model inputs to yield[4]:

- No new private, State or Federal oil and natural gas leases
- A complete ban on the use of hydraulic fracturing technology in drilling for oil and gas
- No new coal mines or expansion of existing mines
- No new energy infrastructure (e.g., pipelines)
- Restricting imports/exports to existing trade infrastructure
- No expansion of international gas pipelines into the U.S.

In addition to the Reference and KIG scenarios, a sensitivity case that limited construction of new nuclear power plants was evaluated.

OnLocation made appropriate modifications to the KIG-NEMS model[5] to run the alternative "Keep It in The Ground" scenario in KIG-NEMS.

[4] See Appendix II for a detailed discussion of the changes to the inputs and model code that were used to reflect these specifications.

[5] To constrain the penetration of PV generation to reasonable levels given its potential impact on the grid, OnLocation modified the NEMS code. OnLocation previously made this modification in an earlier version of the NEMS code and the latest AEO2017 version of NEMS includes this code modification.

Results

U.S. policies of "keep it in the ground" (KIG) generate the following impacts relative to the EIA's Annual Energy Outlook 2016 Reference Case. The keep it in the ground scenario includes no new oil and natural gas leases on private, State or federal lands, a ban on hydraulic fracturing, no new or expansions of existing coal mines, and no new energy infrastructure to transport oil and natural gas within and outside of North America. The KIG scenario model projects the following potential impacts:

- The KIG scenario leads to significantly higher energy prices, with oil prices $40 per barrel higher by 2040 and natural gas prices $21 per MMBtu higher than in the reference case. Retail electricity prices increase by 24 percent in 2020 and 56% in 2040.
- Domestic production of crude oil and natural gas liquids (NGLs) decreases by 6 million barrels per day (MMbpd) in 2020 and 11.7 MMbpd in 2040 while natural gas production decreases by 25 and 81 billion cubic feet per day (Bcfd) in the same years respectively relative to the reference case.
- These higher energy prices and lower domestic fossil energy production lead to lower economic growth with a cumulative loss in GDP of $823 (real 2009$) billion by 2020 and $11.8 (real 2009$) trillion by 2040[6].
- Job losses associated with the KIG scenario in 2020 were estimated to by 4.1 million and in 2040 were as high as 5.9 million.
- Net liquid petroleum imports increase by 6 MMbpd in 2020 and 11 MMbpd in 2040.
- Economy-wide energy expenditures increase by a cumulative $470 million by 2020 and $8.8 trillion by 2040 despite reduced energy consumption. In 2020 the increase equates to $1,900 *per household* and by 2040 the increase is $4,440.
- While coal prices rise due to limiting production capability in each region, overall coal consumption rises relative to the reference case due to fuel switching in the power sector.
- Economy-wide energy related CO_2 emissions decrease from the reference case by 3 percent in 2020 and 13 percent in 2040.

While the outcomes are on the edge of the model's capabilities, they are indicative of the likely pressures that would result from a scenario as extreme as was modeled here. See Caveats and Limitations section for more discussion.

[6] Macroeconomic values are presented in 2009 chain-weighted dollars. Unless otherwise stated, all other monetary values are in real 2015 dollars.

Economic Impacts (based on KIG-NEMS model)

GDP Impacts

- Lower U.S. energy production and higher energy prices reduce GDP by $440 billion in 2020 and $850 billion in 2040; the percentage difference ranges between 2.0 to 3.0 percent in the KIG scenario relative to the reference case.
- The cumulative loss is $ 820 billion by 2020 and $11.8 trillion by 2040 (undiscounted).

Industrial Output Impacts

- Industrial output expressed in monetary terms is initially lower (by $250 billion in 2020) but then remains relatively unchanged from the reference case in the long-term due to higher embedded energy prices.
- The cumulative reduction from the reference case is $470 billion by 2020 and $4.3 trillion by 2040.

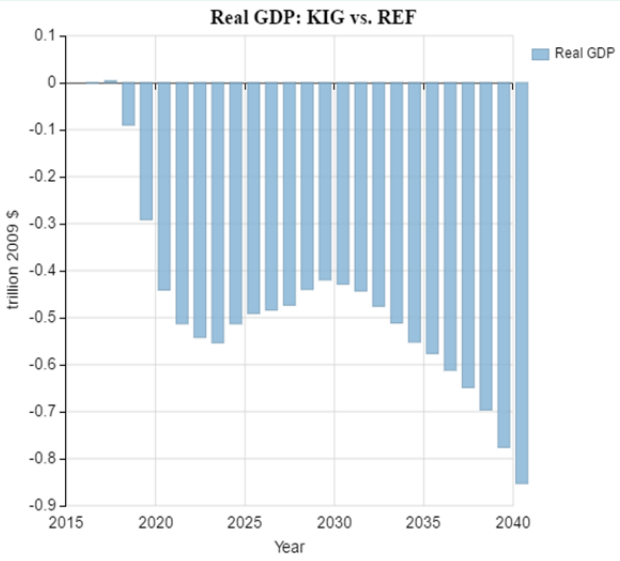

Figure 5: Loss in GDP (2009 Chain weighted dollars)

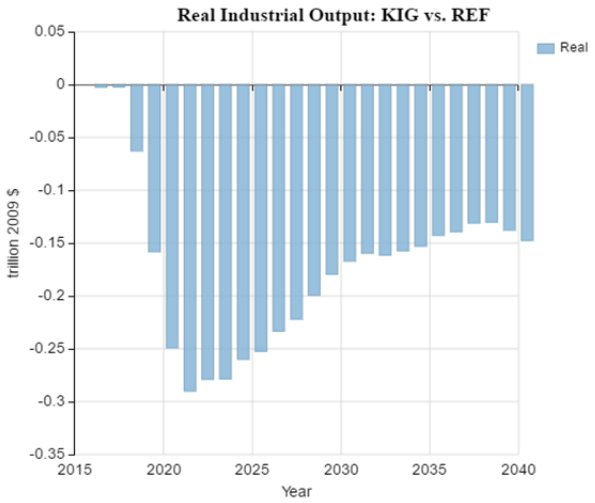

Figure 6: Loss in Real Industrial Output

Job Impacts (based on KIG-NEMS model)

Jobs Supported in US Economy

- A major result of the KIG scenario is the loss of an average of about 4.2 - 4.3 million job-years annually between 2020 and 2040.in the U.S., compared to the Reference Case.
- Job losses in 2020 were estimated to be 4.1 million and in 2040 were as high as 5.9 million.

Increases in Unemployment

- The KIG scenario results in a persistent recession level unemployment throughout the 2020-2040 period.
- Unemployment rates of 8.2% have been exceeded only twice in the past 70 years – in 1982-3 and 2009-11.

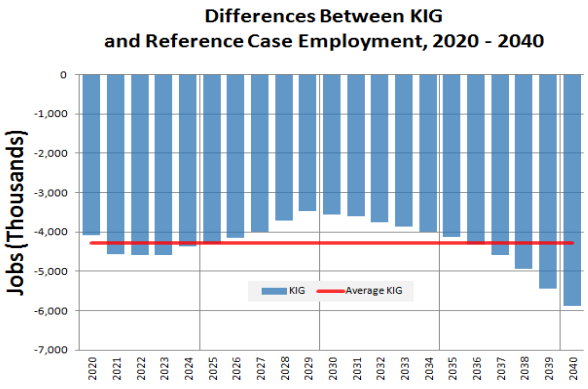

Figure 7: Loss in Jobs

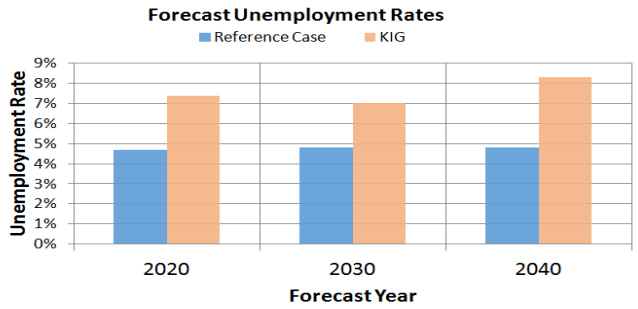

Figure 8: Unemployment

Jobs Losses by State in 2040

- The major state job losses are concentrated in those states that are the most energy industry-dependent and that lack a strong base of non-energy industries and jobs, such as North Dakota, West Virginia, and Wyoming.
- To derive the state job estimates, MISI used the KIG-NEMS estimates of the regional outputs compared to the Reference Case, across the nine Census Regions and the 22 Electricity Market Module Regions to determine the relative impacts among the states.
- MISI assumed that employment changes are related to the *changes* in energy production and consumption and estimated job changes as a function of the energy data series for electricity production and consumption by region.
- The resulting job estimates corresponding were determined by the energy market perturbations caused by the scenarios and the forecast state-by-state employment changes through 2040. (*see following description of MISI Approach*)

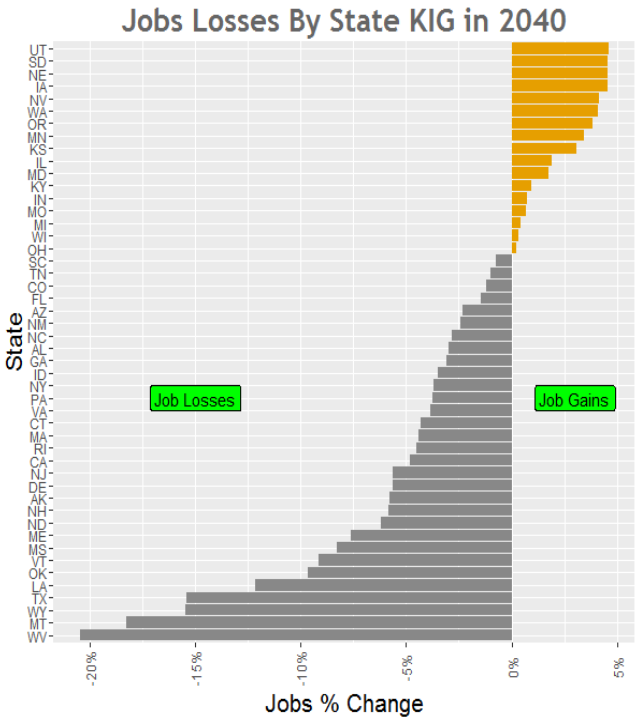

Figure 9: Job Losses by State in 2040

Management Information Systems, Inc. (MISI) Approach to Modeling Job Impacts [1]

- Using data from the KIG-NEMS scenarios, MISI was asked to estimate the employment impacts of the KIG scenario at the state level because KIG-NEMS does not generate state-level data.
- MISI estimated the employment and jobs impacts (direct and indirect) of the KIG scenario through 2040 using the full time equivalent job concept.
- MISI estimated job impacts in the U.S. for the years 2020 through 2040 and job impacts of lower 48 states for 2020, for 2030, and for 2040.
- MISI employment estimates may vary from those available from KIG-NEMS for several reasons.
  - State employment forecasts are not available from KIG-NEMS.
  - First Reference Case state population forecasts were developed using Weldon Cooper Center for Public Service, Demographics Research Group, projections, and using EIA AEO 2016 Reference Case total U.S. population forecasts as the control totals for each year.
  - Then Reference Case employment forecasts for each state were derived using the ratios of employment in each state to state population, available from BLS and Census. To be consistent, the national employment forecasts were reconciled with the state population and employment forecasts.
  - To derive the state job estimates corresponding to the KIG and the NN scenarios, MISI used the KIG-NEMS estimates of the regional outputs of the two scenarios, compared to the Reference Case, across the nine Census Regions and the 22 Electricity Market Module Regions to determine the relative impacts among the states.
  - MISI assumed that employment changes are related to the changes in energy production and consumption resulting from the two scenarios, and estimated job changes as a function of the energy data series for electricity production and consumption by region.
  - The resulting job estimates corresponding to each of the two alternate scenarios were determined by the regional energy market perturbations caused by the scenarios and the forecast state-by-state employment changes through 2040.
  - Relatively few states gained jobs and the state employment gains were usually much less than the job losses experienced in the most severely affected states.
    - Nevertheless, several states gain jobs under both scenarios, including Maryland, Minnesota, Nevada, Oregon, Utah, and Washington. The relatively few states that gain jobs are not fossil energy-dependent and have a strong base of non-fossil energy dependent sectors, industries, and jobs.
    - Thus, under both scenarios large job gains would likely occur in non-fossil energy dependent services and in industries such as Electric Vehicles, Hydrogen Vehicles, Solar Electric Power Generation, Wind Energy Systems, Geothermal Energy, Biomass Energy Systems, Photovoltaic Cells and Devices Manufacturing, Hydrogen Manufacturing, Hydro Energy, Energy Efficiency and Conservation Products and Systems, Hydrogen Energy Systems, Alternative Energy Systems, etc.
  - It is also important to note that job gains in these states are net job gains. Some jobs in certain sectors and industries could be lost under each scenario. However, these job losses could be exceeded by job gains in these states in other sectors and industries. Further, the job gains in these states could be accompanied by substantial job shifts among industries, sectors, and occupations within each state. That is, even in the states that gain jobs some industries and sectors would lose jobs. Further, even in those sectors and industries that gain jobs, some workers may be displaced.

[1] **EMPLOYMENT AND JOBS FORECASTS CORRESPONDING TO TWO "LEAVE IT IN GROUND" SCENARIOS** , Prepared For OnLocation, Inc. By Management Information Services, Inc., January 4, 2017

Energy Prices (based on KIG-NEMS model)

Home Energy Bills per Household

- Households could spend on average $630 per year (up to almost $800 in 2040) or over 30 percent more for energy use in their homes in the KIG case, even while consuming less energy (roughly 5 percent less in 2020 and 13 percent in 2040).
- Higher fuel prices could push up the average price of electricity by 24 percent in 2020 and 56 percent by 2040. The coal and gas price increases appear to compound at the end of the horizon
- Natural gas prices could be severely impacted by reduced domestic production, with Henry Hub prices potentially rising to almost $26 per MMBTU by 2040 and residential prices potentially rising to almost $28.
- Home heating oil prices potentially rise to significantly higher levels in the KIG scenario to over $5.60 in constant 2015 dollars.

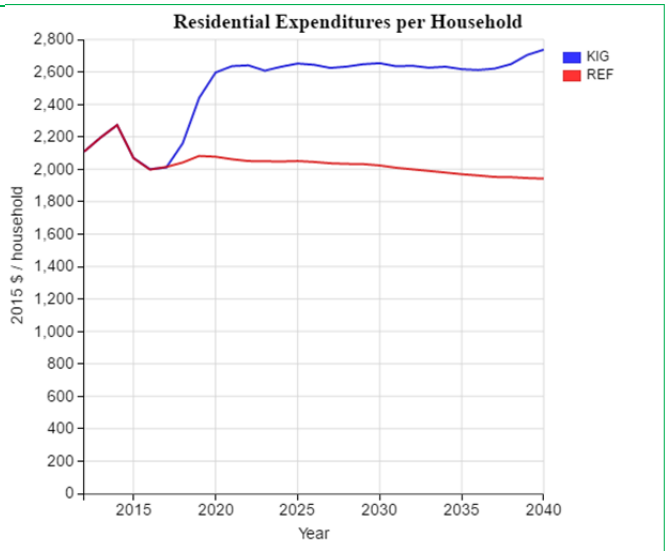

Figure 10: Residential Energy Expenditure Per Household

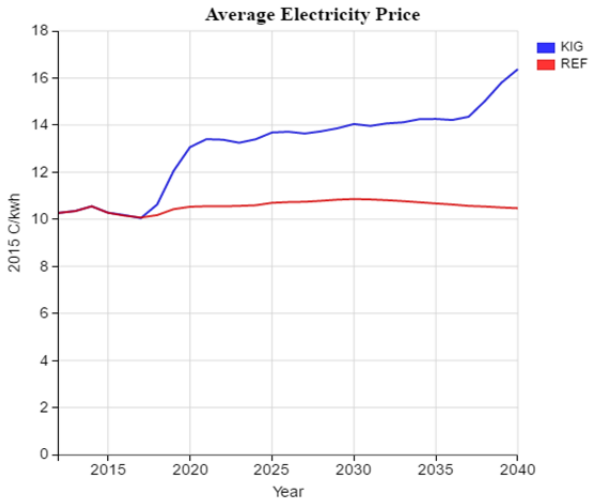

Figure 11: Average Electricity Price

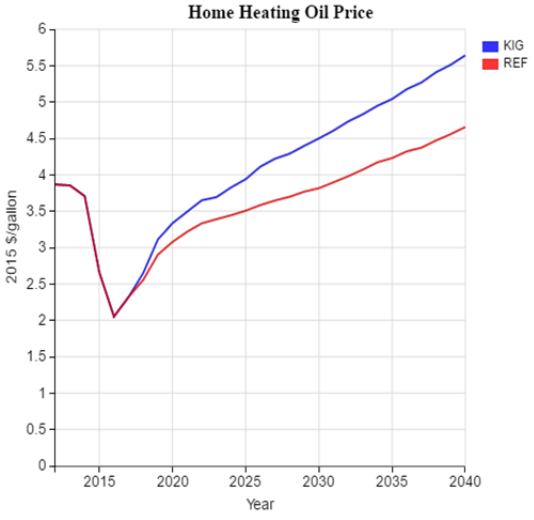

Figure 12: Home Heating Oil Price

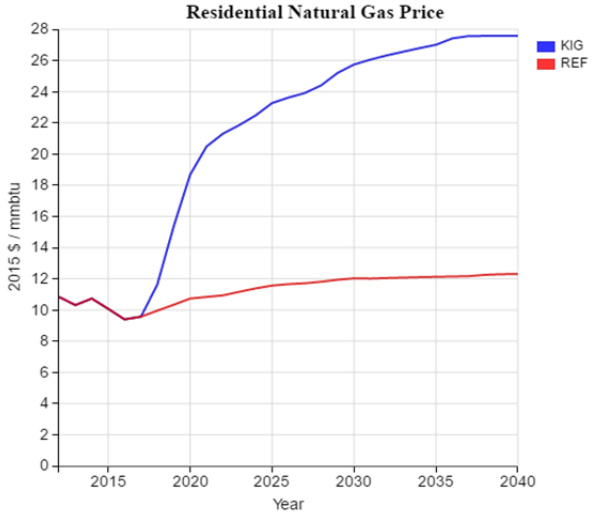

Figure 13: Residential Natural Gas Price

Energy Prices Continued (based on KIG-NEMS model)

Total Household Energy Bills

- When vehicle energy costs are included, the average household could spend an average of $930 more per year or up to roughly $1,167 in 2040.
- In the KIG scenario gasoline prices could rise to over $4.70 in constant 2015 dollars significantly higher than in the Reference case scenario.

Total Economy-wide Energy Expenditures

- Total energy expenditures could be 18 percent higher in the KIG case than the reference case in 2020 and could increase to 38 percent higher in 2040, or a cumulative increase of $470 billion by 2020 and $8.8 trillion by 2040.
- On a per household basis, the expenditure increase could be $1,958 in 2020 and $4,552 in 2040.

Loss in Disposable Personal Income

- Disposable personal income is lower as energy prices could rise with a reduction of $320 billion in 2020 and $790 billion in 2040 relative to the reference case, which equals a cumulative reduction of $560 billion by 2020 and $10.7 trillion by 2040.
- On a per household basis this loss could be $2440 in 2020 and $4990 in 2040.

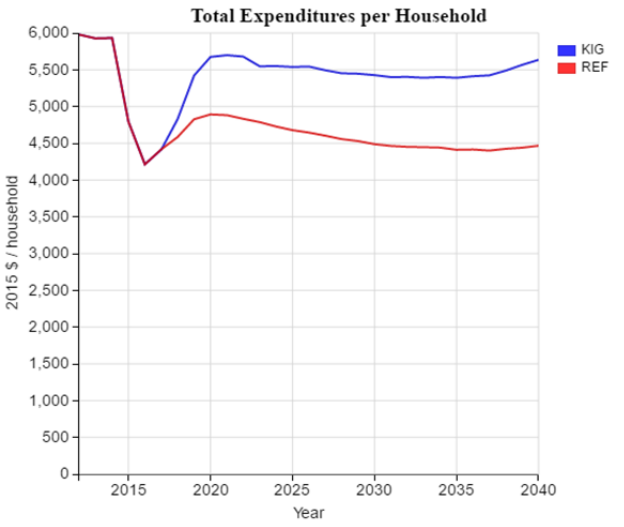

Figure 14: Total Expenditures Per Household

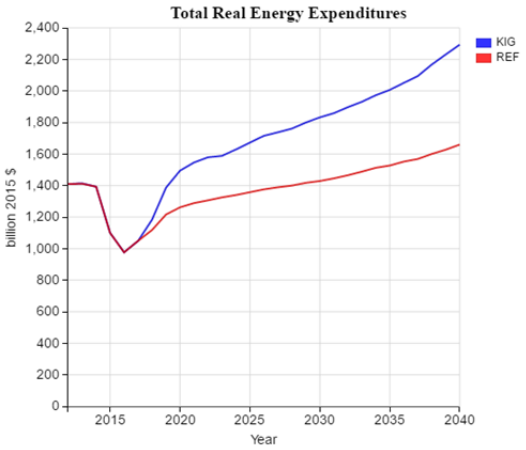

Figure 15: Total Real Energy Expenditures

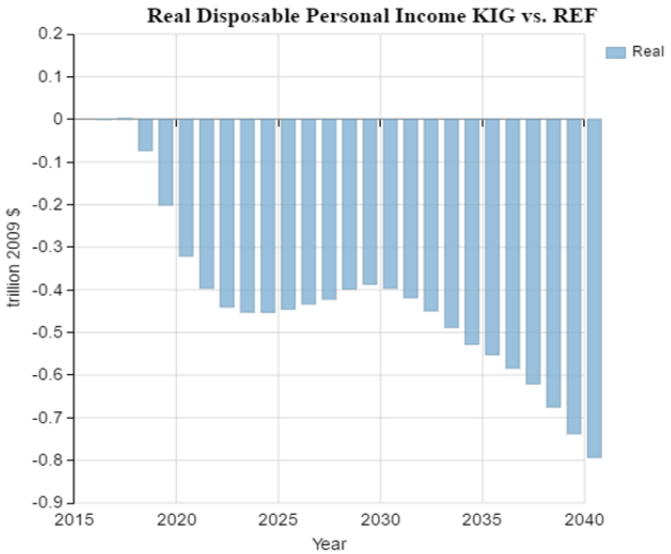

Figure 16: Loss in Real Disposable Income

Energy Prices Continued (based on KIG-NEMS model)

Other Energy Prices

- The model predicts that crude oil prices are driven up by lower U.S. production in the KIG scenario due to eliminating hydraulic fracking and without new private, State or Federal leases. They could rise to $176 per barrel by 2040 compared to $136 in the reference case.
- Gasoline prices could rise in parallel with crude oil prices, potentially increasing 11 percent by 2020 and 24 percent by 2040.
- Henry Hub natural gas prices could rise dramatically in response to no hydraulic fracturing and without new private, State or Federal natural gas leases. According to the model, natural gas prices were the most dramatically impacted by the KIG scenario, potentially rising by almost $21 per MMBtu or 440 percent by 2040.
- By 2040, the model predicts that the price of coal to electric generators could increase by almost 40 percent relative to the reference case.

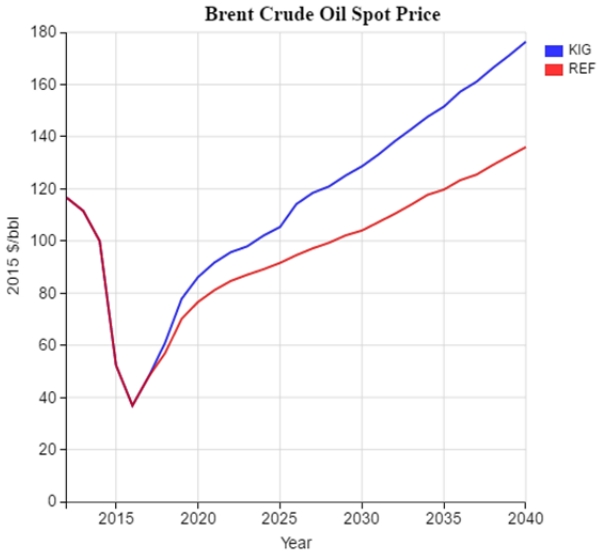

Figure 17: Brent Crude Oil Spot Price

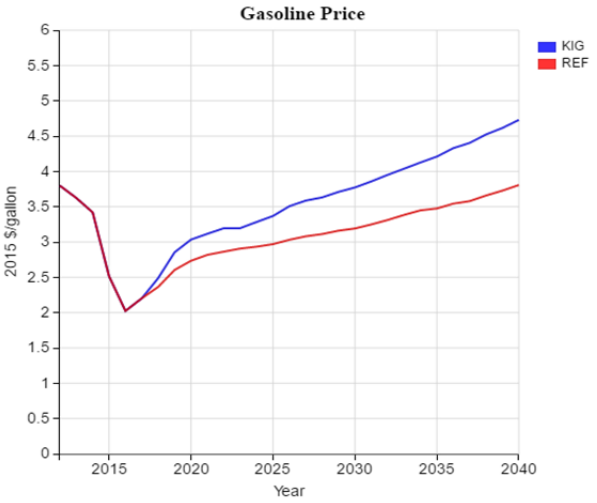

Figure 18: Gasoline Price

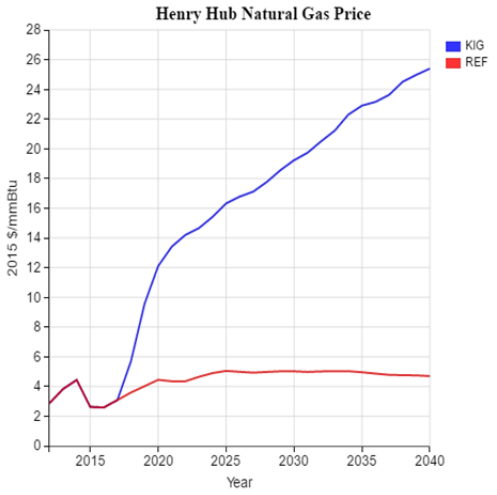

Figure 19: Henry Hub Natural Gas Price

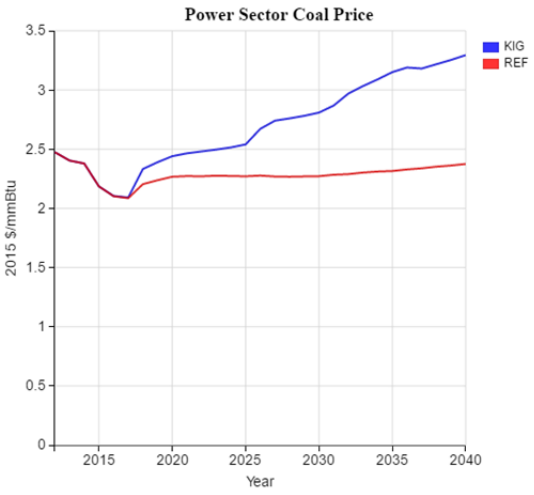

Figure 20: Power Sector Coal Price

Fossil Energy Production (based on KIG-NEMS model)

Oil and NGL Production Domestic oil production is significantly reduced immediately due to restrictions on hydraulic fracturing with a 6 MMbpd decrease in 2020, and further reductions occur over time as existing leases are depleted. By 2040 the loss in production is almost 12 MMbpd.

Natural Gas Production Similar reductions occur for natural gas, with significant reductions in shale gas production that was otherwise projected to provide the major share of increased production in the reference case. In 2020 production is 9 tcf or 25 Bcfd lower and by 2040 the loss is 29 Tcf or 81 Bcfd.

Coal Production

- Coal production is projected to decline in the reference case due to shrinking demand from the power sector.
- Although coal production is constrained, it still is higher than in the reference case due to the very high cost of natural gas and fuel switching in the power sector.
- Coal production increases by 67 million tons or 8 percent in 2020 from the reference case but stays below historic levels. The peak increase occurs in 2030 with an additional 155 million tons or 8 percent increase.

Energy Imports Restricted production leads to reversals in energy trade trends. The US goes from a net exporter of energy by 2029 in the reference case to an ever increasing net importer. By 2040 the US is importing almost 1/3 of its total energy needs.

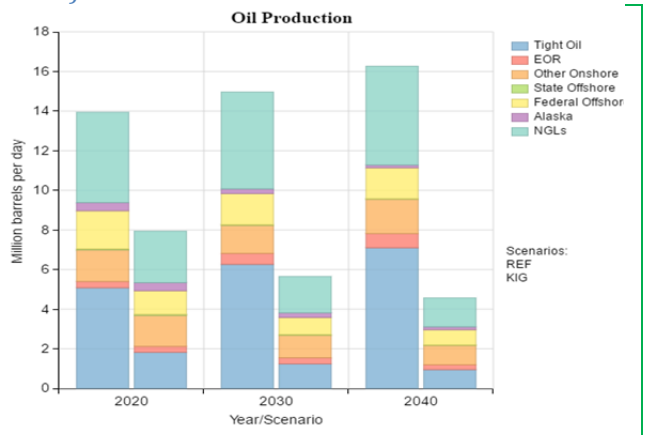

Figure 21: Oil Production

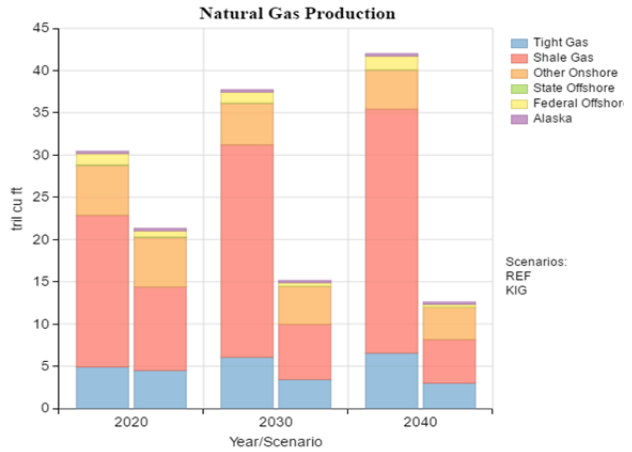

Figure 22: Natural Gas Production

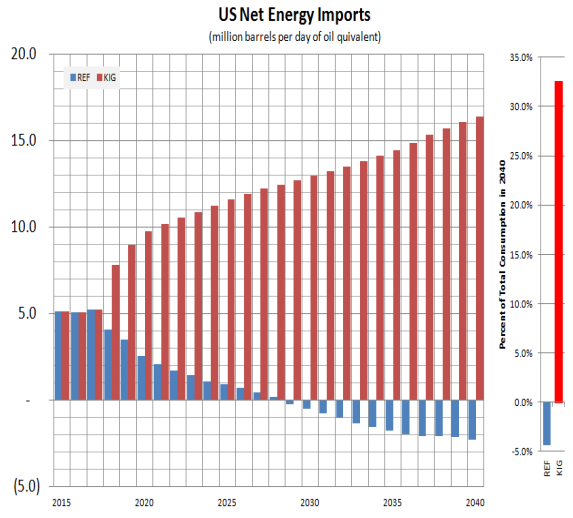

Figure 23: US Net Energy Imports

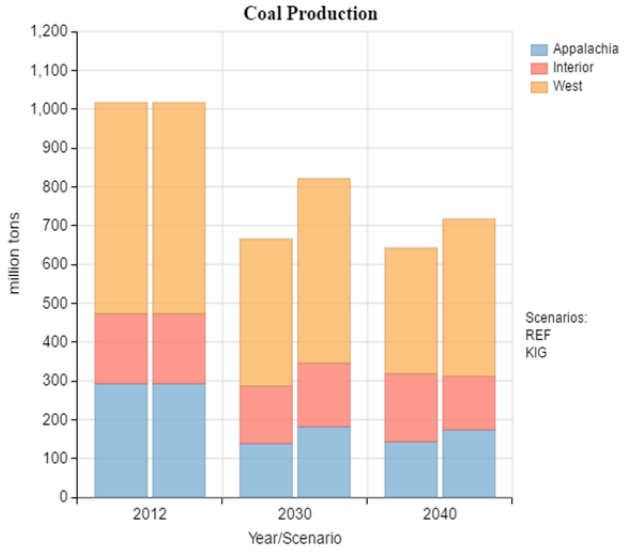

Figure 24: Coal Production

Fossil Energy Demand (based on KIG-NEMS model)

Liquids Fuel Demand The demand for liquid fuels (petroleum and biomass based) remains relatively constant between the cases as transportation demand shrinks due to higher prices while industrial demand increases due to substitution for natural gas.

- Transportation demand decreases by 0.6 quads in 2020 and 0.7 quads by 2040 (2 to 3 percent)
- Industrial liquids demand increases by 0.2 quads or 2 percent in 2020 and 0.5 quads or 4 percent in 2040.

Natural Gas Demand Natural gas demand is lower in all sectors in the KIG scenarios due to much higher prices, especially in the power sector where it is reduced by over 10 quads or 80 percent by 2040.

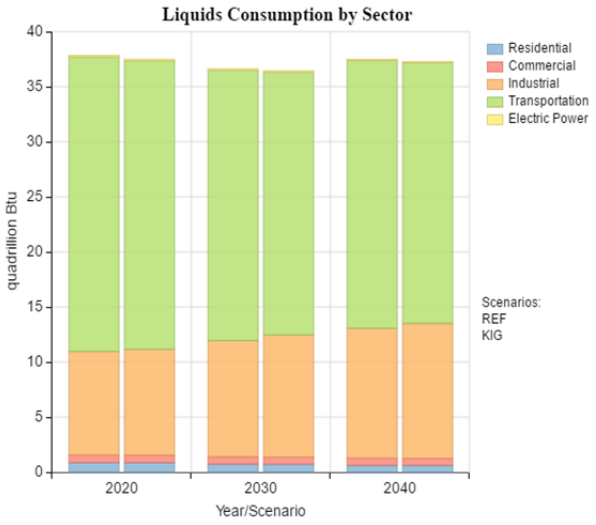

Figure 25: Liquid Fuels Consumption by Sector

Coal Demand

- Coal use in the power sector increases in the KIG scenario by 1.4 quads in 2020 and 3.0 quads in 2040 relative to the Reference case.
- Coal use increases as part of the shift away from natural gas due to the latter's significantly higher relative price.
- The use of coal is declining in both scenarios driven by the Clean Power Plan; it just declines slower in the KIG scenario.
- In the last few years of the forecast, coal imports rise slightly.

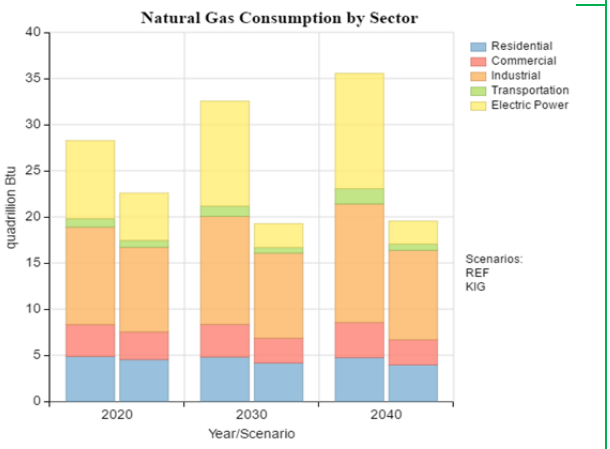

Figure 26: Natural Gas Consumption by Sector

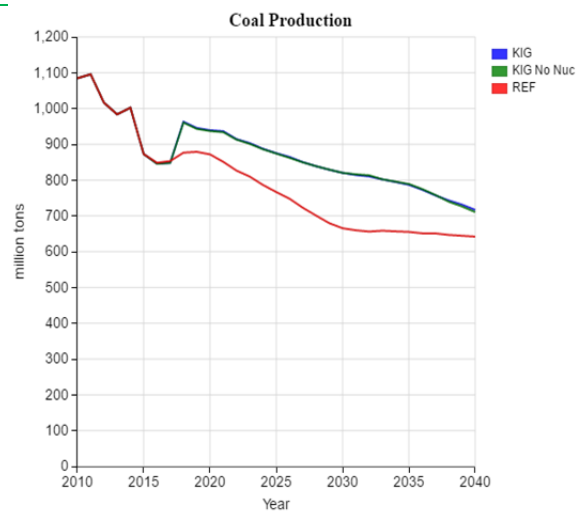

Figure 27: Coal Production Total

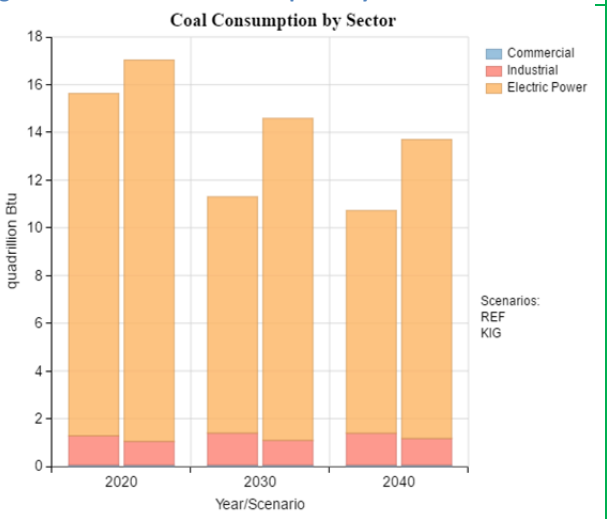

Figure 28: Coal Consumption by Sector

Fossil Energy Imports and Exports (based on KIG-NEMS model)

Net Oil Imports Instead of declining as in the reference case, net petroleum imports are projected to increase significantly in the KIG scenario.

- By 2020, net oil imports are 5.6 MMbpd higher than in the reference and by 2040 11.1 MMbpd higher, reaching a total of 12.5 MMbpd.

Natural Gas Imports and Exports

- Imports of natural gas rise to make up some of the domestic lost production although remain within the limits of the current infrastructure capacity
- At the same time, exports fall due to higher prices in the U.S.
- The total annual cost of imports rises to roughly $6 billion in 2020 and $129 billion in 2040 in the KIG case compared to a net revenue of $48 billion and $57 billion respectively in the Reference case.
- The cumulative difference is a net increase in outflows of $2.2 trillion by 2040.

Net annual oil import expenditures Net annual expenditures for crude and product imports increase by $150 billion in 2020 and $580 billion 2040, leading to a cumulative increase in outflows of $7.5 trillion by 2040.

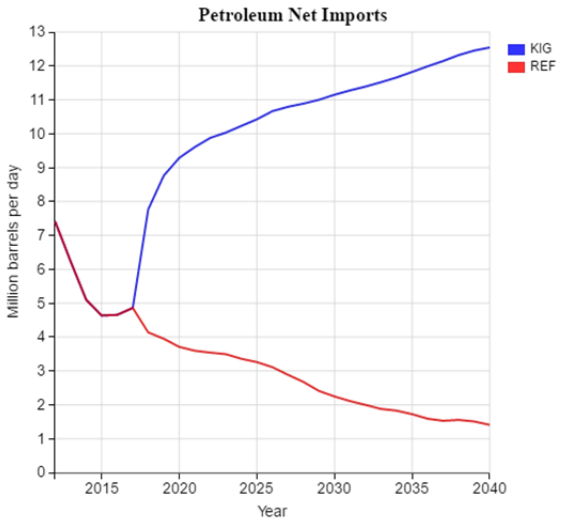

Figure 29: Petroleum Net Imports

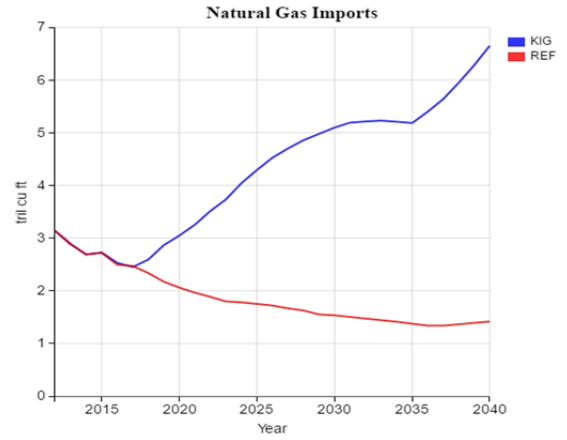

Figure 30: Natural Gas Imports

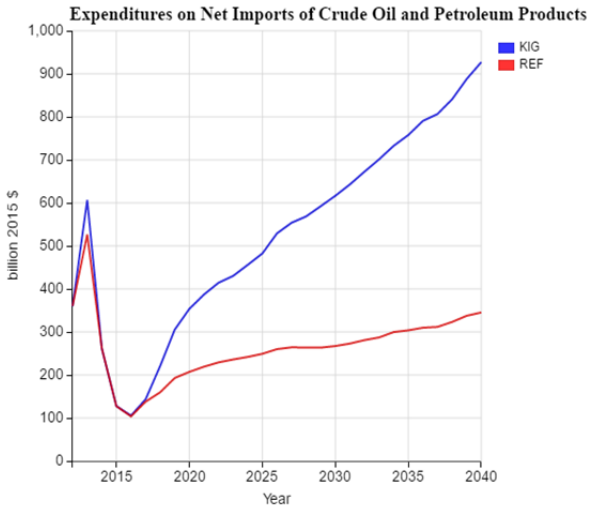

Figure 31: Expenditures on Net Imports of Crude/Petroleum Products

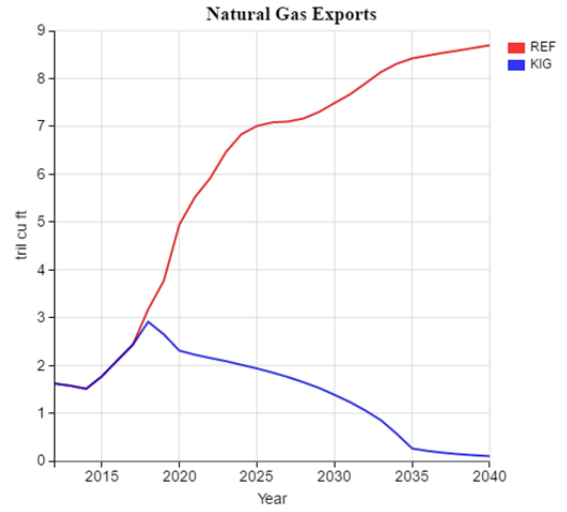

Figure 32: Natural Gas Exports

Electricity Generation (based on KIG-NEMS model)

Electric Power Due to the current diversity in power generation capacity, the power industry has the greatest ability to substitute fuels.

- As such the industry responds rapidly to the higher priced natural gas by shifting generation.
- The higher price of natural gas quickly could translate into a higher electricity price with a 24 percent increase from reference in 2020 and a 56 percent increase by 2040.
- Despite being relatively inelastic, the demand for electricity is reduced in response to the higher electricity price. Total electricity sales are 4 percent and 8 percent lower in the KIG case relative to reference in 2020 and 2040 respectively.

Electricity Generation

- As shown in Figure 35, in the face of higher natural gas prices, generation shifts away from natural gas.
- Natural gas generation is displaced by renewable energy sources (wind and solar), coal generation and nuclear power generation, as illustrated in Figure 36.

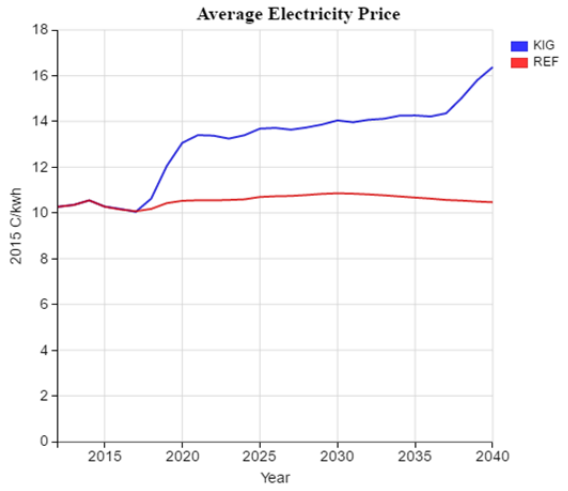

Figure 33: Average Electricity Price

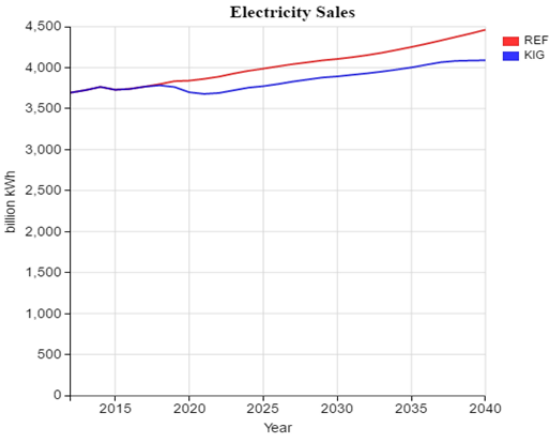

Figure 34: Electricity Sales

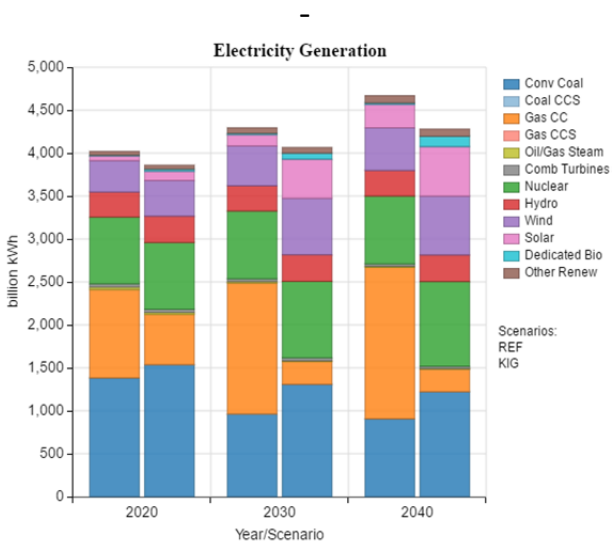

Figure 35: Electricity Generation

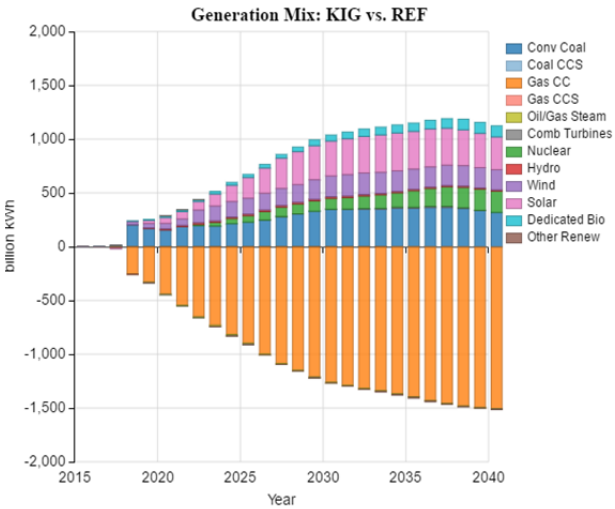

Figure 36: Changes in Generation Mix

Electricity Generation Continued (based on KIG-NEMS model)

Electricity Capacity

Reference Case has approximately 390 GW of capacity additions while the KIG case has about 520 GW.

- Reference and KIG cases have *no new coal* capacity additions.
- Reference case has only planned nuclear additions of 4.4 GW while the KIG case has an additional 25 GW of nuclear capacity built.
- In the Reference case about 200 GW of renewable capacity is added while in the KIG scenario the *majority* of new capacity is renewable with over 400 GW being built.
- Due to the intermittent nature of wind and photovoltaic (PV), more total capacity is needed even though generation is lower.

Capacity Retirements

The Reference case has a total of 190 GW of retirements. The KIG case retires an additional 55 GW of capacity.

- Higher natural gas prices lead to over 100 GW greater retirements of the less efficient and now more expensive oil and gas steam, gas turbine and combined cycle capacity in the KIG case.
- On the other hand, 48 GW less coal capacity retires in the KIG case.

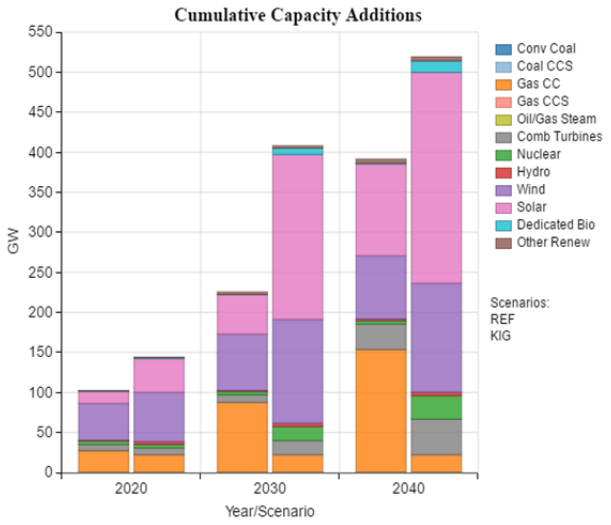

Figure 37: Cumulative Electric Capacity Additions

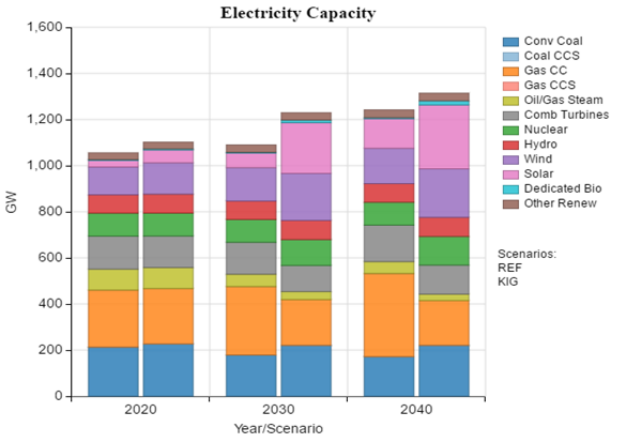

Figure 38: Electric Capacity in Select Years

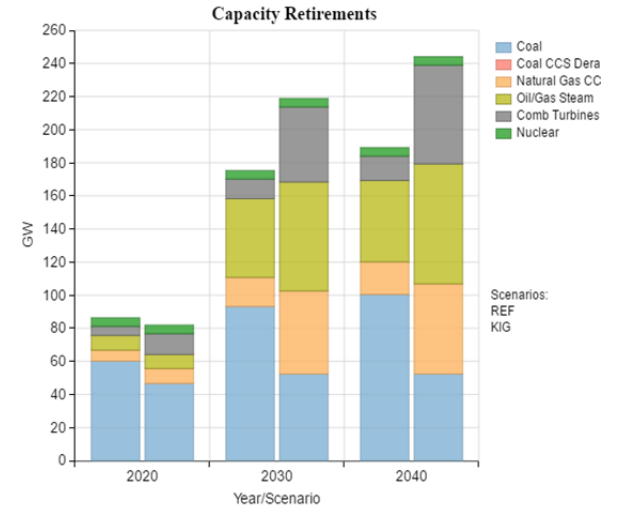

Figure 39: Cumulative Electric Capacity Retirements

No New Nuclear Power Plant Construction (based on KIG-NEMS model)

In the KIG case, new nuclear construction added about 25 GW of capacity. A case that did not allow any nuclear construction was added to assess the degree to which the new nuclear capacity was impacting the KIG results. This case assumed no new nuclear power plant construction was allowed except for the current 4GW planned and under construction.

GDP Impacts The restriction on nuclear construction had virtually no measurable impact on the KIG case.

Energy Prices Henry Hub natural gas prices could increase on average by $1.00 (or 5 percent) as a result of the ban on new nuclear capacity in the KIG case, while electricity prices could rise on average 2 percent over the KIG case.

Energy Expenditures The natural gas and electricity prices could be incrementally higher in the No Nuclear case, which results in increased household expenditures and total energy expenditures.

Restricted Capacity Additions The restriction on new nuclear construction resulted in more wind and PV capacity.

Capacity Retirements The restriction on new nuclear construction resulted in greater retention of natural gas fired capacity (CC, Oil and Gas steam and combustion turbines)

Electricity Generation When new nuclear capacity cannot be added, additional generation is provided by gas combined cycles, wind and PV.

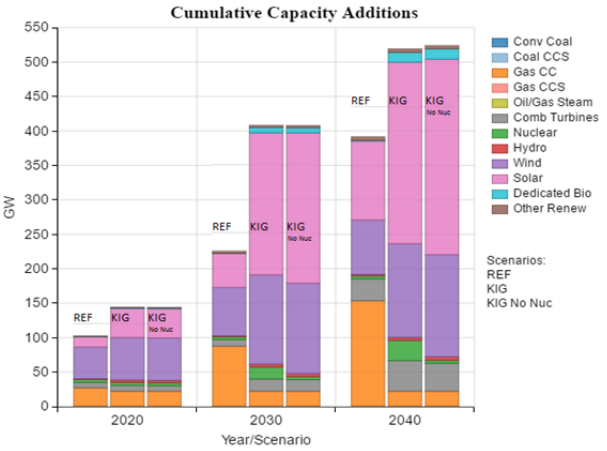

Figure 40: No New Nuclear: Cumulative Electric Capacity Additions

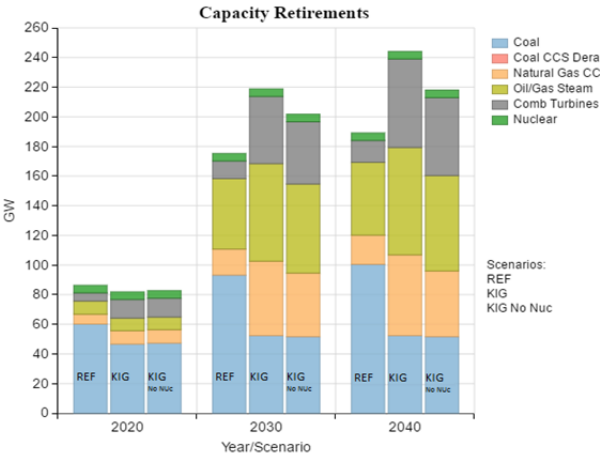

Figure 41: No New Nuclear: Cumulative Capacity Retirements

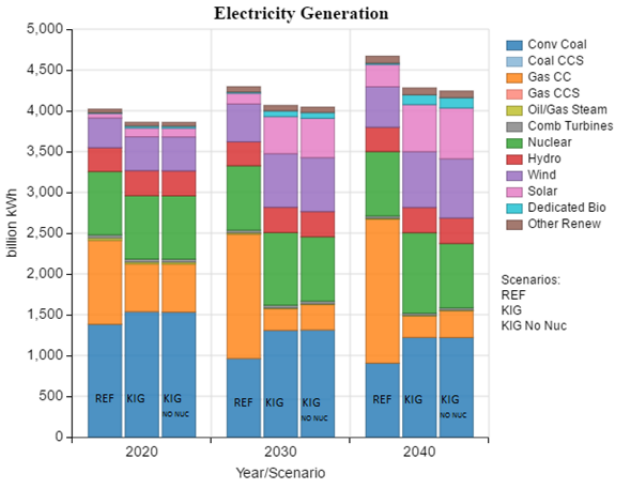

Figure 42: No New Nuclear: Electricity Generation

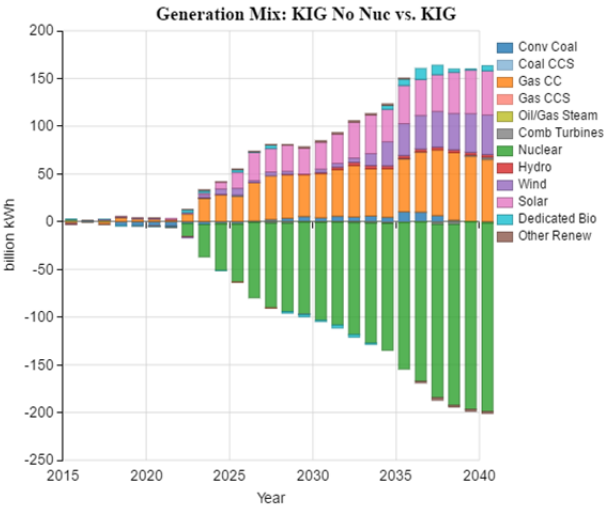

Figure 43: No New Nuclear: Changes in Generation Mix

Carbon Emissions (based on KIG-NEMS model)

Power Sector CO2 Emissions

The decline in fossil-fueled electricity generation reduces CO2 emissions relative to the reference case, but not dramatically due to an increase in coal generation.

- The inclusion of new nuclear capacity additions makes a relatively small difference
- Emissions are 20 to 24 MMT (1 percent) lower than the reference case in 2020, and 284 to 296 MMT (18 to 19 percent) lower in 2040, depending on whether new nuclear capacity is built
- Cumulative reductions are 0.1 gigatonnes by 2020 and 2.4 to 2.8 Gt or 6 to 7 percent lower in 2040
- In 2015 power emissions were 22 percent below their 2005 level. In the KIG scenarios in 2040, power sector emissions are roughly 48 percent below their 2005 level

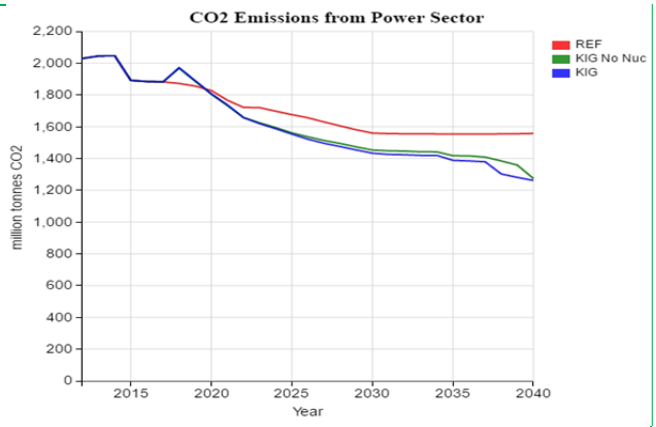

Figure 44: CO2 Emissions from Power Sector By Year

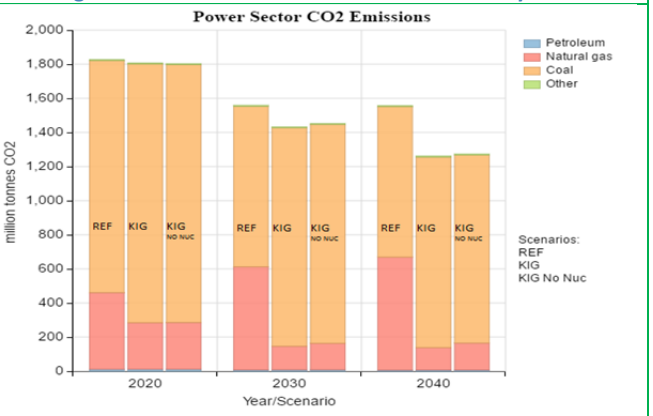

Figure 45: CO2 Emissions from Power Sector Select Years

Economy-Wide CO2 Emissions

- Emissions economy-wide are reduced by roughly 185 MMT in 2020 and 660 in 2040 or 3 and 13 percent respectively
- Cumulative emissions are 3.9 Gt lower in 2030 and 8.9 to 9.1 Gt in 2040 than the reference case which is a 7 percent reduction in each period
- In 2015 emissions were 12 percent below their 2005 level. In the KIG scenarios in 2040, the KIG achieves a 27 percent reduction from 2005 energy-related CO2 emissions

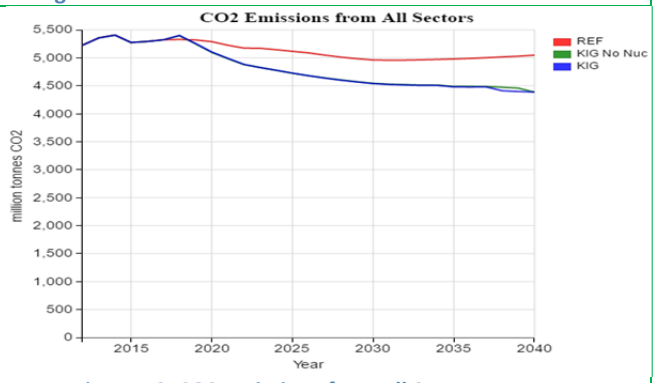

Figure 46: CO2 Emissions from All Sectors By Year

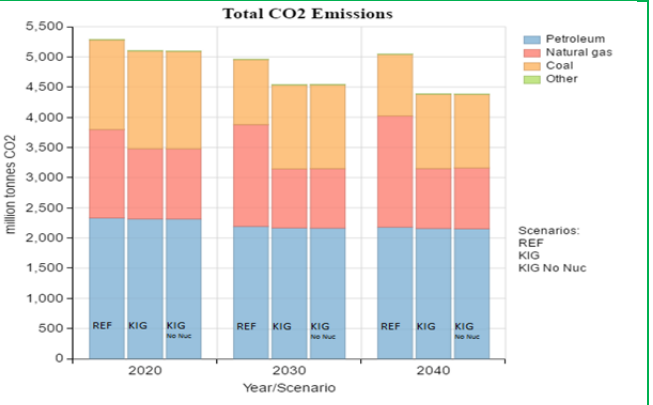

Figure 47: CO2 Emissions from All Sectors Select Years

Caveats and Limitations

Given the extreme nature of the KIG scenario, KIG-NEMS is stretched to respond to the KIG assumptions. OnLocation did not attempt to modify the model structure to allow more flexibility in the way that it responds to the KIG assumptions. Despite the model operating outside the range which it generally operates, we believe that the results of the KIG scenarios are directionally correct and provide a potential range of outcomes. The following list of bullets describes factors that might affect where one might fall in this range.

- **Oil Supply**: The significant reductions in domestic oil supply associated with the KIG scenario result in the model depending heavily on oil and petroleum product imports. The external supply curves used to represent the rest of the world oil supply and demand are hard pressed to reflect the KIG oil market conditions. If the international markets of oil supply and demand were represented more fully, the steep price rises would be ameliorated to an unknown extent.

- **Natural Gas Supply:** In addition to the restrictions on domestic natural gas supply, the KIG scenario restricts the ability of the model to import alternative supplies. The scenario limits the imports across Canadian pipelines to effectively current capacity levels and does not allow the expansion of LNG import terminals. Both assumptions reflect the KIG scenario. By shutting off alternative sources of natural gas, the model seeks a solution within its fuel substitution capability. The power sector can and does respond but the industrial sector and other sectors have much less flexibility in this modeling framework. As the very high natural gas prices persist throughout the model forecast, these prices would likely result in more adjustments in these sectors and perhaps even a preferential allocation of supply to certain sectors (e.g., residential) as has been the case in the past. In addition, the energy consuming equipment choices in the industrial and buildings sectors are based on historical buying behavior that would likely change given the prospect of perpetual high fossil energy prices.

- **Coal Supply:** Limits were imposed on coal production expansion by restricting coal output to levels recently achieved. To represent the depletion of existing coal mines, a gradual reduction in the coal supply potential in each region was imposed. As the power sector moves away from high priced natural gas, there is an initial surge in the use of coal, but this is quickly reversed and a steady decline in coal consumption emerges. Since the restriction in coal output was modeled through a proxy, the coal industry response might likely yield a variation of this response. The initial surge in coal use provides a relief valve for the model and thereby reduces the shorter-term impacts within the scenario.

- **Uncertainty:** Projections get more uncertain the further into the future they go, but the severe fuel availability limitations imposed by the KIG scenario make the projections even more uncertain since the model's use of trends based on historical and current technologies and behaviors do not include the extreme assumptions of the KIG scenario.

About OnLocation, Inc.

OnLocation/Energy Systems Consulting is recognized as a leading energy consultant providing objective quantitative analysis to a diverse set of energy policy stakeholders. Since 1984, OnLocation has served a broad range of government and industry clients with a common interest in energy and the environment. OnLocation's experienced professionals rely on thorough research and analysis to achieve practical and customized solutions for our clients. To help our clients understand the implications of the challenges facing our energy system, we develop, modify and apply a variety of computer models to examine potential energy trends, impacts of proposed government policies and the associated financial and economic impacts of energy related investment decisions. Collectively, the staff of OnLocation has over 100 years of working experience with integrated energy models including the National Energy Modeling System (NEMS), EIA's widely recognized energy model. OnLocation's senior staff and associate consultants have provided insights and solutions to the business and policy challenges of the Department of Energy, Environmental Protection Agency, energy corporations and various non-governmental organizations that support policymakers in Congress and elsewhere.

A common interest of many of our clients has been the design and potential impact of various energy and greenhouse gas reduction policies. OnLocation uses the NEMS model to analyze a wide variety of carbon policy formulations include carbon taxes, cap-and-trade schemes, and clean energy standards, as well as rate-based and mass-based options proposed in the Clean Power Plan. We have also used NEMS to examine the potential impacts of energy policies such as various types of tax incentives, and efficiency standards under a variety of energy futures. Each policy option has a unique set of incentives and challenges for market players that produce different outcomes for carbon emissions reductions, energy prices, fuel mix, energy supply markets and energy efficiency. Analysis of energy and environmental policies such as these require a fully integrated assessment of key issues and policies within a single model combined with the multi-sectoral expertise that OnLocation offers. A thorough understanding of all the NEMS energy sectors is vital to properly analyzing and understanding the implication of alternative energy policies.

Prior Clients and Studies

Our experience includes a wide variety of energy policy and climate-related modeling for government agencies, non-government organizations, and energy corporations. Our modeling activities in support of the Department of Energy Office of Energy Policy and Systems Analysis (DOE-EPSA) encompass a wide variety of climate-related issues, complementary policies, model comparison activities, and collaboration with DOE program offices and laboratories for scenario design and data needs. Our long-term support for the Bipartisan Policy Center adds to our experience using NEMS for a variety of climate and energy studies. Comprehensive multi-sector analysis for Resources for the Future (RFF), the National Energy Policy Institute (NEPI) and the U.S. Climate Action Partnership (USCAP) provided us with opportunities to analyze complementary policies in all sectors of the economy using NEMS as well as communicate with a diverse mix of stakeholders. NEMS modeling support for the USCAP Blueprint report and for Congressional testimony by the Clean Air Task Force (CATF) on the Lieberman-Warner cap-and-trade proposal provided us with the ability to use our policy insights to influence Congressional legislation on climate change and to work with clients who were not modelers themselves. We also successfully applied NEMS to analyze the impact of current tax provisions on greenhouse gasses for the National Academy of Sciences.

Appendix: KIG-NEMS, A Description of the NEMS Modifications

The reader should refer to the Caveats and Limitations section of this report for a greater perspective on this application of KIG-NEMS.

In order to capture the impacts of limiting US energy production associated with the API specification for the Keep It In The Ground scenario, a number of changes were required in the NEMS model. The following table captures at a high level the changes OnLocation made to accommodate these specifications.

PV Over-Generation Mitigation

- The aggregation of annual time periods in the electricity model leads to an over valuation of utility-scale PV in the AEO2016.
- OnLocation has implemented a model modification that provides a better view of potential over-generation (curtailments) of PV at high levels of penetration -- The model can still build PV that will be curtailed but sees the reduced economic value of the capacity.
- The capacity credit of PV was also reduced more severely as its share of generation is added to reflect the shift in timing of net peak load
- As in the standard NEMS, PV (as well as wind) increase grid spinning reserves requirements
- *Note, the latest AEO2017 version of NEMS includes this code modification.*

Coal Production Restrictions

- Because the KIG-NEMS coal model does not have explicit representation of individual mines, a gradual reduction in the coal supply potential in each region was the next-best proxy for shutting off new mine development
- An annual reduction was applied to the maximum coal production allowed

Oil and Gas Production Restrictions

- All new hydraulic fracking and conventional discovery and exploration wells were eliminated starting in 2018
- Existing EOR was allowed expand but there is less potential available due to reduced conventional production over time
- New federal and state offshore drilling leases were eliminated

Infrastructure Expansion Restrictions

- Canadian cross-border pipeline capacity was restricted to 2015 levels
- Assumed minimum U.S. NG exports to Canada were removed starting in 2018
- Potential Mackenzie and Alberta NG pipeline expansion was eliminated
- No new LNG import terminals are allowed in the KIG scenarios and existing LNG export terminals were not re-permitted to allow for imports.