Environmental, Economic, and Technological Effects of Methane Emissions and Abatement

Garvin Heath, Ethan Warner, and David Keyser
April 20, 2016

www.jisea.org
Presenters

**Garvin Heath** is a senior scientist at the National Renewable Energy Laboratory (NREL). His areas of expertise include life cycle assessment, sustainability analysis, air quality modeling, and exposure assessment. He was an author of JISEA's first major natural gas report in 2011, Natural Gas and the Transformation of the U.S. Energy Sector: Electricity. His other research interests include health and environmental impacts of energy technologies.

**Ethan Warner** is an energy systems analyst at NREL. His areas of expertise include life cycle assessment, system dynamics modeling, and energy policy. His research interests encompass systems modeling and sustainable analysis, especially focused on increasing understanding of the interconnections between technology supply chains, the economy, and the environment.

**David Keyser** is research analyst at NREL. His areas of expertise include economic impact studies, time series analysis, and analysis of labor and demographic data. His research interests span static and dynamic economic impact models, labor data estimation, econometric modeling and forecasting, and regional economics.
With a focus on methane emissions from the natural gas (NG) sector, the purpose of this report is to:

1. Summarize methods and results of the U.S. Greenhouse Gas Inventory (GHGI)
2. Identify potential gaps and barriers to improvement
3. Identify opportunities to improve accuracy.

Observations and suggestions in this presentation focus on providing an overview of recommendations.

- Additional detail on these recommendations can be found in the report.

http://www.nrel.gov/docs/fy16osti/62820.pdf

Report focuses on 2014 U.S. EPA GHG Inventory, the latest available during the project.
The U.S. Greenhouse Gas Inventory (GHGI) identifies and quantifies emission sources and sinks of greenhouse gases (GHG) from human activities in the United States.

U.S. Environmental Protection Agency publishes the U.S. GHGI; many agencies, organizations, and researchers rely on its results for analyses and decision making.

The U.S. GHGI is a critical resource for:

- Understanding the U.S. contribution to global climate change
- Tracking trends in GHG emission sources and sinks
- Identifying and prioritizing abatement opportunities within the United States
- Informing policy and investment decision making.
NG Produces ~23% of U.S. Anthropogenic Methane Emissions from Several Segments

2012 NG emissions = 156 MMt CO$_2$e/yr

Emissions are distributed among segments:

- Production, Gathering & Boosting: 33%
- Processing: 14%
- Transmission and Storage: 33%
- Distribution: 20%

Note: All GHG emissions in this presentation assumes 100-yr GWP of CH4 = 25. GWP reflects IPCC 2007 (not IPCC 2013) to align with the most recent United Nations Framework Convention on Climate Change (UNFCCC) for national inventories.

Source: 2014 U.S. EPA GHG Inventory
About 43% of NG Methane Emissions are from Compressors

**Note:** GHGIs miscellaneous “compressor station” category for emissions is applied proportionally to all components of the compressor station.

**Source:** 2014 U.S. EPA GHG Inventory
Cast Iron and Unprotected Steel Pipe is ~33% of Distribution Segment Emissions

<table>
<thead>
<tr>
<th>Category</th>
<th>Emission Activity</th>
<th>Emission Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast Iron Mains</td>
<td>~ 32k miles</td>
<td>240 Mcf/mile-yr</td>
</tr>
<tr>
<td>Unprotected Steel Mains</td>
<td>~ 64k miles</td>
<td>110 Mcf/mile-yr</td>
</tr>
<tr>
<td>Plastic Mains</td>
<td>~ 660k miles</td>
<td>9.9 Mcf/mil-yr</td>
</tr>
<tr>
<td>Protected Steel Mains</td>
<td>~ 490k miles</td>
<td>3.1 Mcf/mil-yr</td>
</tr>
<tr>
<td>Unprotected Steel Services</td>
<td>~ 3.9 million services</td>
<td>1.7 Mcf/service</td>
</tr>
<tr>
<td>Protected Steel Services</td>
<td>~ 15 million services</td>
<td>0.18 Mcf/service</td>
</tr>
<tr>
<td>Copper Services</td>
<td>~ 1 million services</td>
<td>0.25 Mcf/service</td>
</tr>
<tr>
<td>Plastic Services</td>
<td>~ 45 million services</td>
<td>0.01 Mcf/service</td>
</tr>
</tbody>
</table>

Total = 30.8

Cast iron and unprotected steel have highest total emissions despite lowest miles of piping.

Source: U.S. EPA 2014 GHG Inventory
Source Prioritization is Affected by Accuracy of Source-Level Emission Estimates

Even when the sum of measured emissions from different sources is equivalent to the inventory, is it due to compensating errors? (Allen et al. 2013)

\[ Gg = \text{gigagrams or thousand metric tonnes} \]
Top-Down (TD) and Bottom-Up (BU) Studies

Nomenclature not consolidated on definition of top-down and bottom-up:

**Top-down**: Infers emissions from measurements of atmospheric methane concentrations or atmospheric models.

**Bottom-up**: Focuses on the specific source or activity causing the emissions.

Measurement-based estimate or modeled (e.g., inventory – see bottom left panel).

*Figure: NREL and NOAA, 2014; Definitions: White House 2014. Climate Action Plan*
Both top-down (TD) and bottom-up (BU) studies have uncertainty and potential for inaccuracy; neither is “truth.”

Both have roles to improve inventory, e.g.:

- **TD**: Useful as comparison to inventory estimates, any differences could help generate hypotheses
- **BU**: Measurement studies can update outdated emission factors (EFs).
Inventory Improvement Through BU Measurement Studies

Challenges with currently used EFs:

• Not representative
  – Outdated
  – Sampling bias
  – Sample size
  – Mean emission factors (EFs) capture fat tail?
  – All salient dimensions of emission variability captured?

POTENTIAL IMPROVEMENTS:

• Update EFs for prioritized emission sources categories
• Focus effort of new studies on ensuring robust sample size, strong sampling design to capture source variability and minimization of self-selection bias
• Leverage available evidence to explore how to characterize emission variability within the EF metric
• Explore regional variability and variability along other dimensions.
Most efforts to improve the inventory have focused on EFs; activity factors (counts) also need attention:

- **Data sources**
  - GHGRP or new ones
- **Methods** – transparency, simplicity, and accuracy
- **Balance** the need for consistent time series with the need to improve current accuracy.

**POTENTIAL IMPROVEMENTS:**

- Develop new data sources to improve accuracy, completeness, and methodological simplicity
- Develop methods for quantification of activity factor uncertainty.
Inventory Improvement: Completeness and Structure

Prioritized gaps in current knowledge, e.g.:

- Abandoned wells
- Measurements on gathering pipelines
- “After the meter” leaks at site of end use
- Well work-overs that are not recompletions*

Inventory structure

- Currently organized sectorally, which creates challenges when comparing to a measurement representative of a certain spatial domain
  - Oil and gas wells in the same area
  - Associated gas
- Certain segments are grouped, e.g., gathering with production.

POTENTIAL IMPROVEMENTS:

- Fill prioritized source gaps in GHGI
- Align future studies to the structure of the GHGI for easier incorporation OR
- Consider restructuring the inventory to better capture robust results of recent studies
- Gridded inventory to enhance measurement-based validation.

*Work-overs are included in the GHGI, but are defined as recompletions. Other work-over activities can also be performed in the industry.
Uncertainty Quantification

Uncertainty quantification is critical for informed decision making, communication, and verification with measurements. Currently, the GHGI:

- Uses Monte Carlo parametric uncertainty quantification, with lognormal distributions assumed in almost all cases
- Reports an uncertainty range that hasn’t changed since 2010
- Uses expert judgment to assign uncertainty for activity factors.

POTENTIAL IMPROVEMENTS:

- Ensure sponsored studies robustly quantify uncertainty
- Strengthen uncertainty quantification methods and efforts
New Research Efforts in the Context of Many Other Studies

POTENTIAL IMPROVEMENTS:

- Enhance coordination amongst studies.
- Increase confidence in inventory accuracy by pairing measurements with inventory contemporaneously and systematically.

Source: Heath et al. 2015
For Further Information

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The authors wish to thank the U.S. Department of Energy’s Office of Energy Policy and Systems Analysis (EPSA) for their support developing this report.
Potential Cost-Effective Opportunities for Methane Emission Abatement

April 20, 2016
Ethan Warner
JISEA Technical Report

Potential Cost-Effective Opportunities for Methane Emission Abatement

Ethan Warner,1 Daniel Steinberg,1 Elke Hodson,2 Garvin Heath1

1 Joint Institute for Strategic Energy Analysis
2 U.S. Department of Energy, Office of Energy Policy and Systems Analysis

• Technical Report: 6A50-62818

• One of several JISEA reports used as supporting information for the Quadrennial Energy Review

U.S. Anthropogenic Methane Emissions are about 9% of Total Greenhouse Gases (GHGs)

Total emissions: 675 million metric tonnes (MMt) carbon dioxide equivalent (CO$_2$e)/yr.

Source: US GHG Inventory 2014
Goals of the JISEA Report and this Presentation

• Identify potential targets for reducing methane emissions

• Identify strategies for reducing methane emissions.
  – Many possible, but highly variable opportunities are available

• Synthesize published estimates of emissions reduction potential and costs (ICF [2014] and EPA [2013]) to:
  – Provide a comprehensive national analysis of opportunities.
  – Identify the largest opportunities for “low cost”* abatement.
  – Report under what conditions these opportunities are low cost.

*Defined as <$0/Mt CO₂e

Source: US GHG Inventory 2014, Whitehouse “Fact Sheet” 2015
# Breakdown of Low Cost Emission Reduction Opportunities

<table>
<thead>
<tr>
<th>Sector</th>
<th>Supply Chain Segment</th>
<th>Total Potential Reduction</th>
<th>Low Cost Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MMt CO₂e/yr</td>
<td>No revenue from capturing gas in transmission</td>
</tr>
<tr>
<td>Natural Gas (NG)</td>
<td>Production</td>
<td>20</td>
<td>32%</td>
</tr>
<tr>
<td></td>
<td>Gathering and Boosting</td>
<td>7.2</td>
<td>69%</td>
</tr>
<tr>
<td></td>
<td>Processing</td>
<td>12</td>
<td>81%</td>
</tr>
<tr>
<td></td>
<td>Transmission</td>
<td>21</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Storage</td>
<td>3.1</td>
<td>94%</td>
</tr>
<tr>
<td></td>
<td>LNG Import/Export</td>
<td>0.8</td>
<td>88%</td>
</tr>
<tr>
<td></td>
<td>Distribution</td>
<td>3.4</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>67</td>
<td>37%</td>
</tr>
<tr>
<td>Oil</td>
<td>Production</td>
<td>19</td>
<td>31%</td>
</tr>
<tr>
<td>Coal</td>
<td>Production</td>
<td>37</td>
<td>6.2%</td>
</tr>
<tr>
<td>NG, Oil and Coal</td>
<td>Total</td>
<td>120</td>
<td>28%</td>
</tr>
</tbody>
</table>
Overview of Findings

• Some opportunities are already low cost or can become low cost through revenue from capturing the natural gas.

• Four largest low cost emission reduction approaches:
  – Leak detection and repair of sources of fugitive emissions
  – Capturing vented gas
  – Replacing high-bleed pneumatic devices with low-bleed pneumatics
  – Replacing gas-powered pumps with electric pumps.

• These low cost emission reduction options exist across most of the natural gas supply chain and oil production.
  – Abatement in the distribution sector should not be considered for cost reasons alone.
Methane Reduction and Cost Data in this Presentation...

• Explain average cost estimates for potential opportunities to reduce methane missions.
  – Actual opportunities are highly variable and site specific
  – Estimates do not capture the large ranges in primary data sources

• Only represent a subset of potential costs and benefits.
  – E.g., Externalities excluded; social cost of carbon included

• Have potential co-benefits such as:
  – VOC/HAP co-reductions
  – Improved safety by replacing leaking pipelines
Reading Marginal Abatement Cost Curves

The area of each column represents the total annual cost of implementing a given measure. The width of each column represents the annual abatement potential of a given measure. The height of each column represents the cost per unit of abatement per year for a given measure.

Source: Modified illustration from ICF (2014).
~40 MMt CO$_2$e/yr Could be Reduced at a Low Cost

**CAUTION**: This figure shows national average costs of all analyzed opportunities in a single segment of the supply chain.
Low Cost Opportunities Become Available in Transmission when Revenue Can be Captured

CAUTION: This figure shows national average costs of all analyzed opportunities in a single segment of the supply chain.
Low Cost Opportunities by the Opportunity

CAUTION: This figure shows national average costs of all analyzed opportunities across all segment of the supply chain.
Low Cost Opportunities by Opportunity and Segment

CAUTION: This figure shows national average costs.
Thanks to

• This work was funded by the U.S. Department of Energy’s (DOE’s) Office of Energy Policy and Systems Analysis (EPSA).

• The authors acknowledge the support of the Joint Institute for Strategic Energy Analysis.

• The authors wish to thank the following individuals for their thoughtful comments, input, or review of the document in its various stages: James Bradbury, Adrian Down and Judi Greenwald (DOE); Jeffrey Logan, Emily Newes, Margaret Mann, and Dave Mooney of the National Renewable Energy Laboratory (NREL); Doug Arent of the Joint Institute for Strategic Energy Analysis; and Joel Bluestein of ICF International.
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Dan Steinberg: daniel.steinberg@nrel.gov
Quantification of the Potential Gross Economic Impacts of Five Methane Reduction Scenarios

April 20, 2016
David Keyser
Overview

• This analysis estimates gross employment impacts and other economic activity that could be supported by enacting different methane reduction measures.

• Summary of Keyser, Warner, Curley analysis in 2015*

• It independently assesses these impacts from five options for reducing methane emission during natural gas storage, transmission, and distribution (T/S/D) segments of the supply chain:
  1. Leak detection and repair (LDAR)
  2. Gas capture
  3. Low bleed pneumatic devices (LBPD)
  4. Pump down
  5. Pipeline replacement

• These measures represent a subset of available opportunities for reducing methane emissions within the TS&D segments and do not include consideration of reduction opportunities within other segments of the supply chain, including processing, gathering and boosting and production.

• Estimates are of the number of gross jobs and other economic activity that could be supported by each of these methane reduction measures independently – no consideration is made for potential interactions between measures.

Methodology

- All estimates were made using the IMPLAN input-output (I-O) model at the national level.
- I-O models represent the way that sectors in an economy interact with each other at a point in time via purchased inputs and sold outputs:
  - Inputs are purchases made from other businesses or industries that are necessary for production.
  - Outputs are the sales that businesses or industries make to one another.
- An advantage of these models is that they allow analysts to capture a wide range of activity that arises as a result of these linkages.
- Methane reduction expenditures are modeled as demand for output from the industries that provide the respective good or service.
  - Increased pipeline maintenance, for example, is demand from the natural gas distribution sector.
- I-O models do have certain limitations such as the assumption that prices remain fixed and that all inputs necessary for production will be available.
Results Taxonomy

• **Direct** effects are first order impacts that are solely associated with an expenditure. The direct effect of a generator purchase, for example, would be jobs at the generator manufacturer.

• **Indirect** effects are second order impacts that arise as industries purchase goods and services in an economy. The generator manufacturer may need to purchase copper wire, so employment at the copper wire manufacturer would be part of the indirect effect.
Interpreting Results and Limitations

• Estimates are gross, not net, and do not consider many other far-reaching effects that could also impact net jobs such as changes in wages, land use, migration, input substitution, changes in consumer behavior, productivity, or changes in technology.

• Opportunity costs are not considered – this analysis does not consider alternative uses of investment funds.

• Estimates assume that prices remain constant and that inputs needed for production such as raw materials, workers, are available.

• Social costs of carbon are not included in this analysis – value of captured gas is solely what could conceivably be sold.

• Each measure is considered independently. It is conceivable that there could be economies of scale associated with implementation of multiple scenarios simultaneously – these are not estimated.
## Summary of Cost and Abatement Data

<table>
<thead>
<tr>
<th></th>
<th>Pipeline Replacement(^1)</th>
<th>LDAR(^2)</th>
<th>Gas Capture(^2)</th>
<th>LBPD(^2)</th>
<th>Pump Down(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost ($ Million, 2013)</strong></td>
<td>$45,833</td>
<td>$1,561</td>
<td>$368</td>
<td>$81</td>
<td>$118</td>
</tr>
<tr>
<td><strong>Emission Abatement (Tg CO(_2)e/yr)</strong></td>
<td>0.94</td>
<td>14</td>
<td>6.5</td>
<td>0.97</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Total Abatement (Tg CO(_2)e, 2015 - 2019)</strong></td>
<td>4.7</td>
<td>69</td>
<td>32</td>
<td>4.8</td>
<td>10.0</td>
</tr>
</tbody>
</table>

\(^1\) Blue Green Alliance (Barrett and McCulloch 2014) and the US Environmental Protection Agency (2013)

\(^2\) ICF International (2014)
Employment, Earnings, and GDP – Pipeline Replacement

- Over 83,000 direct and indirect jobs could be supported annually from 2015 through 2019 with earnings per worker ranging from $60,000 to $75,000
- Estimated $7.8 billion in GDP could be supported annually

<table>
<thead>
<tr>
<th></th>
<th>Employment</th>
<th>Earnings ($ Million, 2013)</th>
<th>GDP ($ Million, 2013)</th>
<th>Average Annual Earnings per Job</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>46,000</td>
<td>$3,400</td>
<td>$4,100</td>
<td>$75,000</td>
</tr>
<tr>
<td>Indirect</td>
<td>37,000</td>
<td>$2,200</td>
<td>$3,700</td>
<td>$60,000</td>
</tr>
<tr>
<td>Total</td>
<td>83,000</td>
<td>$5,700</td>
<td>$7,800</td>
<td>$68,000</td>
</tr>
</tbody>
</table>

Totals may not sum due to rounding
• Over 1,600 annual direct and indirect jobs could be supported from 2015 through 2019 with average salaries ranging from $79,000 to $100,000

• Nearly $240 million in GDP could be supported annually

<table>
<thead>
<tr>
<th>Employment</th>
<th>Employment (Million, 2013)</th>
<th>Earnings ($ Million, 2013)</th>
<th>GDP ($ Million, 2013)</th>
<th>Average Annual Earnings per Job</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>570</td>
<td>$60</td>
<td>$100</td>
<td>$100,000</td>
</tr>
<tr>
<td>Indirect</td>
<td>1,000</td>
<td>$80</td>
<td>$140</td>
<td>$79,000</td>
</tr>
<tr>
<td>Total</td>
<td>1,600</td>
<td>$140</td>
<td>$240</td>
<td>$87,000</td>
</tr>
</tbody>
</table>

Totals may not sum due to rounding
Employment, Earnings, and GDP – Gas Capture

- Nearly 500 direct and indirect jobs could be supported annually from 2015 through 2019 with average earnings between $72,000 and $95,000 per worker.
- Over $60 million in GDP could be supported annually.

<table>
<thead>
<tr>
<th></th>
<th>Employment</th>
<th>Earnings ($ Million, 2013)</th>
<th>GDP ($ Million, 2013)</th>
<th>Average Annual Earnings per Job</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>150</td>
<td>$10</td>
<td>$20</td>
<td>$95,000</td>
</tr>
<tr>
<td>Indirect</td>
<td>340</td>
<td>$20</td>
<td>$40</td>
<td>$72,000</td>
</tr>
<tr>
<td>Total</td>
<td>490</td>
<td>$40</td>
<td>$60</td>
<td>$79,000</td>
</tr>
</tbody>
</table>

Totals may not sum due to rounding.
Employment, Earnings, and GDP - LBPD

- Over 100 direct and indirect jobs could be supported annually from 2015 through 2019 with average earnings from $72,000 to $95,000 per worker
- Estimated $13 million contribution to GDP annually

<table>
<thead>
<tr>
<th></th>
<th>Employment</th>
<th>Earnings ($ Millions, 2013)</th>
<th>GDP ($ Million, 2013)</th>
<th>Average Annual Earnings per Job</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>30</td>
<td>$3</td>
<td>$5</td>
<td>$95,000</td>
</tr>
<tr>
<td>Indirect</td>
<td>80</td>
<td>$5</td>
<td>$9</td>
<td>$72,000</td>
</tr>
<tr>
<td>Total</td>
<td>110</td>
<td>$8</td>
<td>$13</td>
<td>$79,000</td>
</tr>
</tbody>
</table>

Totals may not sum due to rounding
Employment, Earnings, and GDP – Pump Down

- Over 60 direct and indirect jobs could be supported annually from 2015 through 2019, with average earnings per worker ranging from $97,000 to $160,000 each year.
- Estimated $16 million in GDP could be supported annually.

<table>
<thead>
<tr>
<th></th>
<th>Employment</th>
<th>Earnings ($ Million, 2013)</th>
<th>GDP ($ Million, 2013)</th>
<th>Average Annual Earnings per Job</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>20</td>
<td>$3</td>
<td>$8</td>
<td>$160,000</td>
</tr>
<tr>
<td>Indirect</td>
<td>40</td>
<td>$4</td>
<td>$7</td>
<td>$97,000</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>$7</td>
<td>$16</td>
<td>$118,000</td>
</tr>
</tbody>
</table>

Totals may not sum due to rounding

- Over 85,000 jobs, on average, could be supported annually by undertaking all five of the methane reduction measures under the scenarios studied.
- Employment impacts vary considerably across the scenarios addressed, with pipeline replacement accounting for the majority.

### Annual Average Employment, 2015 - 2019

<table>
<thead>
<tr>
<th></th>
<th>LDAR</th>
<th>Gas Capture</th>
<th>LBPD</th>
<th>Pump Down</th>
<th>Pipeline Replacement</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Jobs</td>
<td>570</td>
<td>150</td>
<td>30</td>
<td>20</td>
<td>46,000</td>
<td>47,000</td>
</tr>
<tr>
<td>Indirect Jobs</td>
<td>1,000</td>
<td>340</td>
<td>80</td>
<td>40</td>
<td>37,000</td>
<td>39,000</td>
</tr>
<tr>
<td>Total Jobs</td>
<td>1,600</td>
<td>490</td>
<td>110</td>
<td>60</td>
<td>83,000</td>
<td>85,000</td>
</tr>
</tbody>
</table>

*Totals may not sum due to rounding*
Emissions Reduction Summary: Implementing All Measures

• Potential decrease of up to 24 Tg of CO$_2$ annually - this represents approximately 28% of current (2011) annual methane emissions from natural gas transportation, storage, and distribution

• Total market value of gas captured from 2015 to 2019 of $912 million at a 10% discount rate

<table>
<thead>
<tr>
<th></th>
<th>LDAR</th>
<th>Gas Capture</th>
<th>LBPD</th>
<th>Pump Down</th>
<th>Pipeline Replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission Abatement</td>
<td>13.5</td>
<td>6.3</td>
<td>0.9</td>
<td>2.0</td>
<td>0.9</td>
</tr>
<tr>
<td>(Tg CO$_2$e/yr)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Abatement</td>
<td>67.3</td>
<td>31.5</td>
<td>4.6</td>
<td>9.8</td>
<td>4.7</td>
</tr>
<tr>
<td>(Tg CO$_2$e, 2015 - 2019)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of Captured Gas</td>
<td>$520</td>
<td>$244</td>
<td>$36</td>
<td>$76</td>
<td>$37</td>
</tr>
<tr>
<td>(10% Discount Rate)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All dollar figures are millions of 2013 dollars; totals may not sum due to rounding

Source: ICF 2014, EIA AEO 2014
Contacts

- David Keyser: david.keyser@nrel.gov
- Ethan Warner: ethan.warner@nrel.gov
- Christina Curley: christina.curley@colostate.edu
Works Cited


Questions?

Type your question into Question box on your screen.

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*Estimating U.S. Methane Emissions from the Natural Gas Supply Chain: Approaches, Uncertainties, Current Estimates, and Future Studies*  

*Potential Cost-Effective Opportunities for Methane Emission Abatement*  

*Quantification of the Potential Gross Economic Impacts of Five Methane Reduction Scenarios*  
Next Webinar

Wednesday, May 4 at 10 a.m. MDT

Spatiotemporal Considerations in Energy Decisions
Dr. Sarah Marie Jordaan, University of Calgary

Register at www.jisea.org/news.cfm