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Contents

EXECUTIVE SUMMARY ........................................................................................................ 1

I. INTRODUCTION .................................................................................................................... 7
   A. Background on Natural Gas in Alaska ............................................................................. 7
   B. Background on LNG Process ......................................................................................... 7
   C. Objectives of Report ........................................................................................................ 8
   D. Outline of this Report ....................................................................................................... 9

II. MODEL DESCRIPTIONS ..................................................................................................... 10
   A. U.S. General Equilibrium Model .................................................................................. 11
   B. Electricity Sector Model ................................................................................................. 12
   C. GNGM ........................................................................................................................... 13

III. MODELING APPROACH ................................................................................................ 14
   A. Modeling Framework ...................................................................................................... 14
      1. Modifications to NERa Model for Analysis of Alaska .................................................. 14
   B. Scenarios for Analysis .................................................................................................... 16
   C. Assumptions Regarding Baseline Projections of the Alaska Economy ....................... 18
   D. Assumptions Regarding Alaska Natural Gas Prices ...................................................... 19
   E. Assumptions Regarding Alaska Natural Gas Supply ..................................................... 21
   F. Assumptions Regarding Alaska Natural Gas Demand .................................................. 22
      1. Railbelt Demand .......................................................................................................... 23
      2. Mining and Other Industrial Demand ......................................................................... 23
      3. Project Demand ........................................................................................................... 24
   G. Assumptions Regarding International LNG Market Conditions ................................ 24
   H. Assumptions Regarding AKLNG Export Project .......................................................... 25
      1. Project Assumptions ................................................................................................. 25

IV. STUDY RESULTS ............................................................................................................. 28
   A. Alaska Energy Market Impacts ...................................................................................... 28
      1. Natural Gas Market Impacts ....................................................................................... 28
      2. Electricity Market Impacts .......................................................................................... 32
   B. Alaska Macroeconomic Impacts ................................................................................... 33
      1. Welfare ....................................................................................................................... 33
      2. Gross Regional Product ............................................................................................. 34
      3. Aggregate Consumption ............................................................................................. 35
      4. Aggregate Investment .................................................................................................. 36
      5. Natural Gas Export Revenues .................................................................................... 37
      6. Trade Impacts ............................................................................................................... 38
      7. Sectoral Output Changes for Some Key Economic Sectors ....................................... 39
      8. Wage Rates .................................................................................................................. 40
   C. U.S. Energy Market Impacts ........................................................................................ 41
   D. U.S. Macroeconomic Impacts ...................................................................................... 43
      1. Welfare ....................................................................................................................... 43
      2. GDP ........................................................................................................................... 44
3. Aggregate Consumption .................................................................45
4. Balance of Trade ........................................................................46
E. U.S. Emissions Impacts .................................................................46

V. SUMMARY OF U.S. ECONOMIC IMPACTS ...................................48
A. DOE Guidelines and Prior LNG Export Applications Approvals ......48
B. U.S. Economic Impacts .................................................................49
   1. U.S. Natural Gas Market Impacts .............................................50
   2. U.S. Macroeconomic Impacts ................................................50
C. Environmental Impacts ...............................................................51
D. Energy Security...........................................................................51

APPENDIX A. HIGH LNG EXPORT SCENARIO ......................................53
A. Alaska Energy Market Impacts .......................................................53
   1. Natural Gas Market Impacts ....................................................53
   2. Electricity Market Impacts .......................................................56
B. Alaska Macroeconomic Impacts .....................................................57
   1. Welfare .................................................................................57
   2. Gross Regional Product .........................................................57
   3. Aggregate Consumption .......................................................58
   4. Aggregate Investment ...........................................................59
   5. Natural Gas Export Revenues ................................................60
   6. Trade Impacts ......................................................................61
   7. Sectoral Output Changes for Some Key Economic Sectors .........61
   8. Wage Rates .........................................................................62
C. U.S. Energy Market Impacts ..........................................................63
D. U.S. Macroeconomic Impacts .........................................................64
   1. Welfare .................................................................................64
   2. GDP ....................................................................................65
   3. Aggregate Consumption .......................................................66
   4. Balance of Trade ..................................................................67
E. U.S. Emissions Impacts .................................................................67

APPENDIX B. ADDITIONAL NEWERA MODEL DETAILS .........................69
1. Overview of Macroeconomic Model .............................................69
2. Model Scope ............................................................................70
3. Electric Sector Model in NEWERA Modeling System .................73
4. Integrated NEWERA Model .........................................................78
List of Figures

Figure 1: Alaska Average Natural Gas Market Price Compared to Baseline (2010$/MMBtu) .... 2
Figure 2: U.S. Average Wellhead Natural Gas Price Compared to Baseline (2010$/MMBtu) .... 3
Figure 3: Alaska Natural Gas Demand in Expected Scenario (Bcf) ........................................ 4
Figure 4: Alaska Natural Gas Demand in High Scenario (Bcf) ........................................... 4
Figure 5: Summary of Alaska Macroeconomic Impacts Compared to Baseline in Expected Scenario .................................................................................................................. 5
Figure 6: Summary of Alaska Macroeconomic Impacts Compared to Baseline in High Scenario ... 5
Figure 7: Summary of U.S. Macroeconomic Impacts Compared to Baseline in Expected Scenario .................................................................................................................. 5
Figure 8: Summary of U.S. Macroeconomic Impacts Compared to Baseline in High Scenario ... 6
Figure 9: The NewERA Modeling Framework ........................................................................ 11
Figure 10: Interdependency of Modeling Tools and Inputs ....................................................... 14
Figure 11: Lower-48 Net Natural Gas Pipeline Export Projections in the Baseline (Tcf) ............ 16
Figure 12: Scenarios Considered in the Analysis ................................................................. 18
Figure 13: Overview of Alaskan Natural Gas Flows ............................................................ 20
Figure 14: Alaska Natural Gas Demand Assumptions by Scenario (Tcf/yr) .......................... 24
Figure 15: Details of GNGM Results Used for AKLNG Project Analysis in NewERA .......... 25
Figure 16: LNG Investment Profile (2010$ billion) .............................................................. 26
Figure 17: Expected Supply and Expected Demand Scenario Alaska Natural Gas Market Prices (2010$/MMBtu) ............................................................................................................ 30
Figure 18: Expected Scenario Alaska In-State Natural Gas Demand by Sector (Bcf/yr) .......... 31
Figure 19: Expected Scenario Alaska Natural Gas Production by Source (Tcf/yr) .................. 31
Figure 20: Expected Scenario Share of Alaska Electricity Generation from Natural Gas (%) ... 32
Figure 21: Expected Scenario Change in Alaska Delivered Electricity Price Compared to Baseline, by Sector (%) ................................................................................................. 33
Figure 22: Expected Scenario Change in Alaska GSP Compared to Baseline (2010$ Billions) 35
Figure 23: Expected Scenario Change in Alaska Consumption Compared to Baseline (2010$ Billions) .......................................................... 36

Figure 24: Expected Scenario Change in Capital in Place in Alaska Compared to Baseline (2010$ Billions) ...................................................... 37

Figure 25: Expected Scenario Average Annual Alaska LNG Export Revenues (2010$ Billions) .................................................................................. 38

Figure 26: Expected Scenario Changes in Output for Key Alaska Economic Sectors Compared to Baseline (%) .......................................................... 40

Figure 27: Expected Scenario Change in Alaska Wage Rate Compared to Baseline (%) ............. 41

Figure 28: Expected Scenario U.S. Projected Wellhead Natural Gas Price (2010$/MMBtu) .................. 42

Figure 29: Expected Scenario Change in U.S. Welfare Compared to Baseline (%) ...................... 44

Figure 30: Expected Scenario Change in U.S. GDP Compared to Baseline (2010$ Billions) ....... 45

Figure 31: Expected Scenario Change in U.S. Consumption Compared to Baseline (2010$ Billions) .............................................................................. 46

Figure 32: Expected Scenario Change in U.S. CO₂ Emissions Compared to Baseline (%) ........ 47

Figure 33: Summary of U.S. Natural Gas and Macroeconomic Impacts in Expected Scenario Compared to Baseline .................................................. 50

Figure 34: High Supply and High Demand Scenario Alaska Natural Gas Market Prices (2010$/MMBtu) ............................................................................. 54

Figure 35: High Scenario Average Alaska Natural Gas Demand by Sector (Bcf/yr) .................... 55

Figure 36: High Scenario Average Alaska Natural Gas Production by Source (Tcf/yr) ............... 55

Figure 37: High Scenario Share of Alaska Electricity Generation from Natural Gas (%) .......... 56

Figure 38: High Scenario Change in Alaska Delivered Electricity Price Compared to Baseline, by Sector (%) ........................................................................ 57

Figure 39: High Scenario Change in Alaska GSP Compared to Baseline (2010$ Billions) ......... 58

Figure 40: High Scenario Change in Alaska Consumption Compared to Baseline (2010$ Billions) .................................................................................. 59

Figure 41: High Scenario Change in Capital in Place in Alaska Compared to Baseline (2010$ Billions) .............................................................................. 60

Figure 42: High Scenario Average Annual Alaska LNG Export Revenues (2010$ Billions) ....... 61
Figure 43: High Scenario Changes in Output for Key Alaska Economic Sectors Compared to Baseline (%) .......................................................... 62

Figure 44: High Scenario Change in Alaska Wage Rate Compared to Baseline (%) ................. 63

Figure 45: High Scenario U.S. Projected Wellhead Natural Gas Price (2010$/MMBtu) .......... 64

Figure 46: High Scenario Change in U.S. Welfare Compared to Baseline (%) ....................... 65

Figure 47: High Scenario Change in U.S. GDP Compared to Baseline (2010$ Billions)......... 66

Figure 48: High Scenario Change in U.S. Consumption Compared to Baseline (2010$ Billions) ......................................................................................... 67

Figure 49: High Scenario Change in U.S. CO₂ Emissions Compared to Baseline (%) ......... 68

Figure 50: Standard NERA Macroeconomic Model Regions ............................................. 71

Figure 51: NERA Electric Sector Model – U.S. Regions ..................................................... 75
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<thead>
<tr>
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<td>AEO</td>
<td>Annual Energy Outlook</td>
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<td>AKLNG</td>
<td>Proposed Alaska Liquefied Natural Gas</td>
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<tr>
<td>C</td>
<td>Residential Sector</td>
</tr>
<tr>
<td>CES</td>
<td>Constant Elasticity of Substitution</td>
</tr>
<tr>
<td>CGE</td>
<td>Computable General Equilibrium</td>
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<td>Carbon Dioxide</td>
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</tr>
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<td>Manufacturing Sector</td>
</tr>
<tr>
<td>MM</td>
<td>Million</td>
</tr>
<tr>
<td>MW</td>
<td>Megawatt</td>
</tr>
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<td>NERC</td>
<td>North American Electric Reliability Corporation</td>
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<td>NERA Economic Consulting</td>
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<td>NGA</td>
<td>Natural Gas Act</td>
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<td>NS</td>
<td>North Slope Region of Alaska</td>
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<td>SRV</td>
<td>Services Sector</td>
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<tr>
<td>U.S.</td>
<td>United States (Lower-48, Alaska, and Hawaii)</td>
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EXECUTIVE SUMMARY

Introduction

NERA was retained by Locke Lord LLP to conduct an analysis of the market and macroeconomic impacts of a proposed Alaska Liquefied Natural Gas (AKLNG) project. The AKLNG project is proposed as a single integrated and interdependent project for the export and sale of liquefied natural gas (LNG) in foreign commerce. The proposed project would include the construction of a natural gas liquefaction and export terminal on the south central coast of Alaska, a natural gas pipeline from the liquefaction plant to the North Slope region of Alaska (NS) and a gas treatment plant and associated pipelines connecting to upstream fields. The study thoroughly analyzes the natural gas market and macroeconomic impacts that the AKLNG project could potentially have on both Alaska and the U.S. as a whole.

Methodology

For this analysis we use our state-of-the-art integrated energy and economic model, the NewERA model, and NERA’s Global Natural Gas Model (GNGM) to estimate the various macroeconomic and market impacts. The GNGM is used to assess impacts of Alaska LNG exports on global LNG demand and prices. Estimates of LNG export levels from the GNGM were then used as inputs into the NewERA model to estimate macroeconomic impacts of the AKLNG project on the Alaska and U.S. economies. We developed various modeling assumptions through cooperation with ISER as well as various publicly available literatures.

Scenarios

To understand the possible range of impacts of the AKLNG project, we developed three scenarios. First a Baseline with no AKLNG project was needed against which to measure the economic impacts of the AKLNG project. Having defined the Baseline, we constructed two scenarios that include the development of the AKLNG project, associated LNG export volumes, and different in-state natural gas demand forecasts: an Expected scenario and a High scenario. To capture the range of potential impacts of the AKLNG project, the two scenarios differ significantly in that the High case assumes:

- 50% greater economic growth rate in Alaska;
- Increased supply of natural gas available to the market; and
- 40 year period of LNG exports for Alaska, as opposed to only a 30 year export period in the Expected scenario.

Most economic assumptions shared amongst the three cases were developed from public sources and with the assistance of consultations with ISER.
Gas Market Impacts

Proceeding with the AKLNG project and exporting LNG would lead to lower natural gas prices in Alaska and the U.S. as a whole. Figure 1 and Figure 2 show the amounts by which the AKLNG project could reduce natural gas prices in the U.S. as a whole and in Alaska as compared to the Baseline. The price reduction is seen to be greatest in Alaska where the 2048 average market price is $5.02/MMBtu lower than the Baseline in the Expected scenario and $4.78/MMBtu lower in the High scenario. The impact on the wellhead natural gas price in the U.S. as a whole is smaller in magnitude but still a reduction in price with the 2048 price being $0.17/MMBtu and $0.23/MMBtu lower than the Baseline in the Expected and High scenarios respectively.

Figure 1: Alaska Average Natural Gas Market Price Compared to Baseline (2010$/MMBtu)
In addition to the reductions in natural gas prices, the benefits of the increased supplies of natural gas brought to market by the AKLNG project include eliminating reliance on imported natural gas to make up for ultimate declines in Cook Inlet production, additional revenues from LNG exports, and increased availability of natural gas for expansion of natural gas intensive industries. Even with the increased levels of natural gas demand in Alaska driven by LNG exports, lower prices, and greater economic growth, we find that our assumed levels of natural gas reserves and resources are sufficient to meet and exceed additional consumption needs in both scenarios. Figure 3 and Figure 4 show the cumulative natural gas demand projections in both the Expected and High scenarios.
### Figure 3: Alaska Natural Gas Demand in Expected Scenario (Bcf)$^1$

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
<th>2038</th>
<th>2043</th>
<th>2048</th>
<th>Cumulative Total (Tcf) $^2$</th>
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<tr>
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<tr>
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<td>255</td>
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<tr>
<td>In-State Use</td>
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<td>116</td>
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<tr>
<td>Total Natural Gas</td>
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<td>357</td>
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<td>1,499</td>
<td>1,508</td>
<td>1,516</td>
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### Figure 4: Alaska Natural Gas Demand in High Scenario (Bcf)

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<th>2043</th>
<th>2048</th>
<th>2053</th>
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<th>Cumulative Total (Tcf)$^4$</th>
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<tr>
<td>Total Natural Gas</td>
<td>353</td>
<td>357</td>
<td>1,281</td>
<td>1,542</td>
<td>1,582</td>
<td>1,612</td>
<td>1,623</td>
<td>1,673</td>
<td>1,719</td>
<td>1,775</td>
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</table>

### Macroeconomic Impacts

Our analysis finds that if the AKLNG project were to be constructed, the economic impacts would be unequivocally positive. The project benefits the Alaska economy by boosting

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$^1$ All results in tables and charts throughout this report, unless specified otherwise, are presented in model years which each represent a span of five years (i.e., 2013 represents the years 2013, 2014, 2015, 2016, and 2017). Each model year result represents the average annual result for the time specified by that model year (i.e., in Figure 3 the 2013 Alaska Demand represents the average annual demand in 2013 through 2017). See APPENDIX B. ADDITIONAL $N_{ERA}$ MODEL DETAILS for further details on the $N_{ERA}$ model.

$^2$ Cumulative totals may not equal the sum of all years due to differences in rounding.

$^3$ This includes LNG-related fuel use and shrinkages (after ramp-up, 1,099 Bcf/year equals approximately 929 Bcf/year for LNG export and 171 Bcf/year for fuel use and shrinkages).

$^4$ Cumulative totals may not equal the sum of all years due to differences in rounding.

$^5$ This includes LNG-related fuel use and shrinkages (after ramp-up, 1,099 Bcf/year equals approximately 929 Bcf/year for LNG export and 171 Bcf/year for fuel use and shrinkages).
Alaskan’s personal income as represented by consumption, their overall economic well-being as reflected in the increase in welfare, and by increasing state tax income which is recycled back into the local economy and increases gross state product (GSP). The increased economic activity in Alaska leads to overall benefits for the U.S. as a whole. In percentage terms, impacts on Alaska would be much larger than impacts on the U.S. as a whole, but economic impacts in both Alaska and the U.S. are positive for both scenarios relative to the Baseline. All key indicators examined for Alaska and the U.S., including consumer welfare, U.S. gross domestic product (GDP), Alaska GSP, and consumption, improved with the construction of the AKLNG project. Tax income accounts for approximately one-third of GSP increases and is recycled back into the Alaskan economy. Figure 5, Figure 6, Figure 7, and Figure 8 show some key macroeconomic indicators for Alaska and the U.S. for both the Expected and High scenarios.

Figure 5: Summary of Alaska Macroeconomic Impacts Compared to Baseline in Expected Scenario

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
<th>2038</th>
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<td>GSP (%)</td>
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Figure 6: Summary of Alaska Macroeconomic Impacts Compared to Baseline in High Scenario

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<td>0.2%</td>
<td>0.1%</td>
<td>0.4%</td>
<td>0.8%</td>
<td>0.9%</td>
<td>0.9%</td>
<td>0.8%</td>
<td>0.5%</td>
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<td>0.1%</td>
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<tr>
<td>GSP (%)</td>
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<td>2.7%</td>
<td>6.3%</td>
<td>8.0%</td>
<td>8.3%</td>
<td>8.7%</td>
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<td>9.4%</td>
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<tr>
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<td>0.4%</td>
<td>0.7%</td>
<td>0.9%</td>
<td>1.0%</td>
<td>1.0%</td>
<td>1.0%</td>
<td>0.9%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

Figure 7: Summary of U.S. Macroeconomic Impacts Compared to Baseline in Expected Scenario

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
<th>2038</th>
<th>2043</th>
<th>2048</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare (%)</td>
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<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.03%</td>
<td>0.02%</td>
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</tr>
<tr>
<td>GDP (%)</td>
<td>0.01%</td>
<td>0.03%</td>
<td>0.05%</td>
<td>0.06%</td>
<td>0.06%</td>
<td>0.06%</td>
<td>0.06%</td>
<td>0.05%</td>
</tr>
<tr>
<td>Consumption (%)</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
</tr>
</tbody>
</table>
Figure 8: Summary of U.S. Macroeconomic Impacts Compared to Baseline in High Scenario

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
<th>2038</th>
<th>2043</th>
<th>2048</th>
<th>2053</th>
<th>2058</th>
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</thead>
<tbody>
<tr>
<td>Welfare (%)</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
</tr>
<tr>
<td>GDP (%)</td>
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<td>0.04%</td>
<td>0.05%</td>
<td>0.06%</td>
<td>0.06%</td>
<td>0.06%</td>
<td>0.06%</td>
<td>0.06%</td>
<td>0.06%</td>
<td>0.06%</td>
</tr>
<tr>
<td>Consumption (%)</td>
<td>0.03%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.04%</td>
<td>0.04%</td>
</tr>
</tbody>
</table>

**Environmental Impacts**

As with impacts on the natural gas market and other macroeconomic metrics, we see improvement in environmental outcomes going along with the increased availability of lower cost natural gas supplies as a result of the AKLNG project completion. Domestically, we see reductions in emissions, particularly from the electric sector, due to lower priced natural gas inducing coal-to-gas fuel switching.

**Conclusion**

Our analysis finds that the construction of the AKLNG project and commencing LNG exports would have strong positive economic impacts on the state of Alaska and also have positive economic impacts on the U.S. as a whole. Increased natural gas supplies in Alaska result in reduced natural gas prices throughout the U.S., not just in Alaska, which lowers costs for energy-intensive industries and households. LNG exports bring in additional revenues to the state government, businesses, and residents. Coal-to-gas switching in the electric sector and other industrial sectors results in reduced emissions of pollutants. Greater domestic supply reduces reliance on the imports of energy supplies. The Alaska natural gas reserves and resources estimated by the engineering consultants are sufficient to meet and exceed the AKLNG project-related and in-state demands. These benefits of increased supply and revenues accrue primarily to the Alaskan economy but also to the U.S. as a whole.
I. INTRODUCTION

This report evaluates the potential economic effects of the AKLNG project in Alaska as well as in United States as a whole. The analyses include the effects of two different scenarios regarding the length of time the AKLNG project would operate: a 30 year scenario, which represents an expected level of natural gas supply and demand; and a 40 year scenario, which represents a high level of natural gas supply and demand.

A. Background on Natural Gas in Alaska

NS oil field operations and the Southern Railbelt are the main consumers of natural gas in Alaska. The Southern Railbelt consists of the regions of Mat-Su Valley, Anchorage, and the Kenai Peninsula. Natural gas needed for the oil field operations is taken directly from the natural gas that is produced when crude oil is extracted from the NS oil fields. The Southern Railbelt relies on natural gas produced in the Cook Inlet. Therefore, Alaska has been self-sufficient and as recently as 2012, Alaska exported its excess natural gas to Japan in the form of LNG.

Historically, the Cook Inlet has been able to produce enough natural gas to keep pace with Southern Railbelt demand. However, according to the Alaska Department of Natural Resources, there is the potential for shortages as early as 2018 assuming full development of known and higher probability reserves. There is believed to be sufficient probable reserves and resources (when taking into account the broader categories of reserves and resources) in the Cook Inlet so that if drilling and exploration were to increase markedly, Southern Railbelt demand could be met for the most part with Cook Inlet produced natural gas through 2030. But thereafter, recoverable reserves are forecasted to decline rapidly forcing Alaska to rely almost solely on imports to satisfy its natural gas needs unless the AKLNG project is undertaken and natural gas is transported from the NS to the Southern Railbelt region.

B. Background on LNG Process

Section 3 of the Natural Gas Act (NGA) (15 U.S.C. Section 717b) requires authorization from the Department of Energy’s Office of Fossil Energy (DOE/FE) in order to export natural gas from the United States. Applications to export to countries with which the United States has a Free Trade Agreement (FTA) “shall be granted without modification or delay.” NGA Section 3 provides that exports to non-FTA countries also are to be authorized by Department of Energy (DOE) “unless, after opportunity for hearing, it finds that the proposed exportation or importation will not be consistent with the public interest.”

As part of its process in determining whether LNG exports to non-FTA countries are consistent or inconsistent with the public interest, DOE commissioned two studies: (1) a domestic price

impact study by the U.S. Energy Information Administration (EIA) and released in January 2012; and (2) an economic impact study by NERA that was released in December 2012. The NERA studies concluded that for all levels of LNG exports considered there would be a net benefit to the U.S. economy.

In addition to these two studies, DOE has provided indications of how to assess “public interest” in various publications, including a set of Policy Guidelines issued in 1984, Order No. 1471, and Delegation Order No. 0204-111. These were primarily related to imports, but DOE has indicated that they also apply to exports.\(^7\) In its approval of Cheniere Energy’s non-FTA permit in May 2011, DOE listed various criteria for determining whether LNG exports to non-FTA countries are or are not in the public interest: “domestic need, adequacy of supply, the environment, geopolitics, and energy security”.\(^8\) In total, DOE has given approval to seven non-FTA applications for approximately 9.27 Bcf/day of LNG exports to date between Cheniere Energy; Freeport LNG Expansion, L.P.; and FLNG Liquefaction, LLC; Lake Charles Exports LLC; Dominion Cove Point LNG, L.P.; Cameron LNG, LLC; and Jordan Cove Energy Project, L.P.\(^9\) These approvals provide additional indications of relevant criteria for public interest analysis: impact on natural gas prices, benefits to local, regional, and national economy, benefits of international trade, and environmental benefits.

It is important to note that the AKLNG facility is located in Alaska, while the other potential LNG facilities that have been considered are located in the U.S. Lower-48 states (Lower-48). Indeed, the DOE-sponsored studies did not specify the location of projects because they were designed as national studies\(^10\) and did not differentiate projects or impacts by their geographical location. In this analysis we take the project location into account insofar as the economic impacts the project may have in its geographic area of operation as well as the potential impacts, or lack thereof, it may have on the rest of the U.S.

C. **Objectives of Report**

The overall objective of this report is to provide a macroeconomic analysis of the potential impacts of LNG exports from Alaska at national and regional levels. We consider the potential effects of the AKLNG project on energy markets as well as on economic, environmental, and energy security impacts. We use a state-of-the-art integrated energy and economic model, the NewERA model, and NERA’s GNGM to estimate these various effects. The versions of NewERA

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and GNGM that we use are updated and customized versions of the model used in the study commissioned by DOE noted above.

In this analysis, the effects of the AKLNG project are measured relative to a status quo Baseline scenario with no AKLNG project or LNG exports related to the project. The Baseline includes an integrated economic forecast that has been calibrated to the reference case from the Annual Energy Outlook (AEO) 2013 of the EIA and then modified to account for Alaska-specific information provided by local experts on the Alaska energy system and economy.

The assessments in this study cover four general categories of impacts:

1. Alaska energy market and macroeconomic impacts;
2. U.S. energy market and macroeconomic impacts;
3. Environmental impacts; and
4. Regional and national security impacts.

There are substantial uncertainties involved in developing these estimates of the effects of the AKLNG project, including uncertainties related to the estimated supplies and prices of global LNG trade and estimated Alaskan natural gas supply and demand. Alaska demand for natural gas is important because although the facility would be primarily designed to export LNG, the pipeline would allow for additional natural gas to be provided to local Alaska industries and residents.

D. Outline of this Report

The remainder of the report is organized as follows. Section II summarizes the New ERA modeling tools. Section III provides information on the modeling approach and the various scenarios we consider: the Baseline and the scenarios involving expected Alaska LNG supply and expected Alaska natural gas demand. Section IV presents the results of our analyses followed by a summary of the macroeconomic impacts at the U.S. level in Section V. The appendices provide results from an additional LNG export scenario and details on the New ERA model.
II. MODEL DESCRIPTIONS

The N\textsubscript{cw}ERA model is a top-down, general equilibrium model of Alaska, Hawaii, and other regions of the Lower-48 combined with a detailed bottom-up model of the North American electricity sector (ELE). The model includes all sectors of the economy and a representative household in each region. Producers and consumers in the model interact in the marketplace such that supply and demand in each market equilibrate. The responses of producers and consumers to a policy change enable the computation of energy and economic impacts.

The N\textsubscript{cw}ERA model is routinely used to project impacts of various policies (including command and control regulations, market based policies, and trade policies, such as LNG export policies) and major projects on regional economies at a sectoral level. Different types of policies and projects could impact a given sector in a variety of ways. When evaluating policies that have impacts on the entire economy, such as LNG exports, which lead to changes in export revenues and changes in the natural gas market, one needs to use a model that captures the effects as they ripple through all sectors of the economy and the associated feedback effects. The N\textsubscript{cw}ERA modeling framework takes into account interactions between all parts of the economy and policy consequences as transmitted throughout the economy as sectors respond to policies. The model’s flexibility allows it to incorporate many different types of policies, such as those affecting the natural gas market, capital investment projects, environmental, financial, labor, and tax matters. Figure 9 depicts the integration of the N\textsubscript{cw}ERA modeling framework.

The GNGM is used to develop estimates of global production, pricing, and trade of natural gas, in particular LNG. When conducting analysis of the economic impacts of LNG export scenarios, the GNGM provides a method of establishing price estimates for the volumes of expected LNG exports which are a key input into the broader macroeconomic impacts modeled by the N\textsubscript{cw}ERA model.

The following sections provide summaries of the major components of the N\textsubscript{cw}ERA model and the GNGM. More detailed examinations of the two models are contained in the Appendices.
A. U.S. General Equilibrium Model

The U.S. General Equilibrium Model (Macro model) of the N_{ew}ERA integrated model is a forward-looking dynamic computable general equilibrium (CGE) model of the United States, represented by 7 regions. The model simulates all economic interactions between the Alaskan economy and the rest of the U.S. economy, including those among industries, households, government, and rest of the world. Industries and households maximize profits and utility assuming perfect foresight. The model represents the circular flow of goods, services, and payments in the economy (every economic transaction has a buyer and a seller whereby goods/services go from a seller to a buyer and payment goes from the buyer to the seller).

The macroeconomic model incorporates all production sectors, including liquefaction plants for LNG exports, and final demand of the economy. The AKLNG project is represented as a separate production function in the modeling scenarios that is absent in the Baseline. In the scenarios, LNG is produced if the market price is higher than the marginal production cost. The model includes a representative household, which characterizes the behavior of an average consumer, and 12 industrial sectors, which represent the production sectors of the economy. In the model, the government collects initial labor and capital tax revenues and returns it back to the consumers on a lump-sum basis.
Households receive income from providing labor and capital to businesses, receive transfers from government, pay taxes to the government, and put savings into financial markets, while also consuming goods and services. Industries produce goods and services, pay taxes to and receive subsidies from the government, and use labor and capital. Industries are both consumers and producers of capital for investment in the rest of the economy. Within the circular flow, equilibrium is found whereby demand for goods and services is equal to their supply, and investments are optimized for the long term. Thus, supply equals demand in all markets. The model finds equilibrium by assuming perfect foresight and ensuring goods and services markets balance, production meets the zero profit condition, consumers maintain income balance conditions, there is no change in monetary policy, and there is full employment within the U.S. economy. Additional details of the macroeconomic model are provided in Appendix B.

The NEwERA model is based on a unique set of databases that NERA constructed by combining economic data from the IMPLAN 2008 database and energy data from EIA’s AEO 2013. The IMPLAN 2008 database provides Social Accounting Matrices for all states for the year 2008. These matrices contain inter-industry goods and services transaction data; we merge the economic data with energy supply, demand, and prices for 2008 from EIA. In addition, we include tax rates in the dataset from NBER’s TAXSIM model. By merging economic data from IMPLAN, energy data from EIA, and tax rates from NBER, we build a balanced energy-economy dataset.

GDP, energy supply, energy demand, and energy price forecasts come from EIA’s AEO 2013. The forecasts for the Alaskan economy have been further refined based on inputs and expertise provided by ISER. Labor productivity, labor growth, and population forecasts from the Census Bureau are used to forecast labor endowments along the baseline and ultimately employment by industry.

B. Electricity Sector Model

The bottom-up Electricity Sector Model (ELE model) simulates the electricity markets in Alaska, the rest of the U.S., and parts of Canada. The model includes more than 17,000 electric generating units, and capacity planning and dispatch decisions are represented simultaneously. The model dispatches electricity to load duration curves. A long-term solution typically includes 10 or more model years out through 2050 (each year is not evaluated but rather represented by a model year). The model determines investments to undertake and units to dispatch by solving a dynamic, non-linear program with an objective function that minimizes the present value of total incremental system costs, while complying with all constraints, such as demand, peak demand, emissions and transmission limits, and other environmental and electric specific policy mandates.

Having a bottom-up ELE representation for the Alaska economy provides an advantage to evaluate trade-offs between different technologies especially in an environment with high supply of natural gas. In addition, the integrated nature of the NEwERA model enables it to provide
impacts on the electricity price consistent with a realistic electric system representation while being able to compute macroeconomic impacts.

We solve the bottom-up and the top-down models iteratively using a decomposition method. The top-down macroeconomic model solves for equilibrium prices, while the bottom-up model solves for equilibrium quantities. The solution process is iterated until prices and quantities converge.

C. GNGM

The GNGM is a partial-equilibrium model designed to estimate the amount of natural gas production, consumption, and trade by major world natural gas consuming and/or producing regions. The model maximizes the sum of consumers’ and producers’ surplus less transportation costs, subject to mass balancing constraints and regasification, liquefaction, and pipeline capacity constraints.

The model divides the world into 14 regions. These regions are largely adapted from the EIA International Energy Outlook (IEO) regional definitions, with some modifications to address the LNG-intensive regions. The model’s international natural gas consumption and production projections for these regions are based upon the EIA’s AEO 2013 and IEO 2011 Reference cases.

The supply of natural gas in each region is represented by a constant elasticity of substitution (CES) supply curve. The demand curve for natural gas has a similar functional form as the supply curve. As with the supply curves, the demand curve in each region is represented by a CES function.
III. MODELING APPROACH

This section provides information on the modeling approach used in this study including the overall framework and specific assumptions made to develop the scenarios that are modeled.

A. Modeling Framework

The NERA modeling approach for this project involves using the N_{ew}ERA model with inputs from the GNGM and ISER in order to develop an analysis that is consistent and covers the key market interactions for this analysis. Figure 10 depicts the interaction of the various inputs and N_{ew}ERA modeling tools utilized to generate the key output measures for the analysis.

Figure 10: Interdependency of Modeling Tools and Inputs

1. Modifications to N_{ew}ERA Model for Analysis of Alaska

Several modifications were made to NERA’s standard N_{ew}ERA model to represent Alaska in a more precise and granular perspective. We made changes to both the Macro and ELE models. For the Macro model, we first developed a database which treated Alaska as a separate region as opposed to its usual inclusion with other states as part of the Pacific-Northwest region. In order to properly analyze the impacts of the AKLNG project on Alaska, we made this separation so that we could better measure the impacts of the project and associated LNG exports on Alaska and the rest of the U.S.
After separating out Alaska, we enhanced the standard representation of a Macro model region as follows:

- Created two sources of natural gas production for Alaska – NS and Cook Inlet production; and
- Added a new natural gas production sector for Alaska to represent the activity of bringing NS natural gas to market either as LNG or conventional gas.

To correctly account for the impacts of NS natural gas on Alaska, it is critical to represent the different uses and the demand for this natural gas supply. NS natural gas can be used to meet domestic demand both in the Northern and Southern Railbelt regions as well as international demand in the form of LNG. Currently most of the Southern Railbelt natural gas demand is met by natural gas produced from Cook Inlet. There is believed to be sufficient probable reserves and resources (when taking into account the broader categories of reserves and resources) in the Cook Inlet so that if drilling and exploration were to increase markedly, Southern Railbelt demand could be met for the most part with Cook Inlet produced natural gas through 2030. But thereafter, recoverable reserves are forecasted to decline rapidly. In the Baseline without any new NS natural gas production, a greater share of the Southern Railbelt natural gas demand will be met by imports. If the AKLNG project comes online, then it will play a greater role in meeting Southern Railbelt demand instead. To capture this trade-off between NS and Cook Inlet natural gas plays, we include two natural gas resources and production sectors.

We account for the cost of shipping natural gas from NS to the LNG facility by incorporating a pipeline construction activity that demands capital, labor, and operating expenses. We also incorporate the liquefaction plant cost into the model in a similar manner. Given that the Alaskan labor supply is insufficient to realistically support the construction of the LNG project facilities, we allow out of state workers to be used in the construction of the LNG facility and the pipeline.

Workers are allowed to migrate from other U.S. regions to Alaska to work on the AKLNG project if the project’s demand for labor causes Alaskan wage rates to increase to a level which would incentivize migrant workers to move, with an associated migration cost, from their current location to work in Alaska. The infrastructure activities are formulated such that the demand for migrant workers and outside capital is based on the size of the project.

Before the recent boom in shale-based natural gas resource development, the U.S. had been a net importer of natural gas through pipelines. Over the last couple of years the U.S. situation has changed, and EIA forecasts place the U.S. as becoming a net exporter of natural gas along pipelines. To represent this changing situation, we modified our model to allow for Lower-48 pipeline exports to be consistent with AEO 2013 projections. The levels of these exports are show in Figure 11.
In addition to changing the macro model and its database, we modified the ELE model and its accompanying database to more closely capture the nuances of Alaska’s ELE. We calibrated Alaska’s electric sector generation profile to the EIA State Electricity profile.\(^{11}\) First, the model was calibrated to match the current electricity production profile in terms of total demand and generation by type. As part of the Baseline forecast, we assumed the construction of the 600 megawatt (MW) Susitna-Watana Hydroelectric Project (Susitna) in keeping with Alaska’s stated goal of supplying more generation from renewable sources. This unit also appears in the Expected scenario but is removed from the High scenario. Susitna was excluded in the High scenario as part of developing a bottom-up natural gas demand forecast commensurate with the high natural gas demand intended for this scenario.

Figure 11: Lower-48 Net Natural Gas Pipeline Export Projections in the Baseline (Tcf)\(^{12}\)

<table>
<thead>
<tr>
<th>Nations Importing Lower-48 Pipeline Exports</th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
<th>2038</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico and Canada</td>
<td>-1.56</td>
<td>-0.73</td>
<td>0.37</td>
<td>0.60</td>
<td>0.83</td>
<td>1.63</td>
</tr>
</tbody>
</table>

B. Scenarios for Analysis

This section summarizes the scenarios we analyze in this study. Figure 12 provides an overview of the Baseline, Expected, and High Scenarios we model.

The Baseline assumes that the AKLNG project is not developed. Thus, the Baseline includes no pipeline construction in Alaska and no Alaska LNG exports.\(^{13}\) It includes Baseline levels of LNG exports from the Lower-48. Susitna comes online in 2023, displacing the need for new natural gas-fired generation and hence reducing natural gas demand.

Economic conditions in Alaska over the Expected and High scenarios differ in terms of the time period of LNG exports from Alaska as well as the levels of natural gas supply and natural gas demand in Alaska. For the Expected scenario, the pipeline and LNG facilities are built in Alaska, and the available reserves and resources are 63 Tcf. The AKLNG project will export 20


\(^{12}\) U.S. Energy Information Agency, “Annual Energy Outlook 2013,” May, 2013. Since AEO 2013 projections only extend to 2040, we held the net export levels in our Baseline modeling constant at the 2038 model year level through the end of the modeling horizon.

\(^{13}\) Although building the pipeline would likely lead to significant reductions in gas prices as compared to the Baseline for all of Alaska in both the Expected and High scenarios, without allowance for LNG exports the pipeline is much less likely to be constructed.
MTPA of natural gas for 30 years from 2023\textsuperscript{14} through 2052 but NS natural gas supply will continue to be available to the domestic Alaska economy beyond 2052 when the export period ends. Demand for natural gas in Alaska develops in line with the Baseline economic forecast and is derived relative to the increased natural gas supplies. Susitna is assumed to come online in 2023.

For the High scenario, the AKLNG project is constructed as scheduled in the Expected scenario and NS available resources are increased to 109 Tcf. Additionally, the time period for exports is extended to 40 years through 2062. The Alaskan economy is assumed to grow 50\% faster than in the Expected scenario. This assumed higher growth rate is based on ISER’s high growth scenario for Alaska.\textsuperscript{15} Furthermore, this scenario assumes mining projects are more prevalent and there is greater natural gas consumption throughout the economy. On the electric side, Susitna is assumed never to come online, so that natural gas demand from the electric sector is higher than in the Expected scenario.

For both the Expected and the High scenarios, the assumed available levels of natural gas reserves and resources act as a constraint that limits the equilibrium supply within the model. Natural gas production cannot exceed the available reserves and resources specified over the period of the modeling horizon, although given the production levels we see in our scenario analyses, the constraint is not binding in either scenario. A detailed breakdown of Alaska natural gas demand in each scenario is presented in the relevant results sections.

A more detailed description of the Baseline, Expected, and High scenarios is provided in the following sections.

\textsuperscript{14} For purposes of this study and the associated economic impact analyses, it is assumed that LNG production and export will begin in 2023. However, variance from this assumption will not have any appreciable effect on the analyses or conclusions of this study. Also, for both the Expected and High scenarios, there is a period of ramp-up activity for the project starting in 2023.

C. **Assumptions Regarding Baseline Projections of the Alaska Economy**

We developed Baseline conditions for the Alaskan economy based upon New ERA (largely based on AEO 2013) and ISER’s economic projections regarding likely future economic and demographic conditions.\(^\text{16}\)

ISER’s Base case labor growth rate averages one percent per year through 2035. Assuming the labor growth rate is about half of the overall economic growth rate, implying labor productivity growth of 1% per year, we assume that the Alaskan economy grows at about 2% per year through 2035 and then declines a bit after this to reflect projections about shifts in demographics toward lower population growth and aging of the population.

The ELE Baseline demand is derived from AEO 2013 data and adjusted to be consistent with ISER’s Base case forecast for the greater Anchorage area. This includes total demand load over time as well as peak load for each year. Specific ELE generating unit characteristics and fuel costs were calibrated to target current operating conditions in the ELE, and we particularly ensured that the generation mix by fuel source was in line with the current market. Additionally, although it is not yet under construction and is not in our default ELE generating unit database for New ERA, we assume, consistent with the recent Federal planning approvals,\(^\text{17}\) that Susitna will be constructed. Therefore, we include this new source of hydroelectric power in our generation build projections for the Baseline as well as the Expected scenario (but not the High scenario).

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D. Assumptions Regarding Alaska Natural Gas Prices

The Cook Inlet natural gas market is structured differently than the Lower-48 natural gas market. It is not connected by a pipeline network to the Lower-48 and natural gas transactions take place between few buyers and sellers without a spot market. This unique structure means that natural gas prices are established through the bilateral negotiation of term gas sales and purchase agreements between a buyer and seller rather than the liquid market trading mechanisms of the Lower-48. The Regulatory Commission of Alaska (RCA) also ensures that the prices that are negotiated between buyers and sellers are reasonable. Natural gas prices in Alaska, in general, are pegged to a basket of Lower-48 price indices including natural gas, crude oil, and heating oil.\(^{18}\) High oil prices in recent years have led to higher natural gas prices in Alaska relative to Lower-48 natural gas prices.\(^{19}\) Additionally, the production from Cook Inlet is expected to decline in the future, as discussed in the following section.

In light of the projected scarcity of Cook Inlet production and the unique makeup of the natural gas market in Alaska, we assume Cook Inlet wellhead price to be 50 cents higher than the Lower-48 wellhead price in 2013 and indexed to the Lower-48 wellhead price in the Baseline in the absence of NS natural gas supplies.\(^{20}\) It should be noted that the Cook Inlet price assumptions we use are not the price delivered to the end user and therefore do not take into account distribution costs. They essentially represent an assumed marginal cost of production of the Cook Inlet natural gas resource based on the literature and are most likely conservative estimates. If one were to assume higher Cook Inlet prices than we do in our analysis then the benefits accrued from the AKLNG project and the access to lower cost NS natural gas supplies would be even greater in magnitude than what our analysis indicates.

Figure 13 illustrates an overview of the natural gas flows in Alaska as handled in our analysis. NS natural gas is first treated prior to supplying the market through the dedicated pipeline. Part of the NS natural gas and Cook Inlet natural gas is commingled before it is supplied to end-users through the existing distribution network. A large volume of NS natural gas production is diverted to the liquefaction plant to produce LNG that is shipped to the international market. The cost of extracting NS natural gas and Cook Inlet natural gas is different in our analysis. In addition, we assumed distribution costs, natural gas treatment costs, pipeline tariffs, liquefaction costs, and storage/loading costs based on secondary sources. Based upon the analysis of Attanasi and Freeman, we estimated the cost of natural gas treatment at $1.50/MMBtu and the cost to


\(^{19}\) According to EIA, Alaskan Citygate price was higher by 50 cents, 90 cents, and $1.40 in 2010, 2011, and 2012, respectively.

\(^{20}\) To calibrate Cook Inlet prices to be close to the Lower-48, RCA approved a contract that is pegged to Lower-48 spot price index, Fay et al (2010).
transport the natural gas by pipeline to be approximately $2.60/MMBtu. Our natural gas price modeling is based on competitive market pricing in South Central Alaska with supplies coming from both NS and Cook Inlet. The delivered price of natural gas to industrial users and utilities includes additional distribution costs in addition to the market price. The LNG export price is high enough to cover storage/loading, liquefaction, and pipeline costs in addition to the NS pipeline inlet price.

**Figure 13: Overview of Alaskan Natural Gas Flows**

We assumed that the first 30 Tcf of natural gas is supplied from the existing NS fields and has a relatively low cost of production. It is expected that in the early years the natural gas will be produced from existing NS fields as associated dissolved natural gas. Over time, as the existing fields deplete, it will be necessary to develop new fields on the NS to continue to supply the liquefaction plant. We assume that the price of natural gas into the liquefaction plant will increase with time reflecting the costs to find, develop, and produce from these new fields. The cost of the new natural gas will be greater than that of the existing gas to reflect the higher marginal cost of production.

The cost of extracting natural gas from existing fields is assumed to be about $0.30/MMBtu. The cost of natural gas increases to about $1.80/MMBtu as additional natural gas production from new fields comes online. Combining the intermediate costs yields an initial market price for natural gas of about $4.50/MMBtu at the LNG plant inlet in the first export period in 2023.

---


22 The values cited do not sum because of rounding.
E. Assumptions Regarding Alaska Natural Gas Supply

NERA developed three different cases for natural gas supply in Alaska. We relied upon information from multiple sources including engineering consultants contracted by Locke Lord LLP, ISER, and publicly available sources. Based upon these sources, we decided to divide the Alaska domestic natural gas reserves and resources into 1) NS resources and, 2) Cook Inlet and other Alaska natural gas (Cook Inlet) reserves and resources. Assumptions about the size of these resources are the two main variables in determining our Alaska natural gas supply curves. For Cook Inlet, we relied upon the engineering consultant’s reserves and resources estimate of 2.4 Tcf. We calibrated the supply curve so that production in the Baseline is targeted to be approximately 90 Bcf per year until 2028 and declining thereafter. For the NS resources, we also relied upon the engineering consultant’s estimates for the range of potential resources. In total, 63 Tcf represents the lower estimate and 109 Tcf the upper estimate of the total Alaskan natural gas reserves and resources (i.e., Cook Inlet plus NS). These estimates include 30 Tcf of recoverable natural gas from the NS fields that are currently producing.

These inputs were used in the construction of our three supply cases:

1. **Baseline** – This supply case assumes that the AKLNG project is not built, so NS natural gas resources are available only for oil field operations on the NS and not for either consumption in Alaska or export as LNG. The natural gas supply forecast for the rest of the U.S. is primarily based on AEO 2013. Natural gas necessary to meet Alaska domestic natural gas demand beyond the approximate 90 Bcf per year provided by Cook Inlet is met by foreign imports.

2. **Expected** – In this supply case, the Alaskan natural gas pipeline and LNG facilities are built. We assume that 63 Tcf of the NS and Cook Inlet natural gas reserves and resources are producible. NS natural gas resources continue to be available to the domestic Alaska economy beyond 2052 when the 30-year export period ends.

3. **High** – This supply case is identical to the Expected case, with the exception that there is an additional 46 Tcf of NS natural gas resources available for a total of 109 Tcf of producible natural gas reserves and resources. As a result, the time period for exports in this analysis is extended to 40 years ending in 2062.

---


The price of natural gas into the liquefaction plant is estimated to be about $4.50/MMBtu starting in the year 2023. It is expected that in the early years after startup the natural gas will be proven natural gas produced from existing NS fields as associated dissolved natural gas. Over time, as the existing fields deplete, it will be necessary to develop new fields on the NS to continue to supply the liquefaction plant. We assume that the price of natural gas into the liquefaction plant will increase with time reflecting the costs to find, develop, and produce from these new fields.

F. Assumptions Regarding Alaska Natural Gas Demand

NERA developed three different sets of assumptions for expectations of natural gas demand in Alaska that are used in the scenarios:

1. **Baseline** – In this case, natural gas demand develops in line with the baseline forecast primarily based on AEO 2013.

2. **Expected** – In this case, demand for natural gas in Alaska develops in line with the baseline economic forecast and is derived relative to the increased natural gas supplies in the Expected Supply case.

3. **High** – The Alaskan economy is assumed to grow 50% faster than in the Expected scenario. Furthermore, this scenario assumes mining projects are more prevalent and there is greater natural gas consumption throughout the economy. On the electric side, Susitna is assumed to never come online.

We consulted several sources to develop our baseline projection for natural gas consumption with and without the AKLNG project.²⁶

The bottom-up construction of natural gas demand divides natural gas use into five key categories, each of which is discussed in turn:

1. End-use demand in the Southern Railbelt;
2. End-use demand in the Northern Railbelt;
3. End-use demand for mining or industrial projects;
4. Demand for natural gas in the oil fields; and


5. Demand for natural gas associated with the export of LNG (this includes the export volumes themselves and all losses associated with taking the natural gas out of the ground and delivering it as LNG to the tanker).

1. **Railbelt Demand**

Demand in the Southern Railbelt comprises three primary categories: space heating (commercial and residential), electricity, and other (includes military, trucking, and industrial). In 2013, space heating, electricity, and other are assumed to consume 90, 105, and 48 MMcf/d of natural gas, respectively. Natural gas demand for space heating is forecasted to grow at 1.1% for the Expected scenario and 1.6% for the High scenario.

For electric sector natural gas demand, we made use of our bottom-up electricity model, calibrated to the North American Electric Reliability Corporation (NERC) forecast for ELE demand. A key assumption centers on Susitna. In the Baseline and Expected scenarios, this unit comes online in 2023, which initially reduces natural gas demand from the electric sector. For the High scenario, this unit never comes online.

Initially, natural gas demand in the Baseline from other sectors drops with the decline in industrial activity in the Southern Railbelt: LNG exports cease and chemical plants close. But over time, with the growth of the economy demand from other sectors is expected to increase.

Demand in the Northern Railbelt is initially close to zero. But by the 2020 time frame, the Northern Railbelt is assumed to have access to South natural gas for space heating and electricity generation. Given the smaller population, the demand is about a quarter of that of the Southern Railbelt.

2. **Mining and Other Industrial Demand**

In the Expected case, we assume a mine similar in size to the proposed Pebble Mine, consuming natural gas estimated at 40 MMcf/d, to be fully operational by 2025. This demand is in addition to the demand from the Flint Hills refinery and the Livengood mine, which are estimated to total about 20 MMcf/d by the 2025 time period. In the High case, the level of mining and other activities is assumed to peak at 220 MMcf/d. In this scenario, we assume that about three to four large mining projects are undertaken and either a chemicals plant is built or the old chemicals plant is brought back online.

---

27 At the time of the analysis herein, NERA assumed that the Flint Hills refinery would continue refining operations. Flint Hills subsequently announced that the refinery will shut down in 2014 and become an oil shipping and storage terminal. [http://www.alaskadispatch.com/article/20140204/blow-fairbanks-flint-hills-says-it-will-close-down-north-pole-refinery](http://www.alaskadispatch.com/article/20140204/blow-fairbanks-flint-hills-says-it-will-close-down-north-pole-refinery). If the Flint Hills refinery shuts down, accounting for this change would have no material effect on the results and conclusions of this report.
3. Project Demand

Demand associated with the oil field operations on the NS is assumed to remain the same in all scenarios for all years.\(^{28}\) Natural gas use in these fields is estimated to be 255 Bcf/yr.\(^{29}\)

Demand associated with natural gas export from LNG includes:

- Export of LNG is 20 MTPA (929 Bcf/yr after ramp-up).\(^{30}\)
- Losses from transporting and liquefying the natural gas amount to 171 Bcf/yr (after ramp-up).\(^{31}\)

Figure 14 summarizes Alaska’s natural gas demand for the three different cases.

**Figure 14: Alaska Natural Gas Demand Assumptions by Scenario (Tcf/yr)**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
<th>2038</th>
<th>2043</th>
<th>2048</th>
<th>2053</th>
<th>2058</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.35</td>
<td>0.36</td>
<td>0.36</td>
<td>0.36</td>
<td>0.37</td>
<td>0.38</td>
<td>0.38</td>
<td>0.39</td>
<td>0.40</td>
<td>0.41</td>
</tr>
<tr>
<td>Expected</td>
<td>0.35</td>
<td>0.36</td>
<td>1.25</td>
<td>1.49</td>
<td>1.50</td>
<td>1.51</td>
<td>1.52</td>
<td>1.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>0.35</td>
<td>0.36</td>
<td>1.28</td>
<td>1.54</td>
<td>1.58</td>
<td>1.61</td>
<td>1.62</td>
<td>1.67</td>
<td>1.72</td>
<td>1.78</td>
</tr>
</tbody>
</table>

G. Assumptions Regarding International LNG Market Conditions

This section summarizes the information developed by the GNGM that were used as inputs into the NewERA model. We used GNGM to develop three sets of input assumptions for the NewERA model:

\(^{28}\) Upstream lease operations fuel is assumed to remain flat to allow for an expected decrease in Prudhoe Bay Unit compression fuel that will serve to offset the potential increased fuel in other existing operations or new fields.

\(^{29}\) Upstream lease operations fuel estimate is average fuel use for years 2007 through 2011 based on EIA data. Available at: [http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SAK_a.htm](http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SAK_a.htm).

\(^{30}\) Using the conversion factor of 1 million metric tons of LNG is equivalent to 46.467 Bcf of natural gas. U.S. Department of Energy, “Liquefied Natural Gas: Understanding the Basic Facts,” at p. 9. Available at: [http://energy.gov/sites/prod/files/2013/04/f0/LNG_primerupd.pdf](http://energy.gov/sites/prod/files/2013/04/f0/LNG_primerupd.pdf). This conversion is appropriate for the AKLNG project because the relatively high heating content (Btu/cubic foot gas) and associated physical characteristics of LNG that would be produced by the AKLNG project are expected to approximate those reflected in this particular conversion table.

\(^{31}\) LNG-related fuel/shrinkage is assumed to be 15.5% of the upstream hydrocarbon stream or “upstream feed” of 1100 Bcf/yr excluding upstream lease operations fuel usage.
1. Baseline U.S. LNG Exports (Alaska exports are assumed to be zero, so all exports are from the Lower-48);

2. Expected scenario U.S. LNG exports (includes Lower-48 and Alaska LNG exports) and Expected scenario Alaska LNG exports; and

3. LNG prices FOB at the terminal outlet in Alaska.

The details of the GNGM results used as inputs into New Era are provided in Figure 15 below.

**Figure 15: Details of GNGM Results Used for AKLNG Project Analysis in New Era**

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
<th>2038</th>
<th>2043</th>
<th>2048</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. LNG Exports – Baseline (Tcf)</td>
<td>-</td>
<td>0.43</td>
<td>0.30</td>
<td>1.04</td>
<td>1.13</td>
<td>1.14</td>
<td>1.14</td>
<td>1.14</td>
</tr>
<tr>
<td>U.S. LNG Exports – Expected (Tcf)</td>
<td>-</td>
<td>0.43</td>
<td>0.83</td>
<td>1.68</td>
<td>1.70</td>
<td>1.72</td>
<td>1.72</td>
<td>1.72</td>
</tr>
<tr>
<td>AK LNG Exports – Expected (Tcf)32</td>
<td>-</td>
<td>-</td>
<td>0.74</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
</tr>
<tr>
<td>AK LNG Export Prices33 (2010$/Mcf)</td>
<td>-</td>
<td>-</td>
<td>$12.76</td>
<td>$14.19</td>
<td>$15.70</td>
<td>$17.43</td>
<td>$17.43</td>
<td>$17.43</td>
</tr>
</tbody>
</table>

H. Assumptions Regarding AKLNG Export Project

1. Project Assumptions

As stated in publicly available documents, the preliminary capital estimate for the AKLNG project is $45-65 billion incurred over a period of about 10 years. In order to infer the timing of the various capital expenditures within the 10 year construction timeline, NERA utilized the AKLNG work plan presented to Alaska legislators in February 201334 and elements of a more detailed investment profile for the Wheatstone LNG project in Australia as estimated in a proprietary data source supplied by Locke Lord.35 Distinct from the Wheatstone LNG project, the AKLNG plant requires the construction of an 800+ mile long, 42-inch diameter pipeline thus, making the initial phases of the AKLNG project substantially more expensive than Wheatstone.

33 These prices represent the LNG price at the dock.


The investment profile was computed based on investment profile of the Wheatstone LNG project. Figure 16 indicates the shape of the investment profile of the average annual capital expenditure inputs for the project in the NewERA model. We assumed the total cost of the AKLNG project to be $65 billion.

**Figure 16: LNG Investment Profile (2010$ billion)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Total Cost</td>
<td>5%</td>
<td>5%</td>
<td>7%</td>
<td>7%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>20%</td>
<td>5%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Using the above investment share, the following average annual capital expenditures were assumed as inputs for the capital investment aspect of the pipeline in the NewERA model:

- 2013 model year input (average of 2013 through 2015 costs), $3.74 billion;
- 2018 model year input (average of 2016 through 2020 costs), $7.31 billion; and
- 2023 model year input (average of 2021 through 2023 costs), $5.74 billion.

The pipeline is assumed to have an initial capacity of 3.2 Bcf/d that the model allows to be expanded to meet demand at a cost equal to the average cost of the initial pipeline.36

The main taxes and royalty calculations were derived from Alaska and Federal government sources and include:

- Production tax rate on the gross value at the point of production in the field minus production costs of non-royalty natural gas;
- Property tax rate (based on assessed value of property, plant and equipment instead of the value of production, and currently represents 2% of gross wellhead value);
- Royalties;
- Federal Corporate Income Tax (35%) applied to the economic profit; and
- State Corporate Income Tax (9.4%) applied to the economic profit.

The 35% production tax rate applies to both oil and natural gas produced in the state under Alaska Statute 43.55.011(e) as amended by chapter 10 of the 2013 Session Laws of Alaska.

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According to the Alaska Department of Natural Resources Division of Oil and Gas the particular royalty rate applicable in a given situation varies from case to case and is based on the associated lease agreement. However, they also state that the most frequently seen rate is 12.5% so that is the level we chose to assume for our inputs.\footnote{Typical royalty rate, as stated by the Alaska Department of Natural Resources Division of Oil & Gas. Available at: \url{http://dog.dnr.alaska.gov/Royalty/Accounting.htm}.} This is not intended to imply any insight into any potential royalty rate agreements that may be negotiated in the future but is simply a representative assumption based on the Alaska Department of Natural Resources Division of Oil and Gas own statements and data.
IV. STUDY RESULTS

This section provides the results of our analysis. We organize the results into the following sections:

- Alaska Energy Market Impacts;
- Alaska Macroeconomic Impacts;
- U.S. Energy Market and Macroeconomic Impacts; and
- U.S. Emissions Impacts.

A. Alaska Energy Market Impacts

This section discusses the impacts on the Alaska energy markets as a result of implementing the AKLNG project scenarios against a Baseline without any LNG exports from Alaska.\(^{38}\)

1. Natural Gas Market Impacts

In the Baseline, no pipeline exists connecting the NS with the Southern Railbelt. Thus the only Alaskan natural gas supplies that can satisfy Southern Railbelt natural gas demand originate from Cook Inlet. There is believed to be sufficient probable reserves and resources (when taking into account the broader categories of reserves and resources) in the Cook Inlet so that if drilling and exploration were to increase markedly, Southern Railbelt demand could be met for the most part with Cook Inlet produced natural gas through 2030. But thereafter, recoverable reserves are forecasted to decline rapidly. Or put differently, the cost of extracting natural gas from the Cook Inlet becomes increasingly more expensive over time. Thus Southern Railbelt demand must be met with greater amounts of imported LNG, which is significantly more expensive than natural gas delivered from the NS.

In the Expected scenario, a pipeline is built so that NS natural gas supplies can be transported to the Southern Railbelt region. The difference between NS wellhead prices, inclusive of natural gas treating costs, and delivered market prices for in-state consumer use is the tariff that recovers the investment in the pipeline that connects the NS producing area with the Southern Railbelt and the liquefaction plant. The Cook Inlet price is set by supply and demand and competition between Cook Inlet and NS natural gas supplies. Cost of production at the NS will increase with cumulative production, as currently unmarketable natural gas production from Prudhoe Bay and

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\(^{38}\) This assumes no exports from the Conoco-Phillips Kenai plant, which was off-line at the time of our analysis. ConocoPhillips Alaska Natural Gas Corporation filed an application with DOE/FE on December 11, 2013, to export a total of 40 Bcf of natural gas from its Kenai plant over a two-year period. If this facility begins exporting gas again, accounting for this change would have no material effect on the results and conclusions of this report. If granted by DOE/FE, ConocoPhillips Alaska Natural Gas Corporation’s two-year export authorization will have been completed well before the AKLNG project would commence operation.
other existing fields must be augmented by new exploration and production in new areas of the NS. 39

The cost of this NS natural gas is well below that of Cook Inlet and imported natural gas because NS natural gas supplies are far more abundant than Cook Inlet and do not require the transportation cost included in the price of imports to Alaska. The Alaskan market price is the price of natural gas to consumers; whereas the NS wellhead price is the price NS natural gas producers charge at the point of inlet to the pipeline. The natural gas market price in Alaska is composed of a weighted average of the Cook Inlet wellhead price and the NS wellhead price (which includes gas treating costs) plus pipeline costs. Therefore, the natural gas market price in Alaska decreases in the Expected scenario relative to the Baseline once increased supply from NS resources becomes available.

The natural gas price path and its response in the scenarios will depend on the availability and accessibility of natural gas resources in NS and also potential structural shifts in Alaska’s economy that might be triggered by greater natural gas availability. The primary driver of the reduced natural gas market price in Alaska is the low cost supply coming from the NS. The NS wellhead price (which includes gas treating costs) plus the cost of pipeline transportation ranges from $4.47/MMBtu to $7.17/MMBtu during the period between 2023 and 2048. Figure 17 shows the natural gas market price to consumers in Alaska for the Baseline and Expected scenarios.

Under the Expected scenario, the Alaska market price of natural gas for in-state consumer use increases significantly less over time than in the Baseline when no NS natural gas is available. By 2048, the Alaska market price of natural gas is $5.02/MMBtu less in the Expected scenario with exports compared to the Baseline, a 39% price difference. The Expected scenario’s lower price relative to the Baseline occurs even though over one Tcf per year of the natural gas extracted from the NS goes toward LNG exports (including LNG-related fuel use and shrinkages).

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39 NS natural gas and Cook Inlet natural gas are assumed to be differentiated products and comingled as an Armington aggregate at the market place.
The drop in natural gas prices over time induces additional consumption of natural gas in Alaska’s economy, ignoring natural gas usage associated with the production and delivery of natural gas and LNG from the NS. By 2048, total Alaskan natural gas consumption is about 10% higher in the Expected scenario than the Baseline. The greatest expansion in natural gas use occurs in the residential sector (C) and natural gas intensive industries. Figure 19 shows that the total natural gas produced over the modeling horizon never exceeds the NS and Cook Inlet resource constraints assumed in this analysis (as specified in Section III.E above).

This expansion in natural gas demand is met primarily through the increased production levels of NS natural gas as can be seen in Figure 19. Cook Inlet natural gas production also continues to contribute to total Southern Railbelt supplies although to a much lesser degree and at lower levels over time given the diminishing economically accessible resources there.
**Figure 18: Expected Scenario Alaska In-State Natural Gas Demand by Sector (Bcf/yr)**

<table>
<thead>
<tr>
<th>Sector</th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
<th>2038</th>
<th>2043</th>
<th>2048</th>
<th>Cumulative Total (Tcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>36</td>
<td>39</td>
<td>25</td>
<td>33</td>
<td>39</td>
<td>42</td>
<td>44</td>
<td>51</td>
<td>1.5</td>
</tr>
<tr>
<td>Commercial</td>
<td>23</td>
<td>23</td>
<td>27</td>
<td>30</td>
<td>32</td>
<td>34</td>
<td>37</td>
<td>41</td>
<td>1.2</td>
</tr>
<tr>
<td>Residential</td>
<td>22</td>
<td>24</td>
<td>34</td>
<td>36</td>
<td>38</td>
<td>41</td>
<td>43</td>
<td>46</td>
<td>1.4</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>6</td>
<td>7</td>
<td>14</td>
<td>17</td>
<td>16</td>
<td>17</td>
<td>16</td>
<td>16</td>
<td>0.5</td>
</tr>
<tr>
<td>Government</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>0.2</td>
</tr>
<tr>
<td>Energy-Intensive</td>
<td>4</td>
<td>5</td>
<td>10</td>
<td>13</td>
<td>13</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>0.4</td>
</tr>
<tr>
<td>Trucking Transportation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Other Transportation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Upstream Lease and Operations Fuel</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>10.2</td>
</tr>
<tr>
<td>Sectoral Total</td>
<td>353</td>
<td>357</td>
<td>370</td>
<td>388</td>
<td>399</td>
<td>409</td>
<td>417</td>
<td>431</td>
<td>15.6</td>
</tr>
<tr>
<td>Total Change from Baseline</td>
<td>0</td>
<td>0</td>
<td>16</td>
<td>25</td>
<td>31</td>
<td>33</td>
<td>34</td>
<td>40</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Figure 19: Expected Scenario Alaska Natural Gas Production by Source (Tcf/yr)**

<table>
<thead>
<tr>
<th>Source</th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
<th>2038</th>
<th>2043</th>
<th>2048</th>
<th>Cumulative Total (Tcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS</td>
<td>0.26</td>
<td>0.26</td>
<td>1.18</td>
<td>1.42</td>
<td>1.45</td>
<td>1.47</td>
<td>1.51</td>
<td>1.52</td>
<td>45.3</td>
</tr>
<tr>
<td>Cook Inlet</td>
<td>0.09</td>
<td>0.10</td>
<td>0.07</td>
<td>0.07</td>
<td>0.05</td>
<td>0.04</td>
<td>0.01</td>
<td>0.01</td>
<td>2.2</td>
</tr>
<tr>
<td>Total</td>
<td>0.35</td>
<td>0.36</td>
<td>1.25</td>
<td>1.49</td>
<td>1.50</td>
<td>1.51</td>
<td>1.52</td>
<td>1.53</td>
<td>47.5</td>
</tr>
</tbody>
</table>

40 The items and totals in this table exclude feed gas and fuel/shrinkage requirements.

41 Cumulative totals may not equal the sum of all years due to differences in rounding.

42 Upstream lease operations fuel estimate is average fuel use for years 2007 through 2011 based on EIA data. Available at: [http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SAK_a.htm](http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SAK_a.htm).

43 Cumulative totals may not equal the sum of all years due to differences in rounding.
2. **Electricity Market Impacts**

Increased supply of natural gas leads to lower natural gas prices and then cheaper delivered electricity prices. This would be a boon for the local economy and could encourage economic growth and improve welfare. Additionally, a greater amount of fuel-switching would occur in Alaska, primarily towards cheaper power generated from natural gas. In the Expected scenario, the abundant supplies of low cost natural gas resources results in a higher degree of availability and use of natural gas-fired generation, as seen in Figure 20. This switch to lower cost fuel results in lower delivered electricity prices to all sectors, as seen in Figure 21.

**Figure 20: Expected Scenario Share of Alaska Electricity Generation from Natural Gas (%)**
**B. Alaska Macroeconomic Impacts**

This section discusses the overall macroeconomic impacts on Alaska for the Expected scenario as a result of incorporating the implementation of the AKLNG project and comparing the results against the Baseline scenario, which assumes no LNG exports from Alaska. We report economic measures such as welfare, aggregate consumption, disposable income, GSP, and loss of wage income to illustrate the impact of the scenarios.

1. **Welfare**

Economic welfare is a concept used by economists that relates to the overall utility that individuals experience from the economy. In NeraERA, welfare is measured by the sum of the values of household consumption and leisure. Technically, welfare is measured as a Hicksian equivalent variation for the representative agent in the model. The equivalent variation measures

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44 The sectors referred to in this chart are C, Energy-Intensive Sectors (EIS), Manufacturing Sector (MAN), and Services Sector (SRV).
the monetary impact that is equivalent to the change in consumers’ utility from the price changes and provides an accurate measure of the impacts of a policy on consumers.\textsuperscript{45}

Expansion of natural gas exports changes the price of goods and services purchased by Alaska consumers. In addition, it also alters the income level of the consumers through increased wealth transfers in the form of tolling charges on LNG exports. These economic effects change the well-being of consumers as measured by equivalent variation in income.

A positive change in welfare means that the policy improves welfare from the perspective of the consumer. The results of the Expected scenario indicate that LNG exports are welfare-improving for Alaska consumers. Consumers\textsuperscript{46} receive additional income from two sources. First, the LNG exports provide additional export revenues, and second, consumers who are owners of the liquefaction plants, receive take-or-pay tolling charges\textsuperscript{47} for the amount of LNG exports. The increase in discounted present value of welfare from the Baseline to the Expected scenario over the export period is approximately $1.4 billion.

2. Gross Regional Product

GDP, or GSP, is another economic metric that is often used to evaluate the effectiveness of a policy; it measures the level of total economic activity in the economy of interest, country, or state, respectively. Figure 22 depicts the changes in Alaska GSP over time. In the short run, the GSP impacts are positive as the economy benefits from capital investment in the infrastructure to bring NS natural gas to the market, increased taxes and royalties, and increase in labor income associated with increased labor demand.\textsuperscript{48} In the long run the LNG exports have a strong positive impact on GSP through increased export revenues and additional wealth transfer in the form of tolling charges. Capital income represents the distributed share of ownership of the resource from the household level. Tax income accounts for approximately one-third of GSP increases in Alaska and is recycled back into the Alaska economy.

\textsuperscript{45} Varian, Hal, “Intermediate Microeconomics: A Modern Approach”, 7\textsuperscript{th} Edition, W.W. Norton & Company, December, 2005, pp. 255-256. “Another way to measure the impact of a price change in monetary terms is to ask how much money would have to be taken away from the consumer before the price change to leave him as well off as he would be after the price change. This is called the equivalent variation in income since it is the income change that is equivalent to the price change in terms of the change in utility.” (emphasis in original)

\textsuperscript{46} Consumers own all production processes and industries by virtue of owning stock in them.

\textsuperscript{47} Note that NERA, for convenience, is assuming a tolling structure for illustration purposes. While alternative structures might change the mechanism the ultimate economic impacts would not be significantly different.

\textsuperscript{48} Direct resource income from developing natural gas resources has been decomposed into capital income, labor income, and taxes.
3. **Aggregate Consumption**

Aggregate consumption measures the total spending on goods and services in the economy. Higher aggregate spending or consumption resulting from a policy suggests higher economic activity and more purchasing power for the consumers. Figure 23 shows the Expected scenario results where consumption increases over time due to increased benefits from the LNG export revenue and increased economic activity within Alaska.
4. Aggregate Investment

Investment in the economy occurs to replace old capital and increase the stock of capital in place (net investment). In this study, additional investment takes place to finance the AKLNG project through the construction of export facilities and the pipeline that will transport natural gas resources from the NS to the export facilities. Investment in new natural gas production capacity is also required over time as NS production moves from the established Prudhoe Bay area into Point Thompson and other new areas. Net investment in Alaska is measured as the increase in the total stock of productive capital in Alaska, which in the scenario includes the value of the gas treating plant, the pipeline, the liquefaction plant, and structures, machinery, and equipment put in place in other industries and in NS natural gas fields.

Figure 24 shows that net investment in Alaska is higher in the Expected scenario than in the Baseline in all years, due to construction of the AKLNG project as well as expansion of other industrial sectors due to the greater availability and lower price of natural gas in the scenario. Financing for this total investment mostly comes from a national pool of investment capital, with a proportional share of investment from Alaska. Though most of the equipment to be installed in the pipeline and liquefaction facility and used for construction and for NS exploration and
production will be manufactured in the Lower-48 or in other countries, when installed in Alaska it becomes part of the capital stock located in the state and is counted as investment in the State. The timing of the changes in investment from the Baseline seen in Figure 24 reflect the timing of the AKLNG project itself with the largest increases seen during years of construction in 2018, 2023, and 2028.

Alaska is able to attract more investment from the rest of the U.S. in the Expected scenario relative to the Baseline because of its lower natural gas prices as well as the opportunity presented by the AKLNG project, and this inflow of investment leads to Alaska having greater economic growth in the scenario than in the Baseline. This greater economic growth and the greater amount of outside investment allow Alaskans to increase their consumption and hence be better off than in the Baseline.

Figure 24: Expected Scenario Change in Capital in Place in Alaska Compared to Baseline (2010$ Billions)

5. Natural Gas Export Revenues

As a result of higher levels of natural gas exports, LNG export revenues offer an additional source of income to the economy. The average annual increase in revenues from LNG exports ranges from about $10 billion to almost $21 billion (2010$) for Alaska as seen in Figure 25.
6. Trade Impacts

The development of the infrastructure to export LNG (i.e., the export facility and connecting pipelines) and the exporting of LNG contribute to the increasing LNG export revenues shown above, but trade in other goods and services depends on how prices and costs in Alaska change relative to its competitors. The development of NS natural gas resources lowers the cost of natural gas in Alaska which lowers the cost of Alaskan goods dependent on natural gas consumption. However, with the construction of the LNG facility and associated pipelines, wage rates and capital costs increase in Alaska thus raising costs of production.

Overall, we see an increase in net foreign exports from Alaska as a result of LNG exports from baseline levels. This results in a large increase in the foreign current account balance. However, on the domestic side, to support higher domestic consumption, as a result of higher income levels, Alaska imports more from the Lower-48. On the whole, the increase in export revenues from LNG exports dominates any decrease in revenues from imports of other goods and services from the rest of the U.S. and results in significant improvement in the terms of trade position for Alaska. In net, the improvement in the current account balance for Alaska is between $10 and $20 billion.
If we only look at net exports of goods and services excluding LNG, Alaska’s net foreign exports are still higher. This suggests that Alaska prefers to import from the Lower-48 and export to the international market to take advantage of the lower natural gas prices.

7. **Sectoral Output Changes for Some Key Economic Sectors**

The effect of changes in natural gas prices on a particular sector depend on the sector’s natural gas intensity and how easily the natural gas use can be substituted with other factors of production and intermediate goods and services. Economic sectors such as the ELE, EIS, and MAN are dependent on natural gas as a fuel and are therefore particularly impacted by changes in natural gas price. Another potentially significant benefit of the lower natural gas prices in Alaska is the possibility of attracting new development such as chemicals or mining to the state or restarting mothballed chemicals facilities. Additionally, natural gas producers and sellers will benefit from natural gas export prices and increased output. These varying impacts will shift income patterns between economic sectors. The overall effect on the economy depends on the degree to which the economy adjusts by fuel switching, introducing new technologies, and the stimulus of new investment.

Figure 26 illustrates how the range of impacts on sectoral output varies considerably by sector. The ELE and SRV sectoral output changes are the largest in the Expected scenario. The ELE, being the most dependent on natural gas and the one able to most easily switch from other fuel inputs to natural gas, sees the largest changes in gas usage – up by almost 13% in 2048. The SRV sector sees output gains starting early on due to the increased economic demand from the start of the pipeline project construction and increases as much as 4% by 2048 due to lower natural gas prices as compared to the Baseline. EIS and MAN see similar patterns of sectoral growth in the expected scenario as SRV although to a slightly smaller degree with maximum output increases of 2% and 3%, respectively. Availability of NS natural gas and sustained lower natural gas prices allow the industrial base to expand and maintain a higher growth path into the future in Alaska.
Figure 26: Expected Scenario Changes in Output for Key Alaska Economic Sectors Compared to Baseline (%)

8. Wage Rates

Sectoral output, discussed in the previous section, translates directly into changes in factors of production for a given sector. In general, if the output of a sector increases so do the inputs associated with the production of this sector’s goods and services. An increase in natural gas output leads to more wage income in the natural gas sector as domestic production increases. In the short run, industries are able to adjust to changes in demand for output by increasing employment if the sector expands or by reducing employment if the sector contracts.

As shown in the previous section, the production of lower cost natural gas lowers delivered natural gas prices and causes production costs for Alaskan industries, hence making Alaska businesses more competitive. The net result is increased output across key sectors. Because the Alaskan economy is supported by a small labor market, wage rates in Alaska could potentially increase significantly if it were to meet the increased demand for labor to support pipeline construction, oil and natural gas production, and increased industrial output with only Alaskan
residents. Instead, the demand for labor which results in wage rate increases attracts workers from other states to move to Alaska, either temporarily or permanently. The supply of out-of-state labor in meeting the increased labor demand in Alaska for the Expected scenario helps moderate the increase in wage rates, particularly in the early years when the pipeline and LNG facility are constructed. Toward the end of the export horizon, the increase in wage rates flattens due to smaller increase in labor demand, relative to the Baseline, as a result of the labor market anticipating the end of the LNG export period and the commensurate boon to economic activity.

Figure 27 shows the change in total Alaska wage rate for the Expected scenario as compared to the Baseline. Overall wage income increases in all sectors commensurate with the increase in wage rates.

**Figure 27: Expected Scenario Change in Alaska Wage Rate Compared to Baseline (%)**

C. U.S. Energy Market Impacts

This section discusses the impacts on the U.S. energy markets as a result of implementing the AKLNG project scenarios against a Baseline without any LNG exports from Alaska. Because

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49 Our initial analysis suggested that the indigenous labor supply is insufficient to support the anticipated demand for labor in the Expected and the High scenario.
Alaska represents a small share of the U.S. economy, changes in Alaska’s economy generally have only a small effect on the rest of the U.S. The only exception is in the energy markets, where Alaska’s production of energy accounts for a modest share of U.S. output.\(^50\)

As a result of Alaska developing the NS and exporting 0.93 Tcf of natural gas per year after 2025, total U.S. exports of LNG are approximately 0.6 Tcf higher than in the Baseline. The reduction in Lower-48 natural gas exports as compared to the Baseline leads to additional supplies for domestic consumption and hence a reduction in the average U.S. wellhead natural gas price, even though Lower-48 exports do increase over the model horizon. One way to view this impact on Lower-48 LNG exports is to consider them being delayed in time rather than permanently displaced (i.e., the curve of export volumes is shifted to the right or forward into time). Under the Expected scenario, the average U.S. wellhead price in 2048 is $9.58/MMBtu compared to $9.68/MMBtu in the Baseline, a 1% decline. The AKLNG project thereby lowers average wellhead prices for the U.S. as a whole. The AKLNG project results in increased levels of U.S. LNG exports as a whole and lower U.S. natural gas prices.

**Figure 28: Expected Scenario U.S. Projected Wellhead Natural Gas Price (2010$/MMBtu)**

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\(^{50}\) According to the U.S. Bureau of Economic Analysis, Alaskan GSP was about 0.30% of the U.S. GDP in 2012. According to the EIA, Alaska’s share of total U.S. energy production was about 2.1% in 2011.
D. U.S. Macroeconomic Impacts

This section discusses macroeconomic impacts for the U.S. as a whole as a result of implementing the AKLNG project in the Expected scenario against a Baseline without any LNG exports from Alaska. We used economic measures such as welfare, aggregate consumption, and GDP to estimate the impact of the scenarios.

1. Welfare

Expansion of natural gas exports changes the price of goods and services purchased by U.S. consumers. In addition, it also alters the income level of the consumers through increased wealth transfers in the form of tolling charges on LNG exports. These economic effects change the well-being of consumers as measured by equivalent variation in income. The equivalent variation measures the monetary impact that is equivalent to the change in consumers’ utility from the price changes and provides an accurate measure of the impacts of a policy on consumers.

We report the change in welfare relative to the Baseline in Figure 29. A positive change in welfare means that the policy improves welfare from the perspective of the consumer. The Expected scenario is welfare-improving for U.S. consumers. Under the Expected scenario, consumers receive additional income from two sources. First, the LNG exports provide additional export revenues, and second, consumers who are owners of the liquefaction plants, receive take-or-pay tolling charges for the amount of LNG exports. Although the Expected scenario does have a positive welfare impact on the U.S. as a whole, it should be noted that the magnitude of the impact is very small.

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51 The financial arrangement assumption for the Lower-48 LNG exports is based on the NERA 2012 study. We assume that the LNG tolling fee was based on a return of capital to the developer and financing of investment is assumed to originate from U.S. sources. The LNG export price received includes a tolling fee plus a 15% markup over Henry Hub price.
2. GDP

GDP is another economic metric that is often used to evaluate the effectiveness of a policy; it measures the level of total economic activity. In the short and medium run, the GDP impacts are positive as the U.S. economy benefits from capital investment in the LNG-related infrastructure, export revenues, taxes, and additional wealth transfer in the form of tolling charges. In the long run, GDP impacts remain positive but become slightly smaller due to a feedback employment effect from Alaska to the rest of the Lower-48. The reduction in labor demand in Alaska towards the end of the exporting period (primarily reducing demand on out-of-state workers) mitigates the decrease in labor supply in the Lower-48 and creates a downward pressure on the Lower-48 wage rates. This small reduction in Lower-48 wage rates therefore reduces the labor income and taxes on labor income components of U.S. GDP at the end of the export horizon. As a whole it should be noted that while the GDP impact of the AKLNG project in the U.S. is positive it is very small in magnitude relative to the size of the whole U.S. economy, less than 0.05% on average.
3. **Aggregate Consumption**

Aggregate consumption measures the total spending on goods and services in the economy. Figure 31 shows that aggregate consumption in the U.S. increases steadily throughout the Expected scenario. Consumption rises more quickly after the AKLNG project is completed because more saving is required to support lower levels of capital investment demand. Additionally, increases in income from export revenues can go toward supporting higher levels of consumption.
4. **Balance of Trade**

The AKLNG project would provide access to low cost NS natural gas supplies and allow the U.S. to produce LNG at a globally competitive price. In other words, LNG exports provide the U.S. with a means to obtain international goods and services with fewer resources. Therefore, the value of U.S. net exports increases because of the increase in revenues from LNG exports. The large surplus in the current account balance of Alaska as a result of the AKLNG project is a primary driver in the increase in net exports which results in an improvement in the U.S. balance of trade.

**E. U.S. Emissions Impacts**

The overall change in U.S. carbon dioxide (CO₂) emissions in the Expected scenario relative to the Baseline is minimal but slightly lower in the long run. The increase in economic activity as a result of greater availability of lower cost natural gas supplies is offset, in aggregate, by the lower carbon intensity of natural gas as a fuel compared to its alternatives. The fuel substitution effect occurs at a domestic level in terms of a coal-to-gas fuel switching in the electric sector due to the lower natural gas prices in the U.S. This fuel switching results in reductions in electric sector emissions of NOₓ, SOₓ, Hg, and CO₂. Given the large portion of total U.S. emissions of
these types accounted for by the electric sector, the fuel switching effect drives reductions in these emissions from the U.S. as a whole.

**Figure 32: Expected Scenario Change in U.S. CO₂ Emissions Compared to Baseline (%)**
V. SUMMARY OF U.S. ECONOMIC IMPACTS

This section provides a summary of implications for macroeconomic impacts, environmental impacts, and national security impacts of producing natural gas and exporting much of it in the form of LNG from Alaska.

A. DOE Guidelines and Prior LNG Export Applications Approvals

The need to consider “public interest” when authorizing exportation of natural gas is stated in the NGA:

…no person shall export any natural gas from the United States to a foreign country or import any natural gas from a foreign country without first having secured an order of the Commission authorizing it to do so. The Commission shall issue such order upon application, unless, after opportunity for hearing, it finds that the proposed exportation or importation will not be consistent with the public interest…

In practice, DOE considers the previous excerpt to imply the creation of a “rebuttable presumption” favoring the exportation of natural gas. It furthermore allows the public to participate in the process as “interveners” that can cite evidence, if any, that the application is inconsistent with the public interest.

In order to preclude any assertion that proposed exports are inconsistent with the public interest, permit applicants typically include supporting arguments and evidence along the following DOE suggested criteria:

1. Domestic demand for the natural gas to be exported;
2. Adequacy of domestic natural gas supply;
3. U.S. energy security;
4. Impact on the U.S. economy, including impact on domestic natural gas prices;
5. International considerations; and

As part of the analysis of domestic need for exportation and adequacy of domestic supply, applicants typically evaluate changes to natural gas prices and compare the total volume of natural gas available for production (both reserves and recoverable resources) during the

53 Panhandle Producers and Royalty Owners Association v. ERA, 822 F. 2d 1105, 1111 (D.C. Cir. 1987).
specified exportation period to the analogous natural gas demand. It is not uncommon for these analyses to incorporate more than one natural gas demand/supply scenario in order to reflect possible outcomes from other potential paths the market may take.

To address the U.S. energy security criteria, applicants sometimes blend in arguments for adequate supply and international environmental considerations. They frequently support the assertion made in MIT’s 2010 “The Future of Natural Gas” claiming that LNG exports “encourage the development of an efficient and integrated global gas market with transparency and diversity of supply.”55 Additionally, applicants will note that increasing global access to natural gas, a fuel that burns cleaner than coal or oil, will aid in slowing global climate change. Lastly, arguments for improvement in balance of trade and trade relations with destination countries, promoting the intent of the National Export Initiative, and consistency with U.S. obligations under the General Agreement on Tariffs and Trade (GATT) are made to complete the analysis of U.S. international concerns.56

B. U.S. Economic Impacts

In this section we briefly summarize the results of our analysis for the U.S. As discussed in the preceding sections, the impacts of the AKLNG project on the U.S. economy are positive in all metrics and the magnitude of the impacts is relatively small. Figure 33 shows the percentage change in the Expected scenario relative to the Baseline of several key metrics we have previously analyzed.


Figure 33: Summary of U.S. Natural Gas and Macroeconomic Impacts in Expected Scenario Compared to Baseline

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
<th>2038</th>
<th>2043</th>
<th>2048</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wellhead Natural Gas Price (%)</td>
<td>-</td>
<td>0.5%</td>
<td>0.4%</td>
<td>-0.6%</td>
<td>-0.8%</td>
<td>-0.9%</td>
<td>-1.0%</td>
<td>-1.2%</td>
</tr>
<tr>
<td>Welfare (%)</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.03%</td>
<td>0.02%</td>
<td>0.03%</td>
</tr>
<tr>
<td>GDP (%)</td>
<td>0.01%</td>
<td>0.03%</td>
<td>0.05%</td>
<td>0.06%</td>
<td>0.06%</td>
<td>0.06%</td>
<td>0.06%</td>
<td>0.05%</td>
</tr>
<tr>
<td>Consumption (%)</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
</tr>
<tr>
<td>CO₂ Emissions (%)</td>
<td>0.02%</td>
<td>0.06%</td>
<td>0.02%</td>
<td>0.01%</td>
<td>0.00%</td>
<td>-0.02%</td>
<td>-0.02%</td>
<td>-0.01%</td>
</tr>
</tbody>
</table>

1. U.S. Natural Gas Market Impacts

Development of the AKLNG project would affect U.S. natural gas markets in the following ways. First, supplies of domestic natural gas would increase because of the increased resource development in NS. The increase in supply would naturally lead to a decline in domestic natural gas prices since there would be more natural gas resources available for consumption. The lower prices would result in a slight rebound effect where U.S. natural gas demand in the Expected scenario exceeds that of the Baseline scenario and that increase in demand would have an upward pressure on natural gas prices, but not enough to offset the decrease in natural gas prices due to increased supply. The net result is higher natural gas demand and consumption but lower natural gas prices in the U.S. in the Expected scenario.

2. U.S. Macroeconomic Impacts

As for broader macroeconomic impacts, the change in the U.S. across all key macroeconomic metrics – GDP, consumption, and welfare – from the Baseline levels is positive.

The AKLNG project would provide access to low cost NS natural gas supplies and allow the U.S. to produce LNG at a globally competitive price. In other words, LNG exports provide the U.S. with a means to obtain international goods and services with fewer resources. Therefore, the value of U.S. net exports increases because of the increase in revenues from LNG exports. The large surplus in the current account balance of Alaska as a result of the AKLNG project is a primary driver in the increase in net exports which results in an improvement in the U.S. balance of trade.
C. Environmental Impacts

The development of the AKLNG project leads to different impacts which have competing effects on emissions. Increased natural gas supplies result in lower natural gas prices which lead to:

- Higher economic growth driving higher demand for natural gas and an increase in emissions; and
- Fuel switching from non-gas fuels to natural gas, particularly in the electric sector, which decreases emissions of CO\textsubscript{2}, SO\textsubscript{x}, NO\textsubscript{x}, and Hg in the long term.

On balance for the U.S., emissions decline in the long-run, but changes in total U.S. emissions are small at approximately -0.01%.

D. Energy Security

Energy security has a number of dimensions: assurance of supply, low and stable energy prices, and freedom of action in foreign policy are classic issues addressed in the case of crude oil and refined products. Although the debate has often been framed in terms of energy independence, until recently policies and planning for oil security assumed that the U.S. would continue to be an importer and affected negatively by supply shocks and price increases for imported oil. Since crude oil is traded in a global and liquid market, physical supply security has not been a real issue. Private inventories of crude oil and refined products have covered any delays in cargo arrivals, and the Strategic Petroleum Reserve stands ready to address longer delays.

Thus oil security came to be focused on reducing the likelihood and magnitude of the oil supply disruptions that could trigger price shocks, and to increasing the resilience of the U.S. economy to those shocks. The most direct measure of the potential magnitude of supply shocks is the share of the world’s oil being produced in vulnerable or unstable regions, originally in the Persian Gulf but now increasingly in certain Latin America countries. Thus questions about how reduction in U.S. oil imports, whether through increased production or reduced demand, would enhance supply security came down to modeling how that reduction translated into a smaller share of world supply coming from vulnerable or unstable regions.

What was a concern about how dependence on oil imports limited freedom of action in foreign policy has been amplified by concern that oil revenues are propping up regimes that deny their people basic human rights and economic development or being funneled by state or private recipients into support of terrorist groups.

Since the U.S. was never a major importer of natural gas except from Canada, the issue of energy security has not been as well developed about natural gas markets. Starting with the basic criteria of supply assurance, low and stable prices, and foreign policy benefits, it is possible to develop some metrics of how natural gas exports can affect energy security.
Supply Assurance: Exporting natural gas requires several investments that are irreversible in the short run: deliverability of natural gas from wellhead to terminal to support exports, and capacity to liquefy and export. From the point of view of U.S. price stability and assured supplies, the production capacity that is supplying export markets is in effect spare capacity that can be diverted to domestic uses. The larger and more liquid the global natural gas market is, the more effective this spare capacity will be. It is not necessary that DOE be prepared to revoke export licenses to ensure this, because as long as exporters are purchasing natural gas in the spot market or under contracts indexed to the U.S. market, U.S. consumers will be able to bid natural gas away from exporters if a domestic shortage were to occur.

Price Stability: Although mostly outside the scope of this study, a number of experts on global commodity markets have concluded that being connected to a global LNG market will serve to reduce natural gas price volatility. Historically, U.S. natural gas prices have been much more volatile than world oil prices, so that even if a global LNG market became linked in some way to oil prices, having U.S. natural gas prices linked to the global LNG market would reduce volatility.\(^\text{57}\) Moreover, to the extent that shocks to the global market and shocks to the U.S. market are not correlated, U.S. volatility would be reduced by the greater size of the market. Finally, export capacity is likely to be fully utilized. Under these conditions, shocks to the world natural gas market and even global LNG price spikes will not be transmitted to the U.S. market, though they would benefit those holding firm export capacity contracts. The reason is that exports will be limited by liquefaction capacity, and once that limit is reached there can be no further increase in exports and therefore no additional demand for U.S. natural gas. As a result the U.S. price will be unaffected by increases in global prices as long as terminals are at capacity.\(^\text{58}\)

Foreign Policy: Natural gas exports can have clear foreign policy benefits: reducing dependence of other countries on exports from countries that are not allies of the U.S. will reduce the influence of those countries on the policies of potentially friendly countries importing U.S. LNG. Removing restrictions on exports will also signal the U.S. commitment to WTO and GATT principles, to support free market regimes in other countries, and make it easier to press other countries to remove export restrictions that are damaging to U.S. industry.\(^\text{59}\)


\(^{58}\) The only case in which an unexpected increase in global prices could affect U.S. prices is if global prices had fallen so low relative to expectations that there was excess capacity at some terminal. Even in this case, U.S. prices would not move directly with world prices but only up to a level consistent with U.S. terminals being used at capacity. Once terminals are at capacity, the U.S. is disconnected from any further increase in global prices.

APPENDIX A. HIGH LNG EXPORT SCENARIO

In this appendix we discuss some results from the High scenario with a 40 year export horizon, natural gas supply resource of 109 Tcf, and higher demand induced primarily by a faster growing economy in Alaska. The economic impacts are generally consistent with the results from the Expected scenario with two exceptions:

1. The impact of not constructing Susitna; and
2. The impact of an extended LNG export horizon in Alaska.

Due to the generally consistent nature of the results in the High scenario, we focus our discussion in the following sections on differences in impacts relative to the Expected scenario impacts presented in the main body of the report.

A. Alaska Energy Market Impacts

This section discusses the High scenario impacts on the Alaska energy markets as a result of implementing the AKLNG project compared to a Baseline without any LNG exports from Alaska, as well as the Expected scenario.

1. Natural Gas Market Impacts

Impacts on natural gas prices in Alaska under the High scenario are similar to those in the Expected scenario. This similarity occurs despite the increased demand primarily caused by the increased natural gas resource assumption but also because of the relatively low resource cost of NS natural gas supplies for the Alaska market. The NS wellhead price plus the cost of pipeline transportation in the High scenario ranges from being $0.05/MMBtu lower to $0.14/MMBtu greater than in the Expected scenario. The price comparisons can be seen in Figure 34. It is interesting to note that by the end of the export horizon in 2058 the Alaska market price of natural gas essentially converges with the NS wellhead price plus pipeline transportation charges. This shows the impact of resource depletion in Cook Inlet and that NS natural gas becomes a larger share of supplies to Alaska markets.

The decreases in natural gas prices relative to the Baseline seen in the High scenario, along with the increased demand assumptions, result in an even greater increase in natural gas consumption. The greatest expansion in natural gas use occurs in the ELE due to the need to replace the generation of Susitna that is not constructed in the High scenario. Figure 36 shows that the total natural gas produced over the modeling horizon never exceeds the NS and Cook Inlet resource constraints assumed in this analysis (as specified in Section III.E above).
Figure 34: High Supply and High Demand Scenario Alaska Natural Gas Market Prices (2010$/MMBtu)

Note: NERA adopted the net-forward pricing to establish a baseline market price path for modeling economic impact and benefits. The market price that NERA estimated is subject to uncertainties influenced by many factors and claims no knowledge of the ultimate negotiated market price. The model estimates overall net benefits regardless of how benefits and costs are distributed across various end-users and consumers.
### Figure 35: High Scenario Average Alaska Natural Gas Demand by Sector (Bcf/yr)<sup>60</sup>

<table>
<thead>
<tr>
<th>Sector</th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
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<th>2043</th>
<th>2048</th>
<th>2053</th>
<th>2058</th>
<th>Cumulative Total (Tcf)&lt;sup&gt;61&lt;/sup&gt;</th>
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<tr>
<td>Electricity</td>
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<td>39</td>
<td>52</td>
<td>59</td>
<td>65</td>
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<td>80</td>
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<td>41</td>
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<td>64</td>
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<tr>
<td>Residential</td>
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<td>24</td>
<td>35</td>
<td>38</td>
<td>40</td>
<td>44</td>
<td>47</td>
<td>52</td>
<td>56</td>
<td>60</td>
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<td>42</td>
<td>47</td>
<td>44</td>
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<td>4</td>
<td>5</td>
<td>5</td>
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<td>5</td>
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<td>5</td>
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<td>255</td>
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<td>141</td>
<td>183</td>
<td>221</td>
<td>267</td>
<td>12.6</td>
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</table>

### Figure 36: High Scenario Average Alaska Natural Gas Production by Source (Tcf/yr)

<table>
<thead>
<tr>
<th>Source</th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>2033</th>
<th>2038</th>
<th>2043</th>
<th>2048</th>
<th>2053</th>
<th>2058</th>
<th>Cumulative Total (Tcf)&lt;sup&gt;63&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS</td>
<td>0.26</td>
<td>0.26</td>
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<td>1.52</td>
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<td>1.66</td>
<td>1.71</td>
<td>1.76</td>
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</tr>
<tr>
<td>Cook Inlet</td>
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<td>0.08</td>
<td>0.08</td>
<td>0.06</td>
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<tr>
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<td>0.36</td>
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<td>1.62</td>
<td>1.67</td>
<td>1.72</td>
<td>1.77</td>
<td>67.6</td>
</tr>
</tbody>
</table>

---

<sup>60</sup> The items and totals in this table exclude feed gas and fuel/shrinkage requirements.

<sup>61</sup> Cumulative totals may not equal the sum of all years due to differences in rounding.

<sup>62</sup> Upstream lease operations fuel estimate is average fuel use for years 2007 through 2011 based on EIA data. Available at: [http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SAK_a.htm](http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SAK_a.htm).

<sup>63</sup> Cumulative totals may not equal the sum of all years due to differences in rounding.
2. Electricity Market Impacts

Without the construction of Susitna, there is a relatively large, but not unexpected, jump in the reliance on natural gas-fired generation in the ELE in the High scenario (Figure 37). This is due to the need to make up for the lack of generation provided by Susitna in both the Baseline and Expected Scenario.

Figure 37: High Scenario Share of Alaska Electricity Generation from Natural Gas (%)

An increase in delivered electricity prices relative to the Baseline is also seen in this scenario, particularly in 2023. Again, this is due to the lack of the generation provided by Susitna in the Baseline and Expected scenarios requiring more construction of natural gas-fired electricity generation which has a higher marginal cost of generation than hydroelectric generation. Even given the early year increases in delivered electricity prices, overall prices drop significantly over time and are in line with the reductions in electricity prices seen in the Expected scenario by 2038.
B. Alaska Macroeconomic Impacts

This section discusses the overall macroeconomic impacts for the High scenario as a result of incorporating the implementation of the AKLNG project and comparing the results against the Baseline scenario, which assumes no LNG exports from Alaska, as well as the Expected scenario.

1. Welfare

The positive impacts in consumer welfare relative to the Baseline seen in the Expected scenario extend to the High scenario in approximately equivalent magnitudes over equivalent periods of the export horizon. The greatest difference lies in the extended modeling horizon for the High scenario which includes an extended period of LNG exports.

2. Gross Regional Product

Like welfare, the positive GSP impacts seen in the High scenario, relative to the Baseline, are similar to those in the Expected scenario over comparable period of time but are even greater further out in the horizon due to the extended period of LNG exports (Figure 39). The steadily
increasing GSP impacts are driven by the increasing costs of natural gas and therefore the increasing LNG export revenues over time.

**Figure 39: High Scenario Change in Alaska GSP Compared to Baseline (2010$ Billions)**

3. **Aggregate Consumption**

The path of increased consumption in the High scenario closely follows that of Expected scenario with the amount of the increase leveling off towards the end of the extended LNG export horizon. The primary driver in the flattening of consumption increases in the High scenario is the greater increases in the Alaska natural gas prices over the 2048 through 2058 period. The higher prices raises the cost of goods in Alaska, leading to a lower rate of consumption growth while still allowing GSP to continue increasing due to the ever increasing LNG export revenues.
4. **Aggregate Investment**

As with welfare and GSP, the change in aggregate investment follows a similar path in the Expected and High scenarios over the time horizon of the Expected scenario. Alaska continues to attract more investment from the rest of the U.S. in the High scenario relative to the Baseline because of its lower natural gas prices as well as the opportunity presented by the AKLNG project. Additionally, the higher economic growth rate in the High scenario contributes to even higher aggregate investment than in the Expected scenario and this inflow of investment leads to Alaska having greater economic growth than in either the Baseline or Expected scenario.
5. Natural Gas Export Revenues

By design, the Expected and High scenarios export the same amount of natural gas over the horizon of the Expected scenario, but the High scenario assumes natural gas exports continue for another ten years, hence the export revenues from the High scenario continue. The revenues continue to increase over time because world natural gas prices increase faster than Alaska’s wellhead price.
6. **Trade Impacts**

Trade impacts are essentially the same in the High scenario as in the Expected scenario. Overall, we see an increase in net foreign exports from Alaska as a result of LNG exports from baseline levels. This results in a large increase in the foreign current account balance.

7. **Sectoral Output Changes for Some Key Economic Sectors**

The biggest differences in sectoral output changes in the High scenario compared to the Expected scenario occur in the ELE. The SRV, MAN, and EIS all show very similar, but slightly higher, changes in output relative to the Baseline when compared with the changes in the Expected scenario. The greater increase in ELE output in the High scenario is primarily a result of the higher economic growth rate assumption which drives significantly greater electricity demand in the state, particularly starting in 2033. By 2048, the last model year comparable amongst all three model runs, electricity generation in the High scenario is 13.1 TWh compared to 10.2 TWh in the Expected scenario and 9 TWH in the Baseline. This represents a demand for electricity in the High scenario which is 28% and 45% greater than in the Expected scenario and the Baseline respectively.
8. Wage Rates

The increase in wage rates in the High scenario generally follows the increases seen in the Expected scenario with two differences. First, from the period through 2043, the level of the wage rate increase is slightly lower than in the Expected scenario due to slightly higher electricity and natural gas prices in the High scenario creating a small downward pressure on labor demand and therefore wage rates. Second, from 2048 through the end of the longer LNG export horizon in 2058, the greater rate of economic growth in Alaska assumed in the High scenario and the increased cost of out-of-state labor at this point in the modeling horizon combine to drive wage rate and labor demand increases to higher levels than seen in the Expected scenario.
C. U.S. Energy Market Impacts

Alaskan exports of natural gas have a minimal impact on natural gas prices in the rest of the U.S. This relationship is true under both the Expected and High scenarios. The percentage change in natural gas prices from the Baseline to the High scenario is nearly constant over time.
D. U.S. Macroeconomic Impacts

As with the natural gas prices, the impacts of the AKLNG project on the rest of the country’s welfare, GDP, etc., is quite small, and the changes in the High scenario closely track those of the Expected scenario throughout the scenario’s horizon. After the time in which the Expected scenario is no longer analyzed, the High scenario sees to exhibit fairly similar macroeconomic impacts. Across all of the following metrics, the difference in impacts of the AKLNG project on the U.S. under both the Expected and High scenarios is positive and, on average over the modeling horizon, smaller than 0.05%.

1. Welfare

The change in welfare in the U.S. in the High scenario is virtually identical to the change in welfare in the Expected scenario. This change is positive but also very small, never exceeding 0.1% in a given modeling year.
Figure 46: High Scenario Change in U.S. Welfare Compared to Baseline (%)

2. GDP

Increases in U.S. GDP generally follow the same pattern in the High scenario as in the Expected scenario with the exception of 2048 onward. Where in the Expected scenario we saw a tapering of GDP growth in 2048, we do not see the same impact in the High scenario due to the differences in wage rates in 2048 and onward. Due to the High scenario’s higher economic growth rate assumption in Alaska as well as the longer period of LNG exports, we do not see the same reduction in Alaskan labor demand which fed back into the Lower-48 and created a downward force on overall U.S. wage rates. Instead the higher levels of sustained labor demand and increased wage rates drive continued growth in labor income and overall U.S. GDP over the High scenario modeling horizon. It should be noted that, much like in the Expected scenario, while the GDP impact in the U.S. is positive, it is still very small and smaller than 0.05% on average over the modeling horizon.
3. Aggregate Consumption

The pattern of consumption increases in the High scenario follows almost exactly along the lines of the increases in the Expected scenario. Overall economic impacts are slightly more positive across the U.S., and the LNG export horizon is longer than in the Expected scenario, but otherwise the pattern is very similar.
4. **Balance of Trade**

The impacts on balance of trade in the High scenario are also almost exactly the same as in the Expected scenario. The large surplus in the current account balance of Alaska as a result of the AKLNG project is a primary driver in the increase in net exports which results in an improvement in the U.S. balance of trade.

E. **U.S. Emissions Impacts**

The change in CO$_2$ emissions for the U.S. in the High scenario relative to the Baseline is similar to what we see in the Expected case with less than a 0.2% move in either direction in any given model year. Higher near term emissions due to investment-driven GDP growth are balanced by lower emissions in the long run due to extended natural gas supplies.
Figure 49: High Scenario Change in U.S. CO₂ Emissions Compared to Baseline (%)
APPENDIX B. ADDITIONAL N_EWERA MODEL DETAILS

1. Overview of Macroeconomic Model

The N_EWERA macroeconomic model is a forward-looking dynamic CGE model of the United States. The model simulates all economic interactions in the U.S. economy, including those among industry, households, and the government. The benchmark year economic interactions are based on the IMPLAN 2008 database, which includes regional detail on economic interactions among 440 different economic sectors. The macroeconomic and energy forecasts that are used to project the benchmark year going forward are calibrated to the most recent AEO produced by the EIA. Because the model is calibrated to an internally-consistent energy forecast, the use of the model is particularly well suited to analyze economic and energy policies and environmental regulations.

The N_EWERA model incorporates EIA energy quantities and energy prices into the IMPLAN Social Accounting Matrices. This approach, which has been developed by the NERA team, results in a balanced energy-economy dataset that has internally-consistent energy benchmark data as well as IMPLAN-consistent economic values.

The macroeconomic model incorporates all production sectors and final demanders of the economy and is linked through terms of trade. The effects of policies are transmitted throughout the economy as all sectors and agents in the economy respond until the economy reaches equilibrium. The ability of the model to track these effects and substitution possibilities across sectors and regions makes it a unique tool for analyzing policies such as those involving energy and environmental regulations. These general equilibrium substitution effects, however, are not fully captured in a partial equilibrium framework or within an input-output modeling framework. The smooth production and consumption functions employed in this general equilibrium model enable gradual substitution of inputs in response to relative price changes thus avoiding all-or-nothing solutions.

Business investment decisions are informed by future policies and outlook. The forward-looking characteristic of the model enables businesses and consumers to determine the optimal savings and investment levels while anticipating future policies with perfect foresight. The alternative approach on savings and investment decisions is to assume agents in the model are myopic, and thus have no expectations for the future. Though both approaches are equally unrealistic to a certain extent, the latter approach can lead the model to produce inconsistent or incorrect impacts from an announced future policy.

A CGE modeling tool such as the N_EWERA macroeconomic model can analyze scenarios or policies that call for large shocks outside of historical observation. Econometric models are unsuitable for policies that impose large impacts because these models’ production and consumption functions remain invariant under the policy. In addition, econometric models assume that the future path depends on the past experience and therefore fail to capture how the
economy might respond under a different and new environment. For example, an econometric model cannot represent changes in fuel efficiency in response to increases in energy prices. However, the N\textsubscript{ew}ERA macroeconomic model can consistently capture future policy changes that envisage having large effects.

The N\textsubscript{ew}ERA macroeconomic model is also a unique tool that can iterate over sequential policies to generate consistent equilibrium solutions starting from an internally consistent equilibrium baseline forecast (such as the AEO reference case). This ability of the model is particularly helpful to decompose macroeconomic effects of individual policies. For example, if one desires to perform economic analysis of a policy that includes multiple regulations, the N\textsubscript{ew}ERA modeling framework can be used as a tool to layer in one regulation at a time to determine the incremental effects of each policy.

2. Model Scope

a. Regional Aggregation

The standard N\textsubscript{ew}ERA macroeconomic model includes 11 regions: NYNE (New York and New England), MAAC (Mid-Atlantic Coast), UPMW (Upper Midwest), SEST (Southeast), FLST (Florida), MSVL (Mississippi Valley), MAPP (Mid-America), TXOL (Texas, Oklahoma and Louisiana), AZMT (Arizona and Mountain states), CALI (California), and PNWS (Pacific Northwest). The aggregate model regions are built up from the 50 U.S. states’ and the District of Columbia’s economic data. The model is flexible enough to create other regional specifications, depending upon the need of the project. The 11 N\textsubscript{ew}ERA macroeconomic model regions and the states within each N\textsubscript{ew}ERA region are shown in Figure 50.

For this study, the state of Alaska is broken out into its own region in order to model state-specific impacts and the relationship of Alaska with the Lower-48. The Alaska region is disaggregated from the PNWS region where it resides in the standard N\textsubscript{ew}ERA database. For the sake of avoiding unnecessary modeling complications, we aggregated the regions of the Lower-48 and Hawaii into six regions, for a total of seven regions modeled in N\textsubscript{ew}ERA.

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\footnote{Hawaii and Alaska are also included in the PNWS region by default.}
b. Sectoral Aggregation

The NewERA model includes 12 sectors: five energy sectors (ELE, coal, natural gas, crude oil, and refined petroleum products) and seven non-energy sectors (SRV, MAN, and EIS, and agriculture, commercial transportation excluding trucking, trucking, and motor vehicles). These sectors are aggregated up from the 440 IMPLAN sectors. The model has the flexibility to represent sectors at different levels of aggregation.

c. Natural Gas and Oil Markets

There are great uncertainties about how the U.S. natural gas market will evolve, and the NewERA modeling system is designed explicitly to address the key factors affecting future natural gas supply and prices. One of the major uncertainties is the availability of shale gas in the United States. To account for this uncertainty and the subsequent effect it could have on international markets, the NewERA modeling system includes two supply curves for U.S. natural gas:

- Conventional natural gas – represents current natural gas production by model region.
- Shale gas represents the potential supply that could come from shale by model region.
By including each type of natural gas, it is possible to incorporate expert judgments and sensitivity analyses about the extent of shale gas reserves, the cost of shale gas production and how it will change as drilling moves to new areas, the impacts of environmental regulations and access restrictions on supply and cost. By combining different possibilities, the model can represent a diverse range of scenarios that leads to different possible natural gas price trajectories.

The natural gas module also accounts for foreign imports and U.S. exports of natural gas, by using a supply (demand) curve for U.S. imports (exports) that represents how the global LNG market price would react to changes in U.S. imports or exports. This makes it possible to provide a consistent analysis of the connection between U.S. import levels, export policy, and the domestic price of natural gas.

Natural gas supply conditions will change over time and the model accounts for depletion of each of the two sources of natural gas by adjusting the available level of the natural gas resource over time. This capability makes it possible to investigate the kinds of assumptions about future shale gas resources and costs that are required to maintain stable prices or lead to rising prices.

The N\textsubscript{e\textsubscript{w}}ERA model represents the domestic and international crude oil and refined petroleum markets. The international markets are represented by flat supply curves with exogenously specified prices. Because crude oil is treated as a homogeneous good, the international price for crude oil sets the U.S. price for crude oil. In the Baseline, we first calibrate the N\textsubscript{e\textsubscript{w}}ERA model to match the desired forecast for crude oil prices (e.g., the price in EIA’s latest AEO forecast). For the scenario, we adjust the price of crude oil in response to the change in U.S. demand for crude oil. For example, if we assume a Baseline that omits the recent agreement on CAFE standards between the President and auto manufacturers, then a scenario, which analyzed the impacts of this policy, would need to account for the effects of this policy on international crude oil markets and hence on domestic oil prices. Almost certainly the new CAFE standards will lead to lower levels of oil consumption and hence lower levels of demand for crude oil. To capture the effect of lower U.S. demand for international crude oil on international crude oil prices (and hence on U.S. domestic crude oil prices), the N\textsubscript{e\textsubscript{w}}ERA model uses an international oil supply curve based on the EIA’s alternate forecasts under different oil prices. For example, if the EIA’s scenarios imply a 10% drop in U.S. demand for crude oil would lead to a 1% drop in international crude oil prices, then we would use this elasticity in conjunction with the drop in U.S. crude oil demand to set the international price of crude oil for the CAFE scenario run. This updating, however, is part of the iterative process as the macroeconomic and electric sector models iterate to a global equilibrium solution.

\textbf{d. Model Features – How LNG export is modeled}

There are many uncertainties in the outlook of natural gas supply. To address this, the model has parameters and structural features to calibrate different natural gas supply outlooks. The natural gas supply curve in the Baseline is consistent with the AEO natural gas price and supply quantity
by region over time. The shape of the natural supply curve in the model is determined by the natural gas resource supply elasticity and the natural gas resource availability. The model is able to calibrate to either an optimistic or a pessimistic natural gas supply curve by adjusting the supply elasticity and resource. For a given supply elasticity, the availability of the resource in the model determines the natural gas price. A constrained resource supply will result in a higher equilibrium price. Hence, the model is able to target to a desired exogenous natural gas price path.

Consumption of electricity as a transportation fuel could also affect the natural gas market. The NewERA model is able to simulate impacts on the supply and disposition of transportation fuels (petroleum-based, biofuels, and electricity) along with responses to consumer driving behavior. Personal driving, or personal transportation services, is represented in the model by vehicle miles traveled, which takes vehicle capital, transportation fuels and other driving expenditures as inputs. The model chooses among changes in consumption of transportation fuels, changes in vehicle fuel efficiency and changes in the overall level of travel in response to changes in the transportation fuel prices.

Along with alternative transportation fuels, the model also includes different vehicle choices that consumers can employ in response to changes in the fuel prices. The model includes different types of Electrified Vehicles: Plug-in-Hybrid Electric Vehicles and Battery Electric Vehicles.

e. Model Outputs

As with other CGE models, the NewERA macroeconomic model outputs include demand and supply of all goods and services, prices of all commodities, and terms of trade effects (including changes in imports and exports). The model outputs also include GDP (or GSP), consumption, investment, cost of living or burden on consumers, and changes in “job equivalents” based on labor wage income.

3. Electric Sector Model in NewERA Modeling System

The electric sector model that is part of the NewERA modeling system is a bottom-up model of the electric and coal sectors. The model is a fully-dynamic model that includes perfect foresight. Thus, all decisions within the model are based on minimizing present value costs over the entire time horizon of the model. The model minimizes present value costs while meeting all specified constraints, most significant of which are demand, peak demand, emissions limits, transmission limits, RPS regulations, fuel availability and new build limits. The model set-up is intended to mimic (as much as is possible within a model) the approach that electric sector investors use to make decisions. In determining the least cost method of satisfying all these constraints, the model endogenously decides:

- What investments to undertake (e.g., addition of retrofits, build new capacity, repower unit, add fuel switching capacity, or retire units);
• How to operate each modeled unit (e.g., when and how much to operate units, which fuels to burn) and what is the optimal generation mix; and

• How demand will respond. The model thus assesses the trade-offs between the amount of demand-side management (DSM) to undertake and the level of electricity usage.

Each unit in the model has certain actions that it can undertake. For example, all units can retire (first year of retirement may be specified to prevent retirements in the near term that likely cannot be accommodated). Any known actions such as planned retirements or planned retrofits (for existing units) or new units under construction can be specified as forced actions. Coal units have more potential actions than other types of units. These include retrofits to reduce emissions of SO$_2$, NO$_X$, Hg, and CO$_2$ (we are also currently exploring representing HCl emissions and technologies that can reduce HCl). Coal units can also switch the type of coal that they burn.

Most of the coal units’ actions would be in response to environmental limits that can be added to the model. These include emission caps (for SO$_2$, NO$_X$, Hg, and CO$_2$) that can be applied at the national, regional, state or unit level. We can also specify allowance prices for emissions, emission rates (especially for toxics such as Hg and HCl) or heat rate levels that must be met.

Existing policies that are part of the model include: Title IV for SO$_2$, the final cross state air pollution rule (CSAPR) for SO$_2$ and NO$_X$ (annual and seasonal), Regional Greenhouse Gas Initiative for CO$_2$ in the Northeast, AB32 for CO$_2$ in California and all existing state renewable portfolio standards.

Just as with investment decisions, the operation of each unit in a given year depends on the policies in place (e.g., unit-level standards), electricity demand, and operating costs, especially energy prices. The model accounts for all these conditions in deciding when and how much to operate each unit. The model also considers system-wide operational issues such as environmental regulations, limits on the share of generation from intermittent resources, transmission limits, and operational reserve margin requirements in addition to annual reserve margin constraints.

To meet increasing electricity demand and reserve margin requirements over time, the electric sector must build new generation. Future environmental regulations and forecasted energy prices influence which technologies to build. For example, if a national RPS policy is to come online, then some share of new generation capacity will need to come from renewable power. If on the other hand, there is a policy to address emissions, then it might elicit a response to retrofit existing fossil-fired units with pollution control technology or enhance existing coal-fired units to burn different types of coals, biomass, or natural gas. Policies calling for improved heat rates may lead to capital expenditure on repowering existing units. All of these policies will also likely affect retirement decisions. The NERA electric sector model captures endogenously all these different types of decisions.
The model currently contains 32 U.S. regions (and six Canadian regions), although we are currently looking into adding Alaska and Hawaii as new regions and splitting some existing regions. Figure 51 shows the U.S. regions.

**Figure 51: NERA Electric Sector Model – U.S. Regions**

The electric sector model is fully flexible in the model horizon and the years for which it solves. To remain consistent with the macroeconomic model and to analyze long-term effects, the model is usually set up to solve out to 2050 in five-year time steps.

**a. Generator Representation**

Each of the more than 17,000 electric generating units in the United States is represented in the model. Coal units are subject to more decisions in the model than any other type of generator. These include choosing among different coal types, investing in different pollution control equipment and/or being forced to retire. As such, larger coal units (greater than 200 MW) are individually represented in the model and smaller units are aggregated based on region, size, and existing controls. The smaller coal units can also be individually broken out within a region, but this will increase the problem size and possibly slow down the run time. All other types of units are included in different regional aggregates based on their operating characteristics. Again, there is considerable flexibility to break out additional units if that becomes more important to do so.
The model includes the following existing generating technologies:

- coal (including IGCC)
- natural gas combined cycle
- natural gas combustion turbine
- gas/oil steam
- oil combustion turbine
- nuclear
- wind (on-shore)
- hydroelectric (run-of-river and dispatchable)
- pumped storage hydroelectric
- biomass
- geothermal
- landfill gas
- municipal solid waste
- solar photovoltaic
- solar thermal

New technologies in addition to the existing ones include advanced coal with carbon capture and storage (CCS) and off-shore wind. Cumulative and annual addition rates can be specified to reflect real world constraints.

b. Electricity Demand

Electricity demand within the model is represented via load duration curves. These curves are created based on sorting the hourly demand for a region within a season and then aggregating together hours into a load block. The model currently has four seasons and a total of 25 load blocks (ten in the summer and five each in winter, spring, and fall). Four seasons are used to better capture the difference between hydroelectric generation in the spring and fall. Peak demand is also included and is used with reserve margins to determine capacity prices within the model.

Because the electric sector model is a non-linear program and it is integrated with the macroeconomic model, electricity demand can respond to changes in model inputs. This response differs from that of a standard linear program that must maintain demand at a fixed level. Furthermore, the electric sector model’s demand constraint allows demand to be satisfied either through electricity production or demand-side management programs. Therefore, in the face of a policy such as a nationwide cap on GHG emissions, the model can choose among meeting demand as forecasted, meeting a lower level of demand (which results in lower values of consumer wellbeing), or implementing DSM programs. The model represents DSM programs through upward sloping supply curves for displaced electricity demand. These curves can be calibrated to the client’s views on the cost and availability of various DSM programs. The resources required for the DSM programs are passed to the macroeconomic model just like other resource requirements for the electric sector.
c. **Coal Representation**

The steam coal sector is represented within the electric sector model of the New ERA modeling system. Similar to the flexibility of the electric sector model to aggregate individual units however we choose, we enjoy great flexibility in selecting the number of coal types that we want to include in the model and how they can be mapped to individual coal generators. We also have the ability to model different scenarios for coal exports and/or non-electric coal demand, each of which would have an impact on the price of coal for the electric sector.

The model currently includes 22 steam coals:

- 3 Central Appalachian coals – differentiated by SO₂ content;
- 5 Northern Appalachian coals – differentiated by SO₂ content;
- 1 Southern Appalachian coal;
- 3 Illinois Basin coals – differentiated by SO₂ content;
- 1 Arizona/New Mexico bituminous coal;
- 1 Montana bituminous coal;
- 2 Rockies coals – 1 in Colorado and 1 in Utah;
- 3 Powder River Basin (PRB) coals – 2 in Wyoming and 1 in Montana;
- 2 Lignite coals – one in the Gulf and one in the Dakotas; and
- 1 Import coal – not represented with a supply curve, but instead represented with a price premium relative to a specified coal (Central Appalachian coal).

Existing coal units each have an initial coal specified and, if they have burned any PRB coal, a maximum percentage of PRB coal that the unit can burn. Units can switch to burn more PRB coal than they currently burn, but would incur a capital cost and heat rate and capacity penalties in order to make the switch. Further, units can switch to burning other coals if the coal can be delivered to the unit. In the near term, the model can limit this switching to reflect the coal market realities that would likely limit a good deal of switching in the first few years of an analysis.

Coal use in the non-electric sectors and for exports is an exogenous input to the model, although it can be changed in each scenario. Non-electric coal use is a small share of total coal and likely to not grow. The much greater uncertainty is thermal coal exports, particularly if domestic coal demand is flat or declining. While export demand is currently driven by factors that are not part of the New ERA modeling system, we can still develop coal export scenarios. For example, if we

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65 Metallurgical coals are represented in the macroeconomic model using a top-down approach. We have had some preliminary discussions about improving the representation of metallurgical coals, but do not anticipate that such a change would happen in the next several months.
have a low natural gas price scenario with strict environmental regulations that lead to significant coal retirements and hence declining domestic coal consumption, we might want to include higher exports of thermal coal than in a scenario without any new environmental limits and with relatively high natural gas prices.

The model utilizes coal supply curves, which paired with inputs for non-electric demand, export demand and endogenously-determined electric sector demand produces coal prices for each coal available in the model. The supply curves include prices at each step of the curve, along with annual production levels and total reserves at the price step. Demand in prior years depletes the total reserves going forward, which generally would lead to higher prices if total reserves at a price step are fully depleted.

There is a complete coal transportation matrix within the model that maps each generating unit to the coals that can be delivered to it, and assigns a transportation cost for each of the deliverable coals. This matrix accounts for costs associated with the different modes of transportation that may be used to deliver the coal, along with the distance that the coal must travel. We have also had some initial discussions about including blending facilities that may be used by generators as coal blending becomes more prevalent, but may be difficult for some units that lack the space needed for multiple coal piles. If this is important, then this is a feature that we would add.

4. Integrated N\text{ew}ERA Model

a. General Approach

The N\text{ew}ERA modeling framework fully integrates the macroeconomic model and the electric sector model so that the final solution is a consistent equilibrium for both models, and thus for the entire U.S. economy.

To analyze any policy scenario, the system first solves for a consistent baseline solution, and then it iterates between the two models to find the equilibrium solution for the scenario. For the baseline, the electric sector model is solved first under the desired forecasts for electricity demand and energy prices. The equilibrium solution provides the baseline electricity prices, demand, and supply by region as well as the consumption of inputs – capital, labor, energy, and materials – by the electric sector. These solution values are passed to the macroeconomic model.

After the electric sector model solves, the macroeconomic model solves the baseline while constraining the electric sector to replicate the solution from the electric sector model and imposing the same energy price forecasts as those used to solve the electric sector baseline. In addition to the energy price forecasts, the macroeconomic model’s non-electric energy sectors are calibrated to the desired exogenous forecast (e.g., EIA’s latest AEO forecast) for energy consumption, energy production, and macroeconomic growth. The macroeconomic model solves for equilibrium prices and quantities in all markets subject to meeting the exogenous forecasts.
After solving the baseline, the integrated N\textsubscript{cew}ERA modeling system solves for the scenario. First the electric sector model reads in the scenario definition (e.g., RPS levels, emission constraints, MACT standards). The electric sector model then solves for the equilibrium level of electricity demand, electricity supply, and inputs used by the electric sector (\textit{i.e.}, capital, labor, energy, emission permits). The electric sector model then passes these equilibrium solution quantities to the macroeconomic model. The modeling system then imposes on the macroeconomic model the appropriate elements of the same policy as imposed on the electric sector. Next, the macroeconomic model solves for the equilibrium prices and quantities in all markets, taking the quantities pertaining to the electric sector as exogenous inputs. The macroeconomic model then passes to the electric sector model the following (solved for equilibrium prices):

- Electricity prices by region;
- Prices of non-coal fuels used by the electric sector (\textit{e.g.}, natural gas, oil, and biofuels); and
- Prices of any permits that are tradable between the non-electric and electric sectors (\textit{e.g.}, carbon permits under a nationwide GHG cap-and-trade program).

The electric sector model then solves for the new electric sector equilibrium taking the prices from the macroeconomic model as exogenous inputs. The framework iterates between the two models – prices being sent from the macroeconomic model to the electric sector model and quantities being sent from the electric sector model to the macroeconomic model – until the prices and quantities in the two models differ by less than a fraction of a percent.

b. \textbf{Policy Analysis Capabilities}

The N\textsubscript{cew}ERA modeling system has the capability to evaluate a range of current and proposed policies. Because the NERA team developed the N\textsubscript{cew}ERA model, we are intimately familiar with how the model responds to various constraints and therefore are able to logically and effectively represent policies designed by regulators within our model. That is for any policy, we know exactly how to implement the real world policies so that the modeled policy affects the economy in a similar manner to how the policy would actually affect the economy.

As an example of policy capabilities, the N\textsubscript{cew}ERA model can represent the following policies and types of policies:

- Emission taxes or prices;
- Emission cap-and-trade programs (\textit{e.g.}, Title IV or CSAPR);
- Renewable portfolio standards (state, regional or national);
- Efficiency standards in electric and non-electric sectors (\textit{e.g.}, MACT, heat rate standards, CAFE);
- Mandated construction of new builds or retrofits (or requirements to retrofit or retire);
• Financial incentives (e.g., for renewables or for electric vehicles); and
• Low carbon fuel standards.

c. **Advantages of an Integrated Modeling System**

When modeling policies that will have significant impacts on the entire economy, one needs to use a model that captures the effects of the policy as it ripples through all sectors of the economy and the feedback effects of these impacts on production and consumption decisions. Of further desire is to use a model that also provides detail on the areas of the economy that are most affected by the policies of interest.

Because of computational limitations and differences in the goals, developing one single model to perform both tasks is infeasible. Therefore, the best solution is to construct an integrated modeling system. To this end we have brought together our top-down, macroeconomic model and our bottom-up electric sector model. A macroeconomic, general equilibrium model can account for the ripple and feedback effects of economy-wide policies, but because of computational issues, these models are unable to represent many specific sector interactions in great detail. Therefore, these models are referred to as top-down models. Models that address the impacts to one sector, or bottom-up models, are well suited to capture the details of the policy impacts on this particular sector, but these models cannot fully capture the feedback of the impacts on the particular sector on the rest of the economy and the impacts of the rest of the economy on the particular sector.

By combining our electric sector and macroeconomic models, we eliminated the shortcomings of each and created our fully integrated NERA model. The integrated framework combines a technologically rich bottom-up model with a top-down macroeconomic model of the rest of the economy to provide a consistent equilibrium.

The main benefit of this integrated framework is that the electric sector can be modeled in great detail as a bottom-up model. Electric technologies within the bottom-up model can be well represented according to engineering specifications. Such a consistent analysis would not be possible in a partial equilibrium framework as it would miss the feedback effects from rest of the economy, hence a partial equilibrium model would provide distorted results.

The integrated modeling approach provides consistent price responses since all sectors of the economy are modeled. For example, evaluating natural gas price response, which is consumed in both the electric and non-electric sectors, by just considering the changes in the electric sector (under a partial equilibrium analysis) will lose the changes that happen to the non-electric sectors thus providing an inaccurate response. Likewise employing only a top-down model of the economy would fail to correctly capture the coal-gas trade-off in the electricity sector.