Implications of Shale Gas Development for Climate Change

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Context

- This presentation is part of larger workshop on the risks of shale gas development, covering issues relating to water, air, health, ecology, community, climate, and other impacts.
- This presentation focuses only on the greenhouse gas impacts of shale gas development.
- Comprehensive analysis should consider the array of risks relative to other energy sources, as well as the benefits of shale gas development.

What questions are at play?

- Greenhouse gas (GHG) accounting
  - **Aggregate level.** What are the total lifecycle GHG emissions of natural gas use, including both combustion and upstream non-combustion emissions?
  - **Sectoral technology level.** What are the ***relative*** GHG impacts of technologies that use natural gas for electricity generation, transportation, and buildings, compared to competing technologies?

- Decisions by producers, policymakers, equipment manufacturers, and corporate and individual purchasers
  - Which technologies are advantageous to promote/develop/market/purchase taking into account GHG impacts?
  - What issues need to be addressed to improve the GHG profile of technologies based on natural gas?
  - How does natural gas abundance change the baseline outlook for GHG emissions and domestic and international policy responses?

Overview

- U.S. natural gas use and shale gas development
- Understanding the potential implications of increased natural gas use on the climate
- Aggregate effects on U.S. energy and economy
- Non-combustion GHG emissions from natural gas
- Sectoral impacts: electricity, residential and commercial buildings, transportation, and industry
- International implications
- Policy interactions and implications

Relevant existing evidence

- Baseline statistics
  - Emissions accounting (EPA, industry, academia, NGOs)
  - Energy data (U.S. Energy Information Administration (EIA), industry)
- Technology lifecycle analysis
  - Various studies (source list at close of presentation)
- Energy modeling projections
  - EIA *Annual Energy Outlook 2013*
    - Reference case: current policies
    - High oil and gas resource case (note also increases oil)
    - Low oil and gas resource case (note also decreases oil)
  - International Energy Agency *World Energy Outlook 2011* and *2012*
    - New Policies case
    - Golden Age of Gas case
  - Other modeling studies

U.S. natural gas use and shale gas development

U.S. natural gas production, distribution, and use

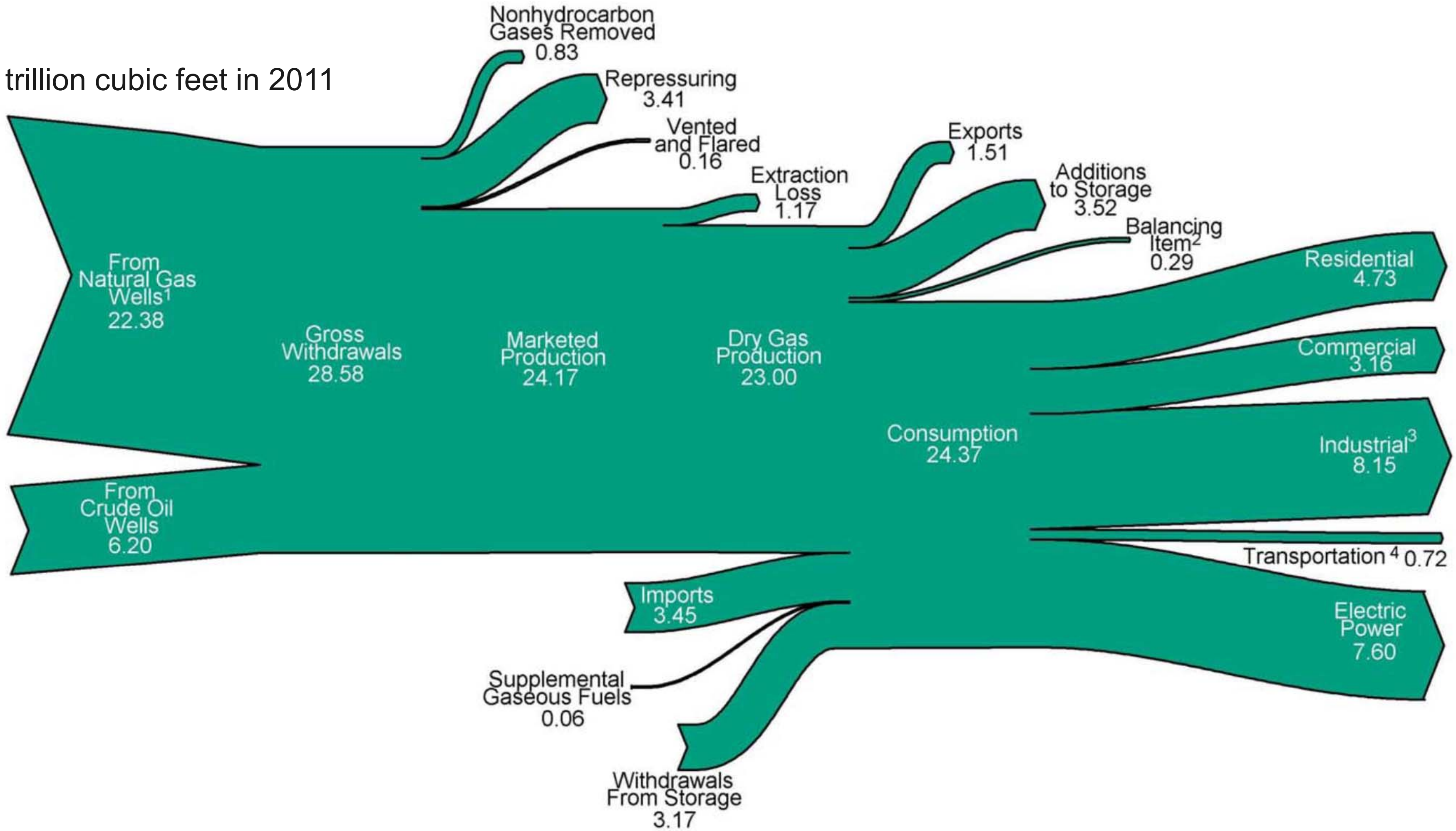
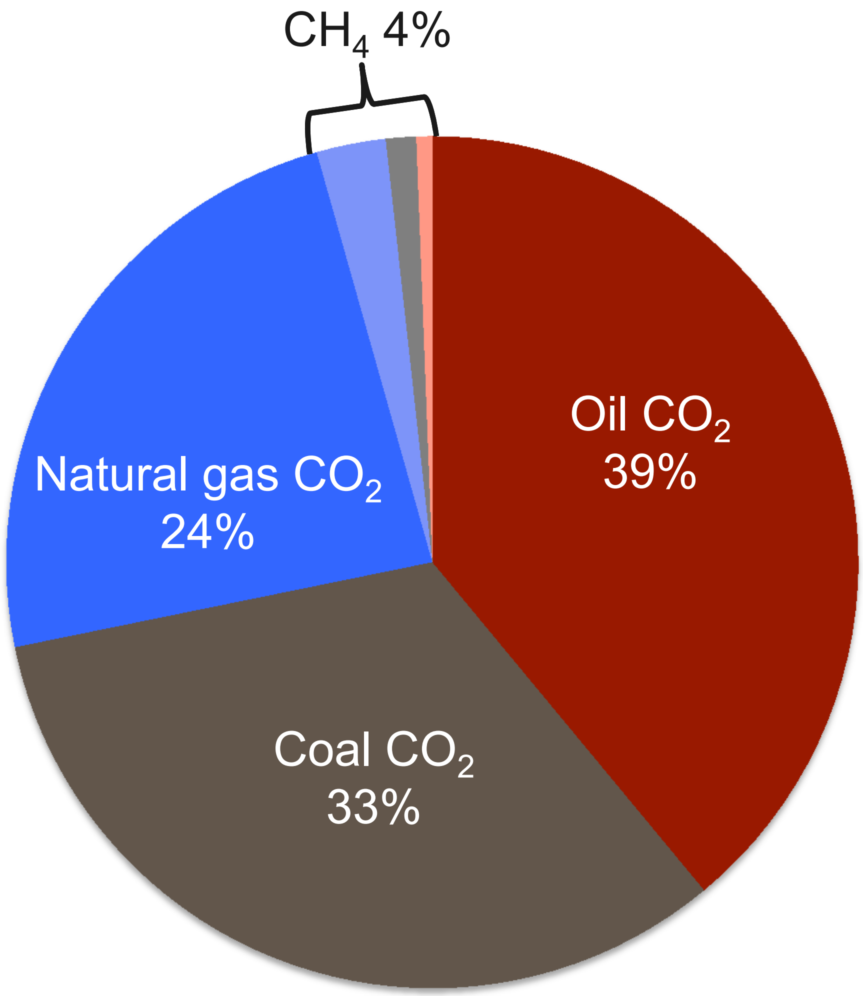


Image source: U.S. Energy Information Administration, Annual Energy Review 2012.

Natural gas was about 26% of total CO_2 and CH_4 emissions from U.S. fossil energy in 2011



2011 fossil energy CO_2 and CH_4 emissions	5,553 Tg CO_2e
Natural gas CO_2 and CH_4	1,469 Tg CO_2e (26%)

Data source: U.S. EPA Greenhouse Gas Inventory 2013.

Shale gas is a globally distributed and abundant resource

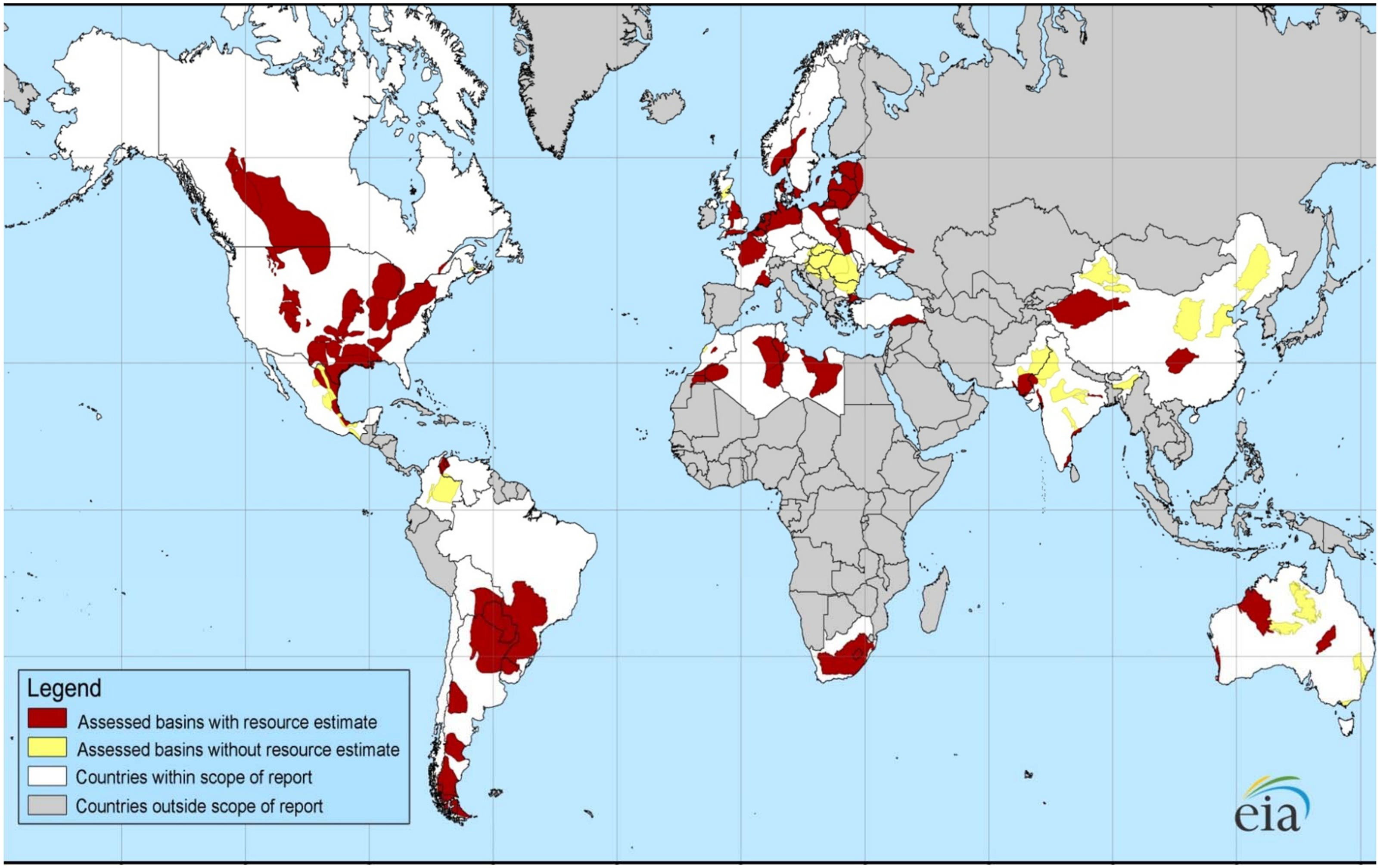
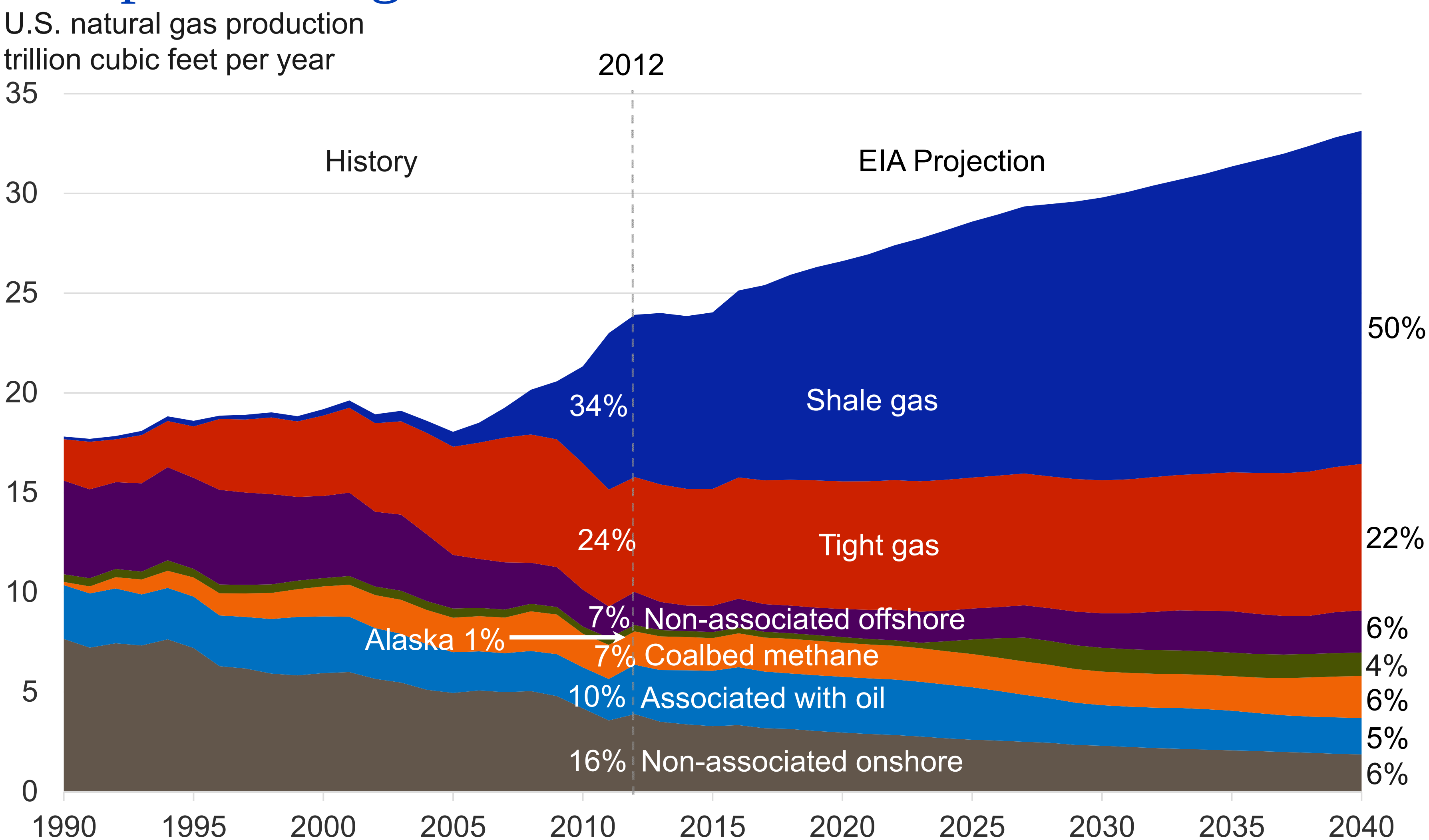


Image source: U.S. Energy Information Administration.

North America has thus far been the focus for shale gas production

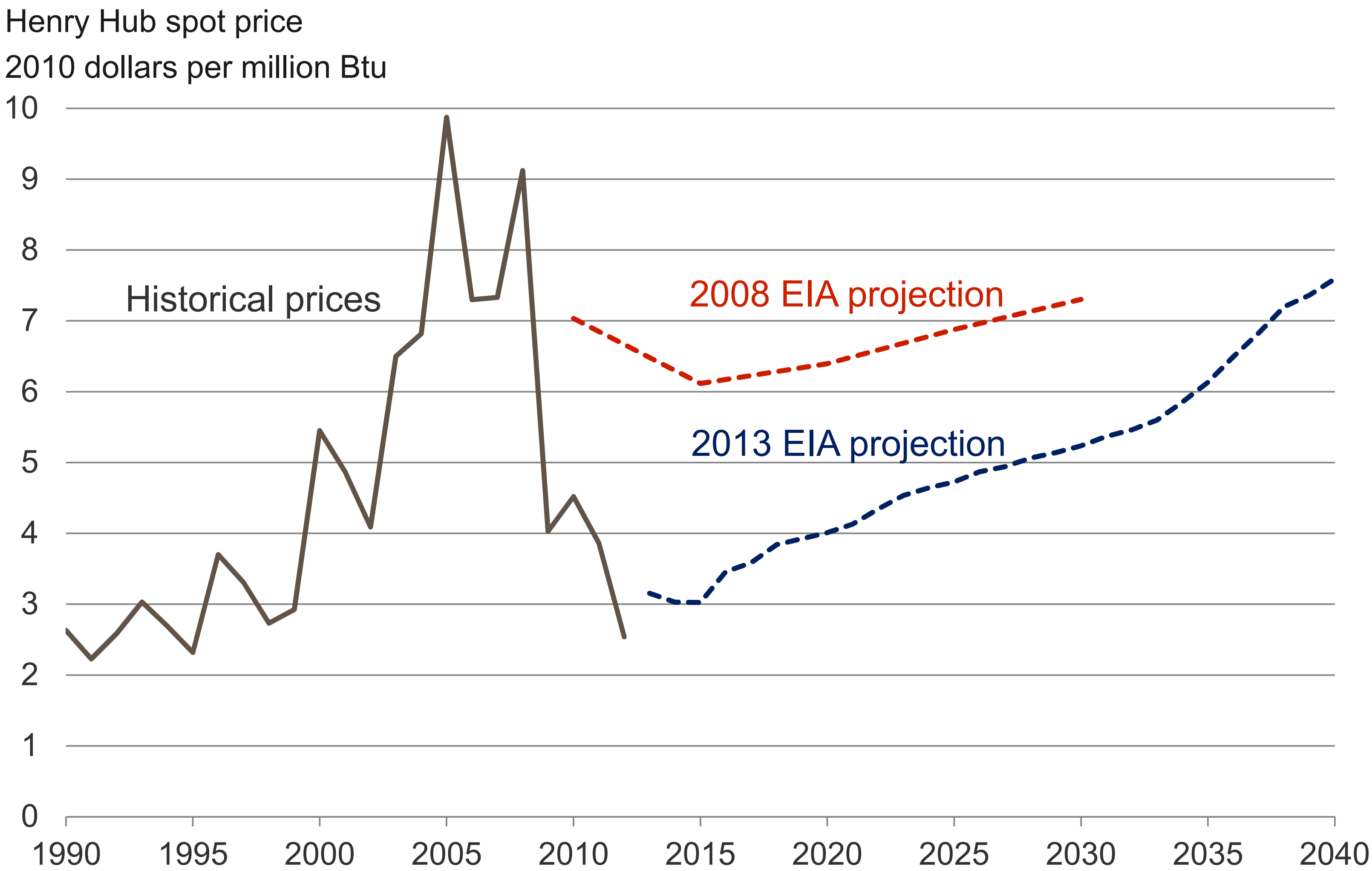
Image source: U.S. Energy Information Administration.

U.S. shale gas production has surged and is expected to growth further



Data source: U.S. Energy Information Administration, Annual Energy Outlook 2013, Reference case.

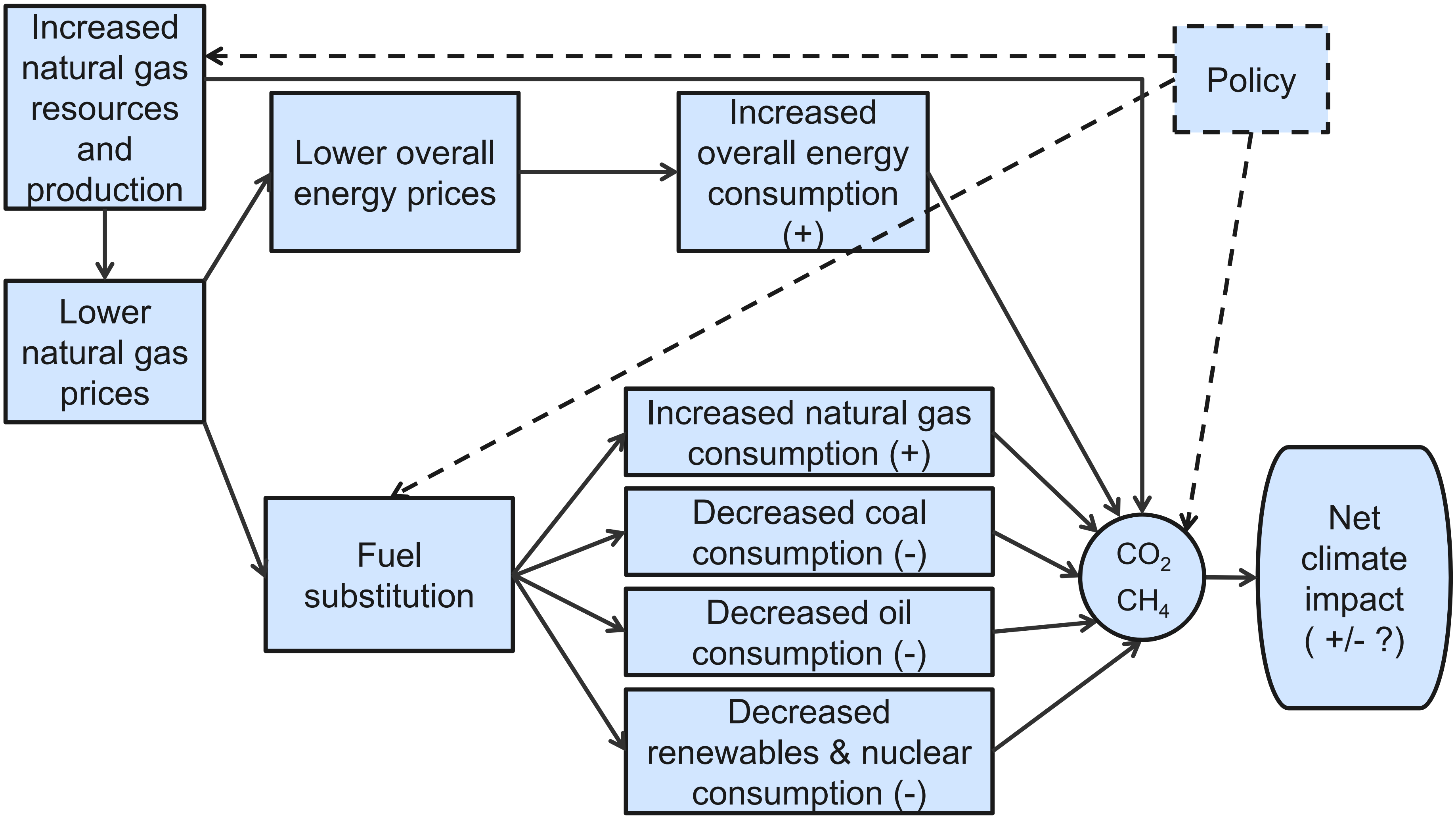
Current and projected U.S. natural gas prices have declined



Data source: U.S. Energy Information Administration, Annual Energy Outlook 2008 and 2013, Reference case.

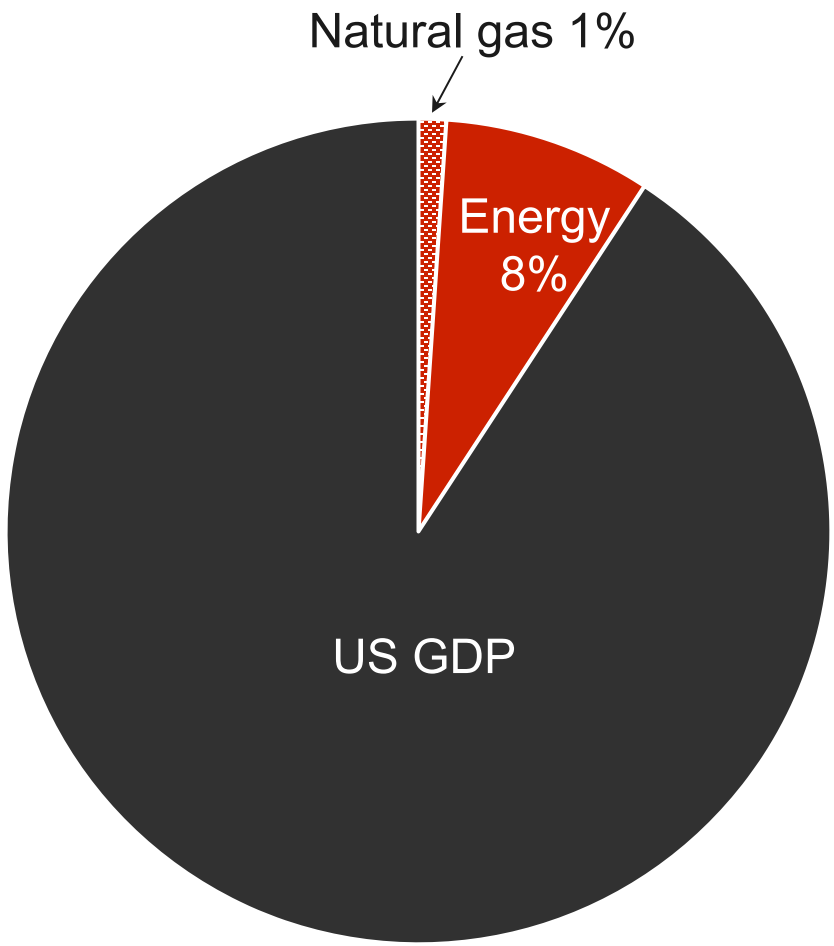
Understanding the potential implications of increased natural gas use on the climate

Natural gas abundance has both direct and indirect effects on GHG emissions and climate



Aggregate effects on U.S. energy economy

Natural gas is an important energy source, but is only 13% of all U.S. energy expenditures and 1% of GDP



2010 US GDP	$15 Trillion
Energy expenditures	$1.2 Trillion
Natural gas expenditures	$159 Billion

Data source: U.S. Energy Information Administration Annual Energy Review 2012.

Effects related to fuel substitution are likely to dominate effects on aggregate energy demand

- Aggregate energy demand is driven primarily by
  - Population growth
  - Overall economic growth and stage of economic development
  - Composition of GDP (e.g., share of services, manufacturing)
- Price changes have much bigger effects on fuel substitution than overall energy demand
  - Economists summarize this responsiveness through *demand elasticities* measuring the % increase in consumption with respect to a % decrease in price
  - EIA modeling, e.g., which embodies numerous such relationships has:
    - very low elasticity of aggregate energy demand with respect to natural gas price changes (<0.1)
    - low-moderate elasticity of natural gas demand with respect to natural gas prices in the residential/commercial (<0.3) and industrial sectors (<0.5)
    - quite elastic demand for natural gas for electricity generation (1.5 - 2.5)

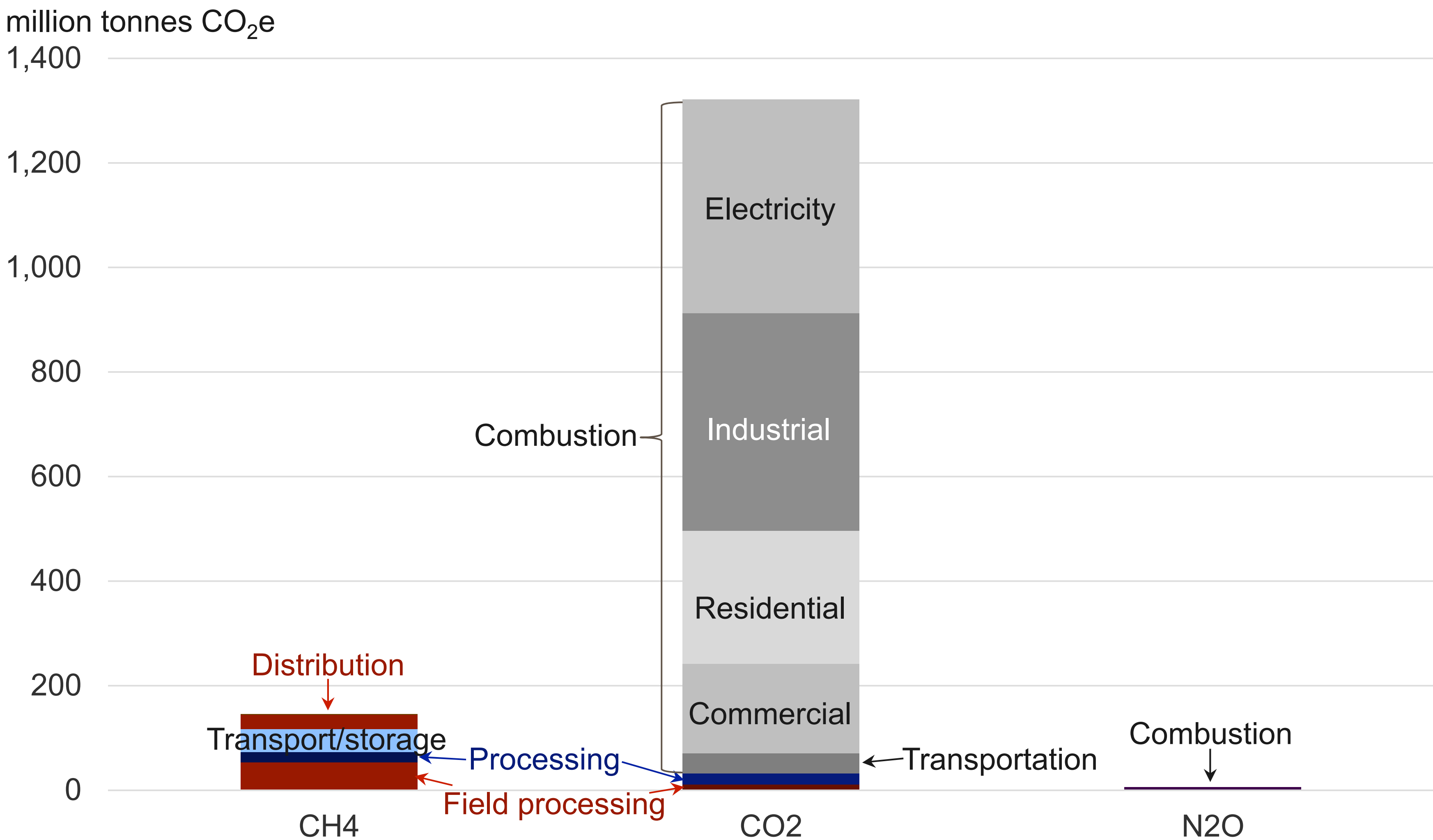
Greater U.S. shale gas leads to lower gas prices, more energy use, slightly higher GDP, and slightly lower GHG emissions in EIA projections

Scenario (for 2040)	Natural gas price $2011 at Henry Hub	Total energy use Quadrillion Btu	GDP Trillion $2005	Cumulative emissions 2010-2040* billion tonnes CO_2e
Reference	7.83 $/mmBtu	108	$27.3	179
Percent difference relative to Reference case				
High oil/gas resource	-45%	+3%	+1%	-0.4%
Low oil/gas resource	+32%	-1%	-0.1%	-0.8%

Data source: U.S. Energy Information Administration, 2013 Annual Energy Outlook.
*Notes: *CO_2e emissions computed by augmenting EIA CO_2 emission estimates for coal, oil, and natural gas by 3.3%,1.5%, and 12.7% respectively to account for non-combustion CO_2 and CH_4 emissions, based on EPA Greenhouse Gas Inventory 2013.*

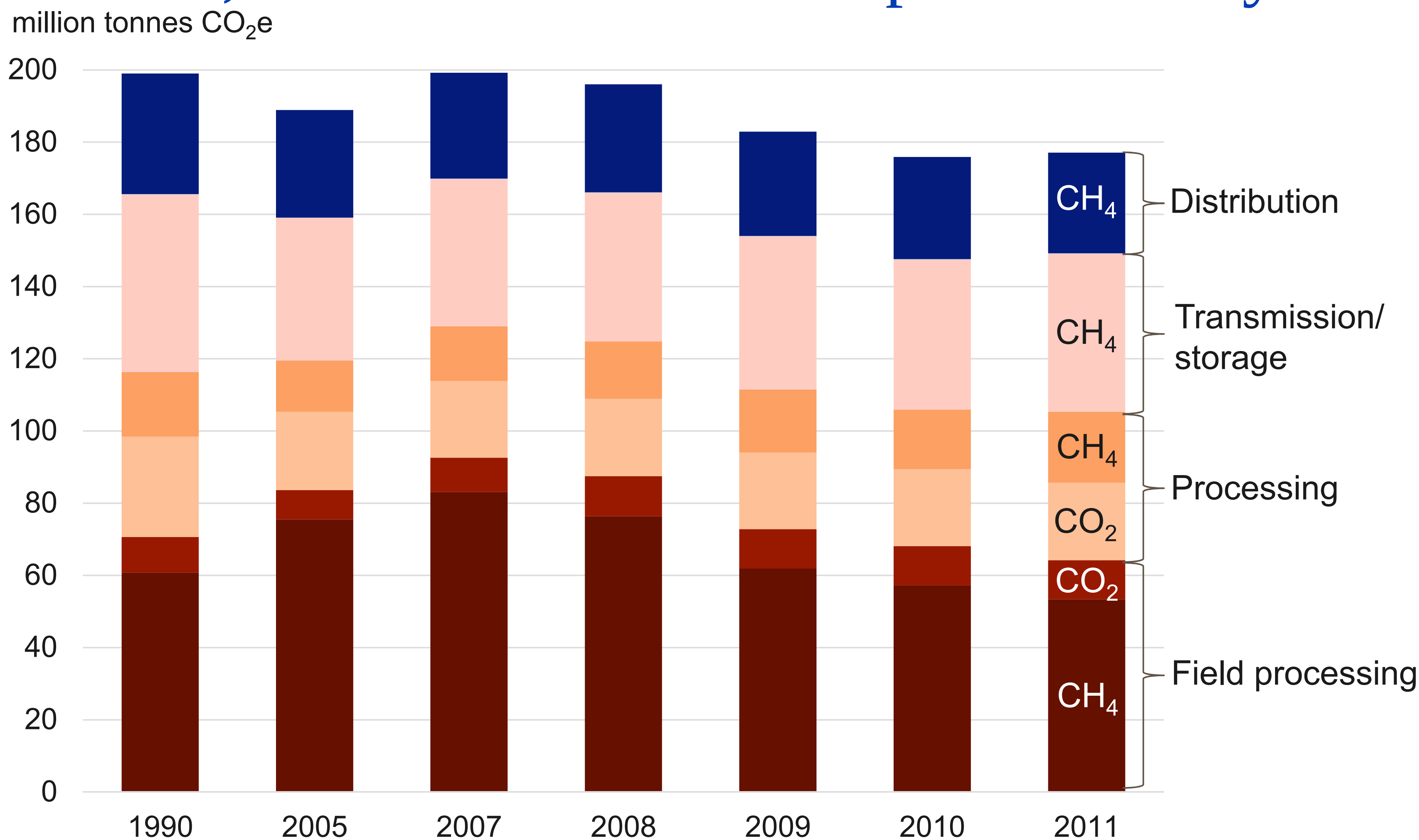
Non-combustion GHG emissions from natural gas

87% of greenhouse gas emissions from natural gas occur during the combustion phase



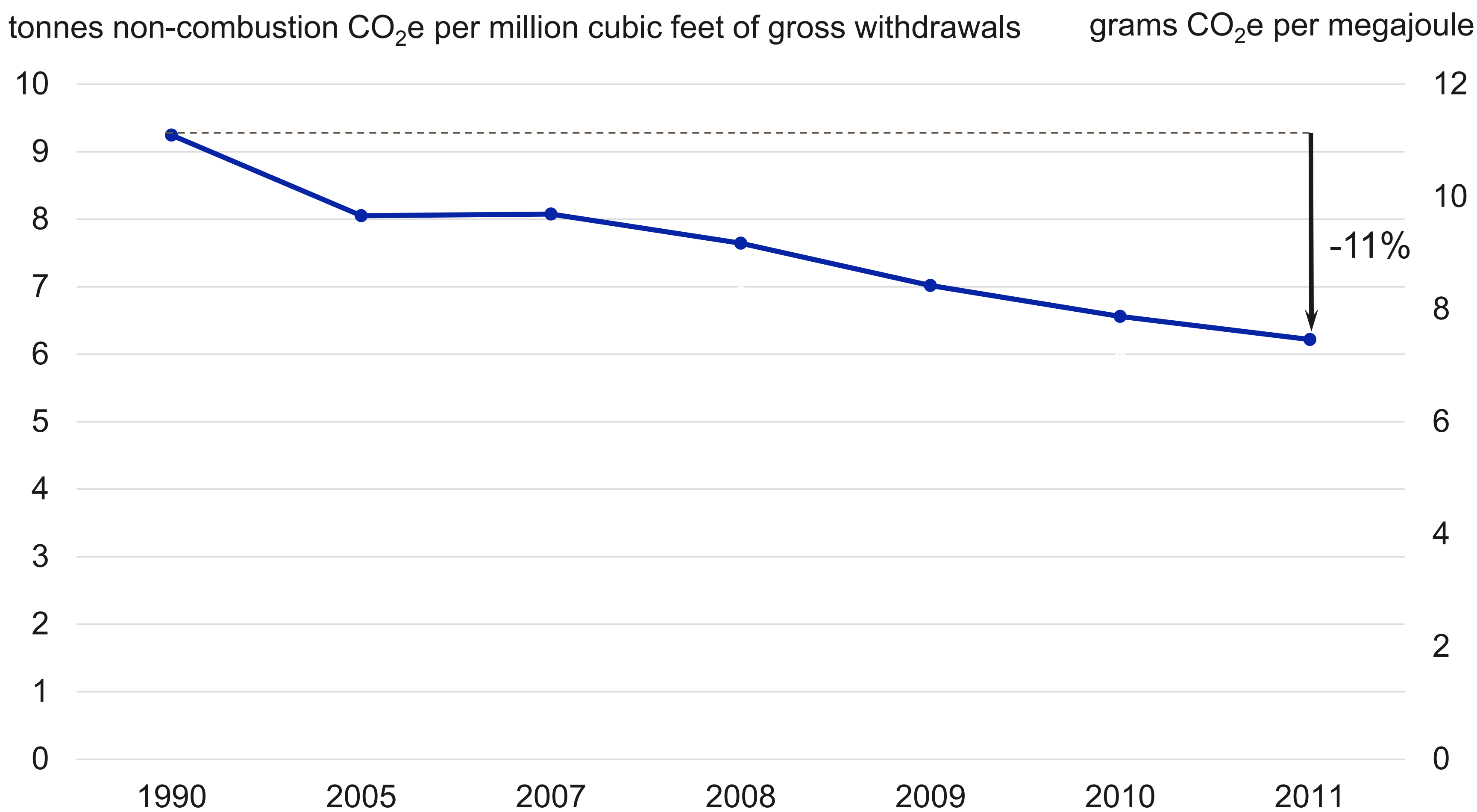
Data source: U.S. EPA Greenhouse Gas Inventory 2013.

Non-combustion emissions from natural gas are variable, but have fallen in the past several years



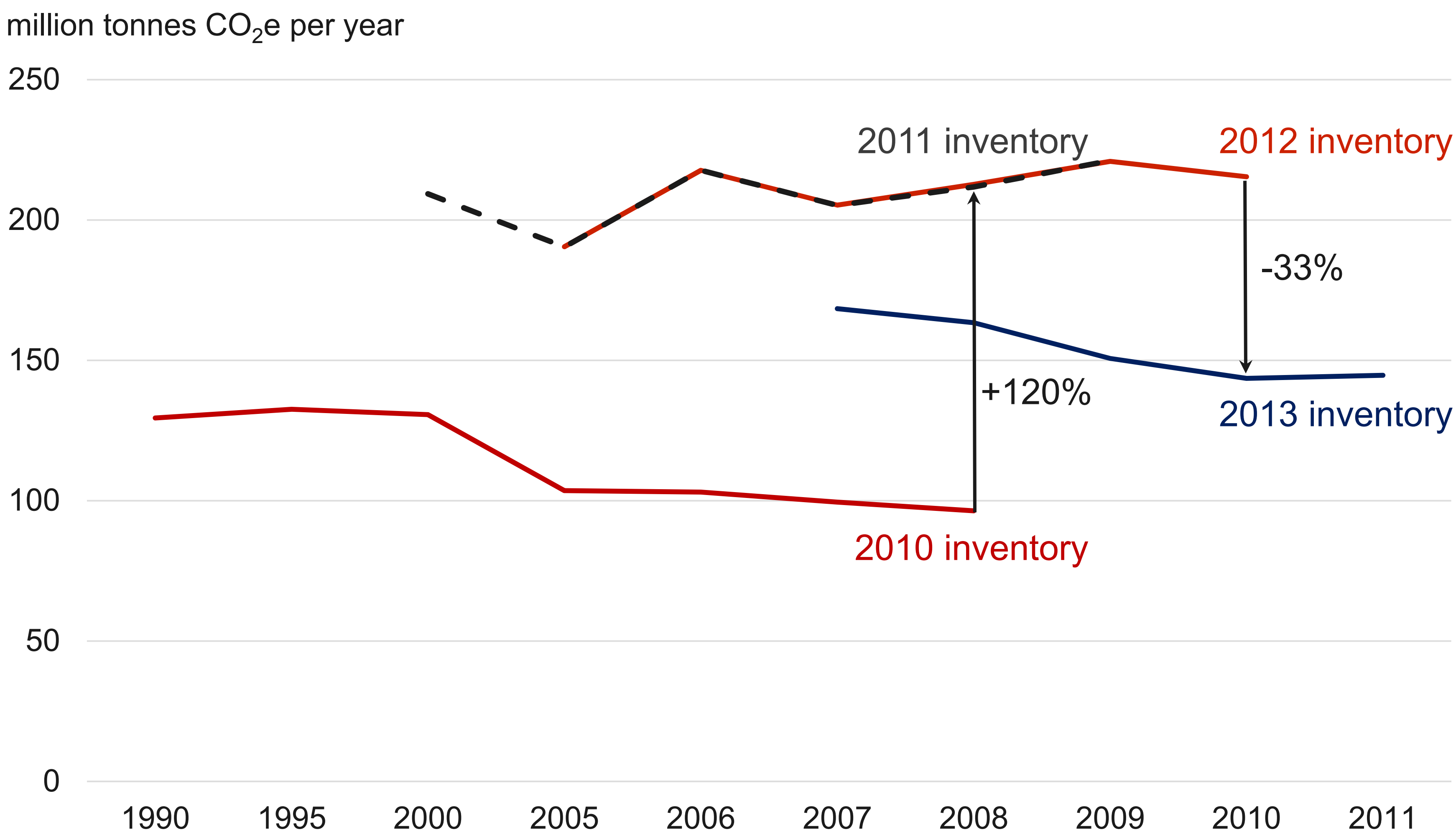
Data source: U.S. EPA Greenhouse Gas Inventory 2013.

Upstream non-combustion GHG emissions have fallen per unit of natural gas production



Data source: U.S. EPA Greenhouse Gas Inventory 2013 and U.S. Energy Information Administration.

EPA estimates of methane emissions from natural gas systems have changed over time



Data source: EPA Greenhouse Gas Inventories 2010, 2011, 2012, and 2013.

Non-combustion GHG emission estimates for shale gas are not consistently lower or higher than conventional gas

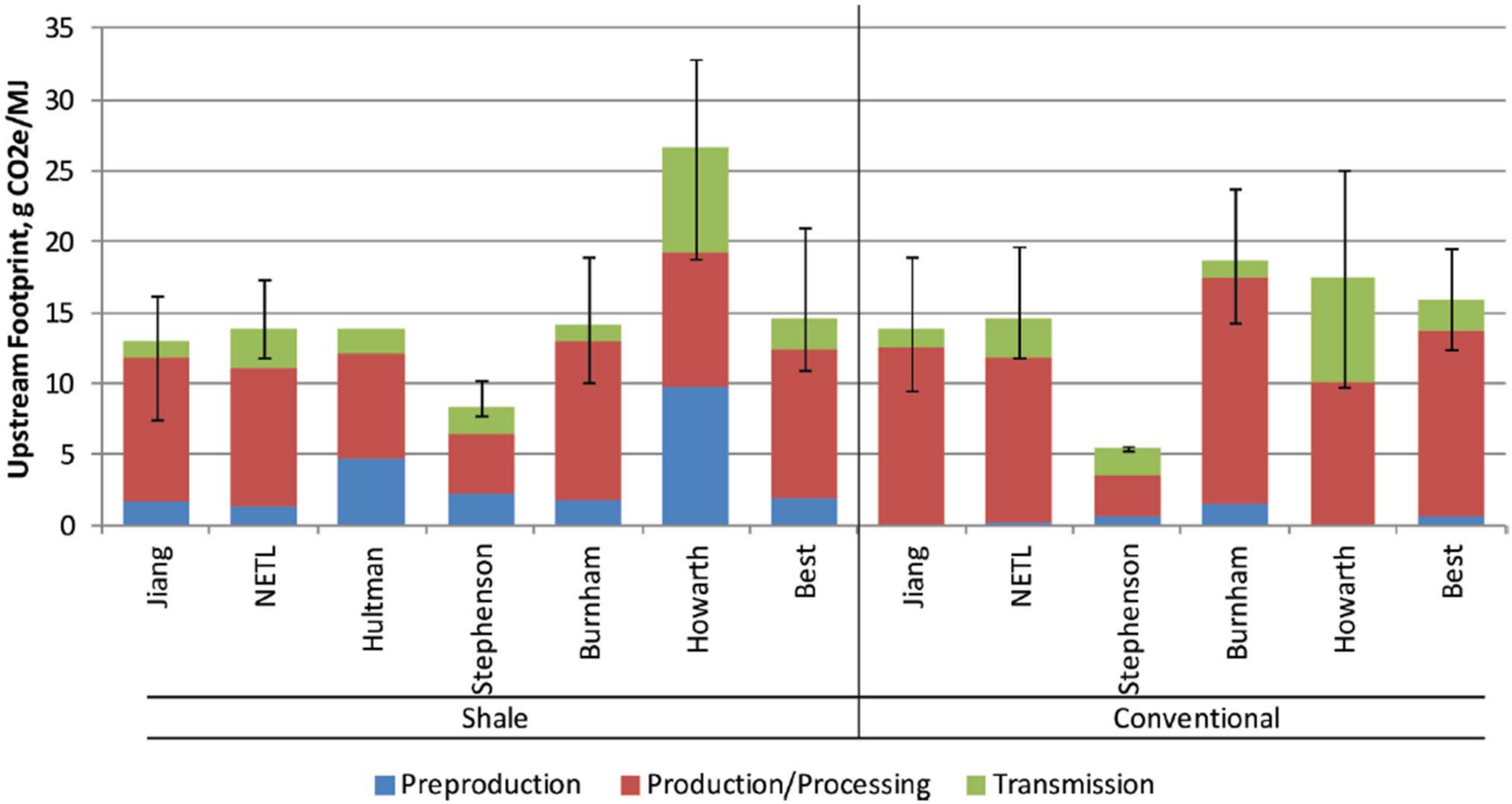
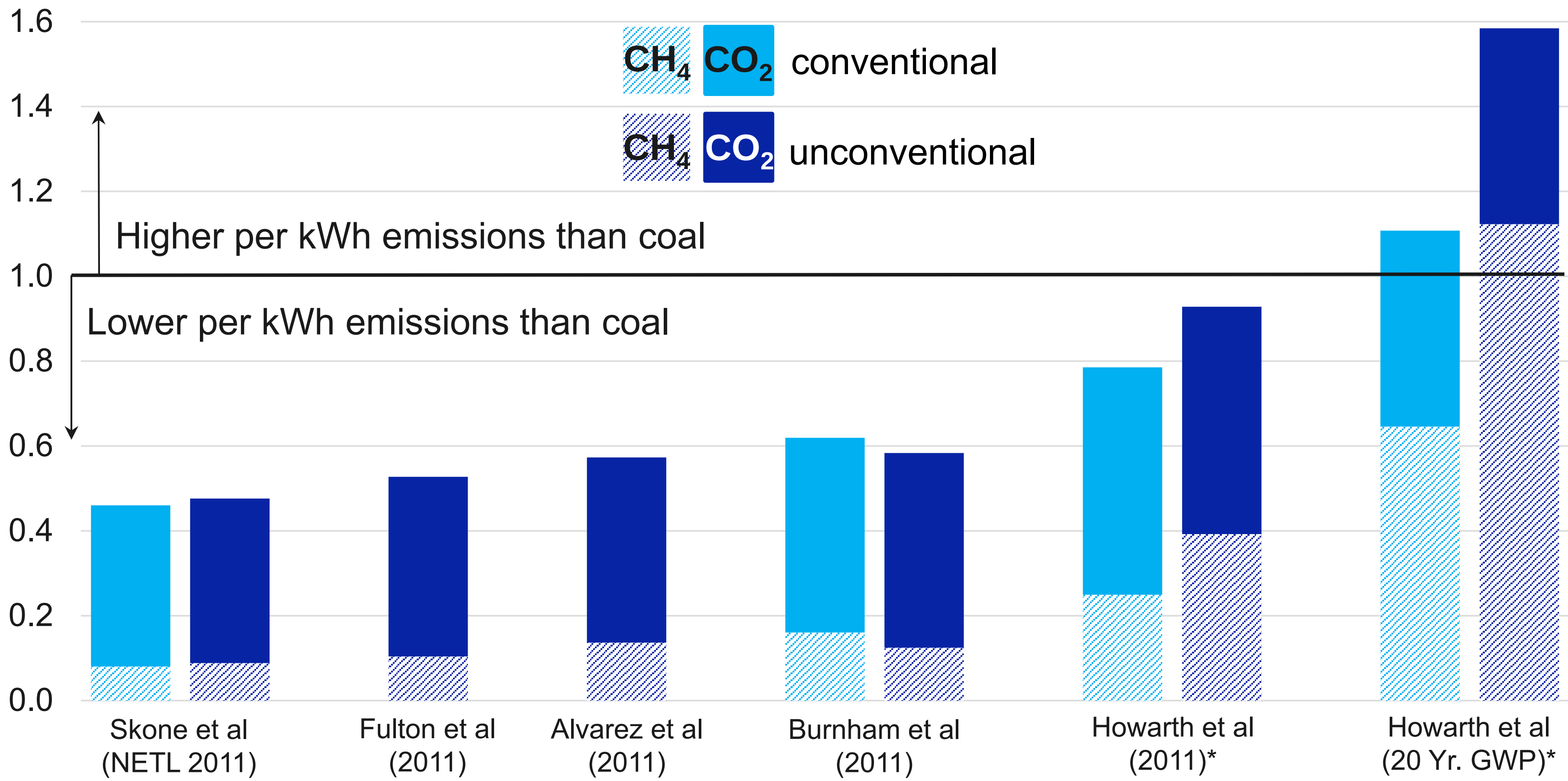


Image source: Weber and Clavin 2012.

Electricity sector

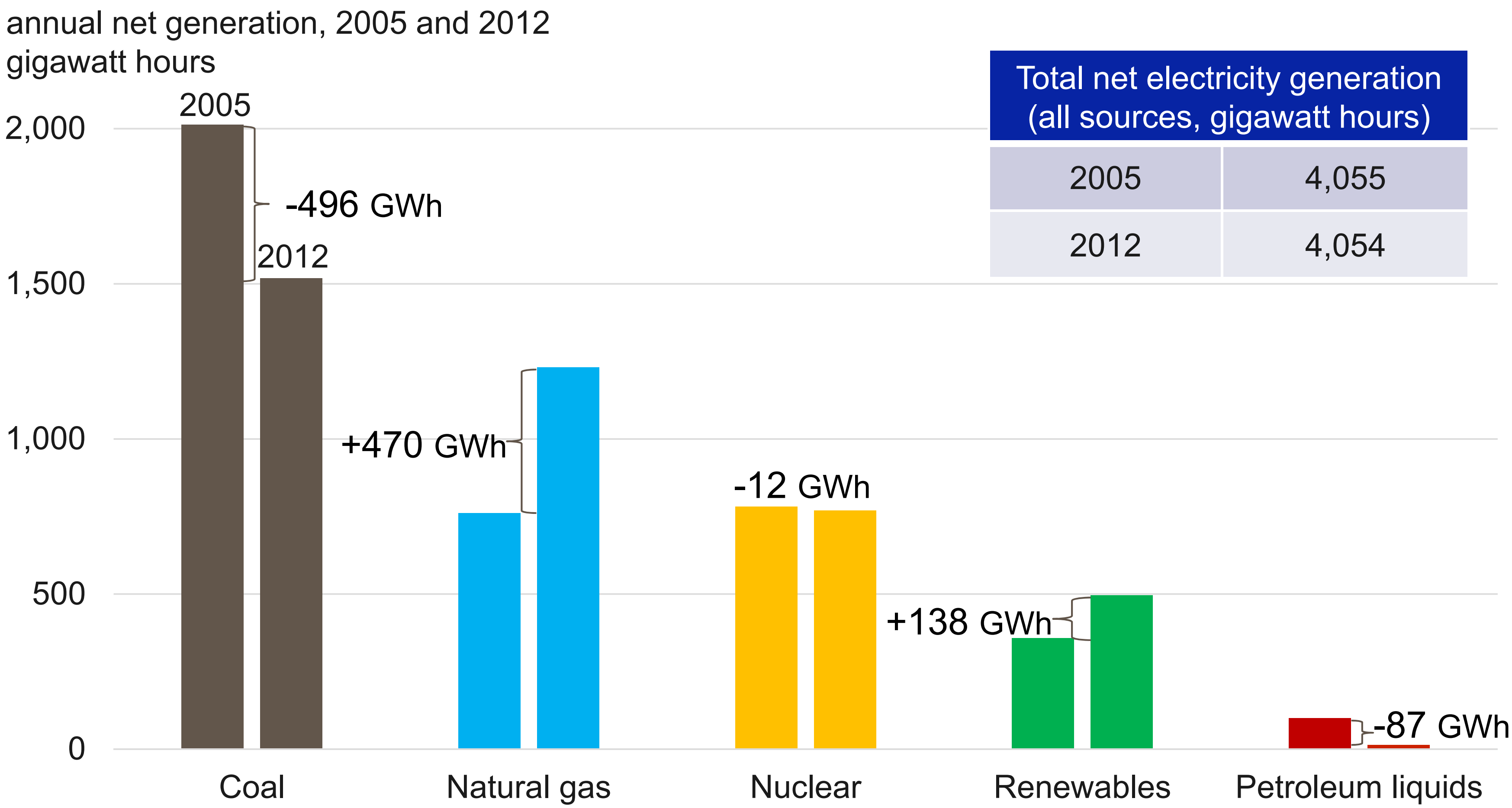
Most estimates have 40%-50% lower lifecycle GHG emissions for electricity from natural gas than coal

life-cycle emissions for power generation
ratio of CO_2e emission estimates for electricity generation from natural gas relative to coal



*Data source: Listed authors. Notes: 100-year global warming potential (GWP) used unless otherwise indicated. *Howarth does not account for differences in combustion efficiency of coal versus gas.*

U.S. electric-sector CO_2 emissions have declined 16% since 2005 due to fuel switching



Total net electricity generation (all sources, gigawatt hours)	
2005	4,055
2012	4,054

Data source: U.S. Energy Information Administration.

Greater shale gas leads to lower prices, fuel switching to gas, and lower electricity GHG emissions in EIA projections

Scenario (for 2040)	Natural gas prices (delivered for elec.)	Average electricity prices	Electricity consumption	Natural gas consumption for electricity	Coal consumption for electricity	Nuclear and renewables consumption	Cumulative electricity CO_2e emissions* 2010-2040
Reference	8.55 $/mmBtu	10.8 ¢/kWh	5,200 GWh	1,600 GWh	1,800 GWh	1,800 GWh	71 billion tonnes
Percent and absolute difference relative to Reference case							
High oil and gas	-39%	-14%	+4.2% (+200 GWh)	+49% (+800 GWh)	-21% (-400 GWh)	-9% (-200 GWh)	-5%
Low oil and gas	+26%	+7%	-2.4% (-100 GWh)	-34% (-500 GWh)	+4% (+100 GWh)	+19% (+300 GWh)	+0.2%

*Data source: U.S. Energy Information Administration, 2013 Annual Energy Outlook. Notes: *CO_2e emissions computed by augmenting EIA CO_2 emission estimates for coal, oil, and natural gas by 3.3%,1.5%, and 12.7% respectively to account for non-combustion CO_2 and CH_4 emissions, based on EPA Greenhouse Gas Inventory 2013.*

Residential and commercial buildings sector

Natural gas space and water heating tends to have significantly lower GHG emissions than electricity

- Space heating*
  - Natural gas boilers are about 50% less GHG-intensive (CO_2 and CH_4) than electric heat from natural gas electricity
  - Natural gas-powered heat pumps could further reduce emissions
  - Lower-GHG electricity would improve the electric heat footprint

- Water heating**
  - Natural gas water heating systems in 46 out of 50 states are less CO_2 intensive than electric heating systems
  - In most states, natural gas water heating systems are ~60% less CO_2 intensive than electric heating systems
  - Variation occurs between states due to electricity fuel mix
  - Lower-GHG electricity would improve the electric water heating footprint

*Sources: *Delucchi 2003 and Brenn et al 2010. **Czachorski and Leslie 2009, Gas Technology Institute.*

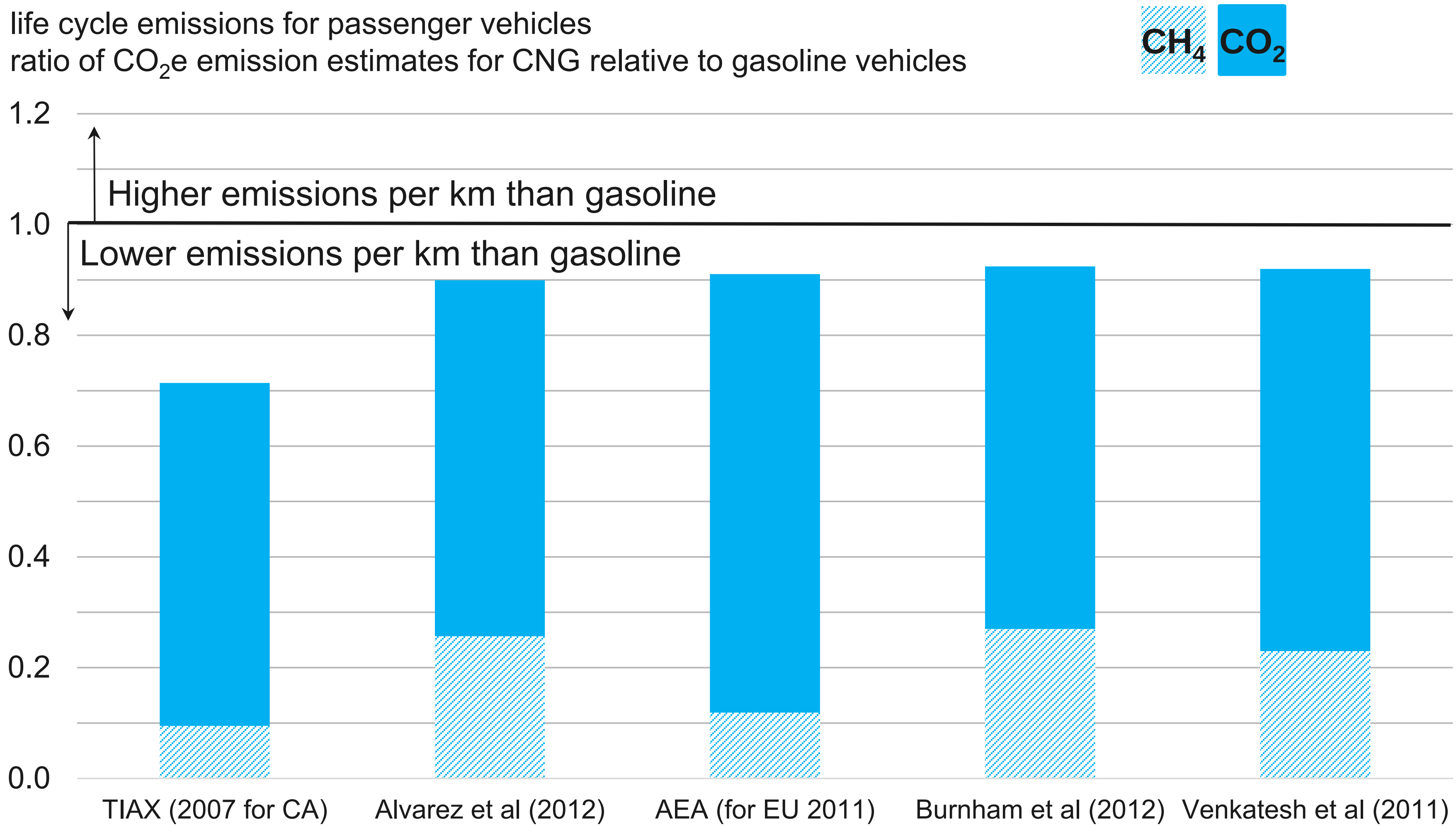
Greater shale gas leads to lower prices, more energy use, and lower GHG emissions in EIA residential and commercial projections

Scenario (for 2040)	**Natural gas prices** (avg. res/ comm price)	**Electricity prices** (avg. res/ comm price)	**Aggregate res/comm energy* consumption**	**Natural gas consumption for res/comm**	**Electricity* consumption for res/comm**	**Cumulative res/comm CO_2e emissions** 2010-2040**
Reference	15.13 $/mmBtu	11.7 ¢/kWh	21.8 QBtu	7.9 QBtu	11.8 QBtu	67 billion tonnes
Percent and absolute difference relative to Reference case						
High oil and gas	-22%	-13%	+5% (+1.1 QBtu)	+7% (+0.6 QBtu)	+4% (+0.5 QBtu)	-3%
Low oil and gas	+18%	+7%	-3% (-0.6 QBtu)	-4% (-0.3 Qbtu)	-2% (-0.2 QBtu)	-0.2%

Data source: U.S. Energy Information Administration, 2013 Annual Energy Outlook. Notes: *Does not include electricity-related losses. ***CO_2e emissions computed by augmenting EIA CO_2 emission estimates for coal, oil, and natural gas by 3.3%,1.5%, and 12.7% respectively to account for non-combustion CO_2 and CH_4 emissions, based on EPA Greenhouse Gas Inventory 2013.*

Transportation sector

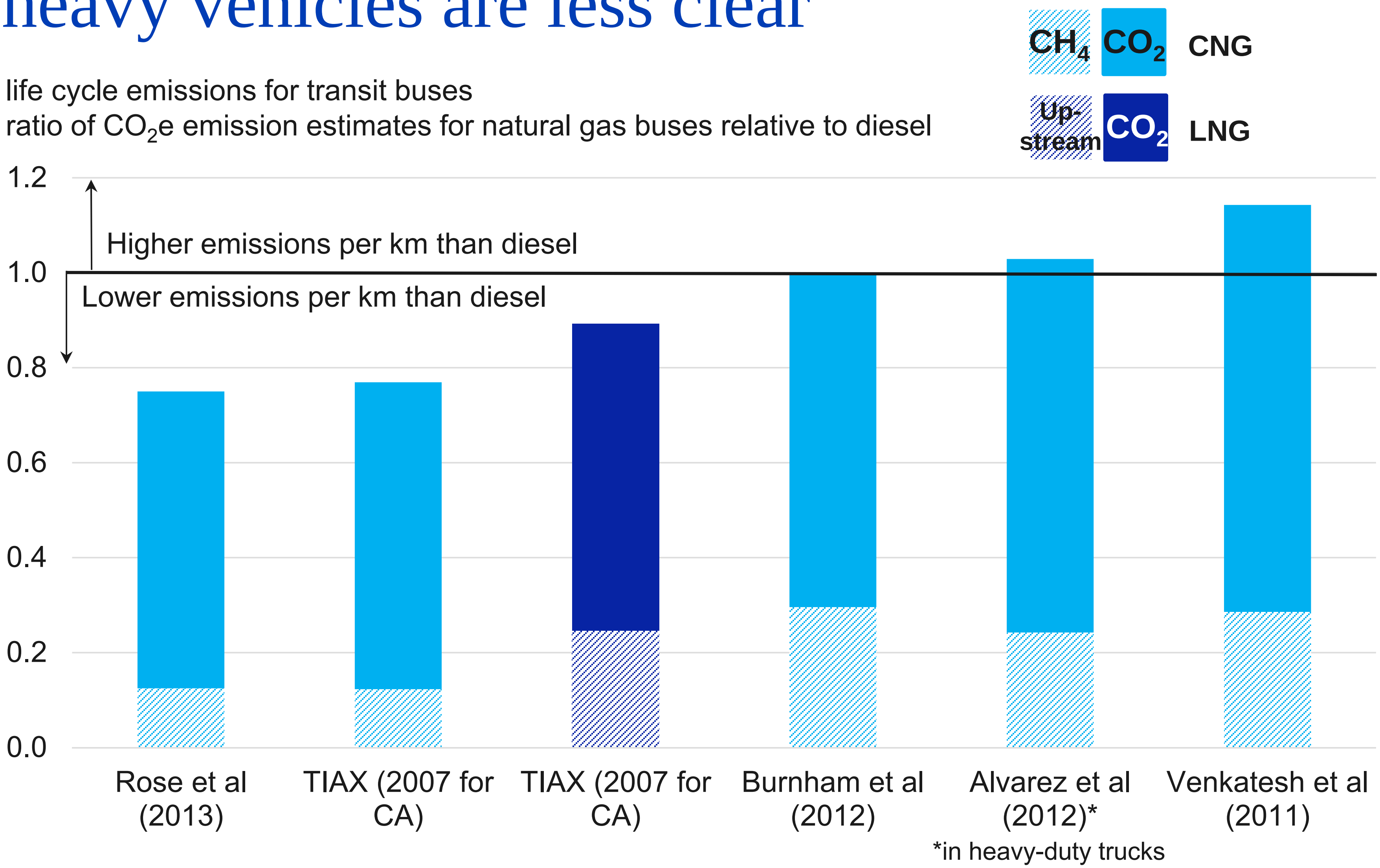
Natural gas passenger vehicles reduce emissions by 10%-30% relative to gasoline



Data source: Listed authors.

Climate benefits from natural-gas powered heavy vehicles are less clear

life cycle emissions for transit buses
ratio of CO_2e emission estimates for natural gas buses relative to diesel



Data source: Listed authors.

Industrial sector

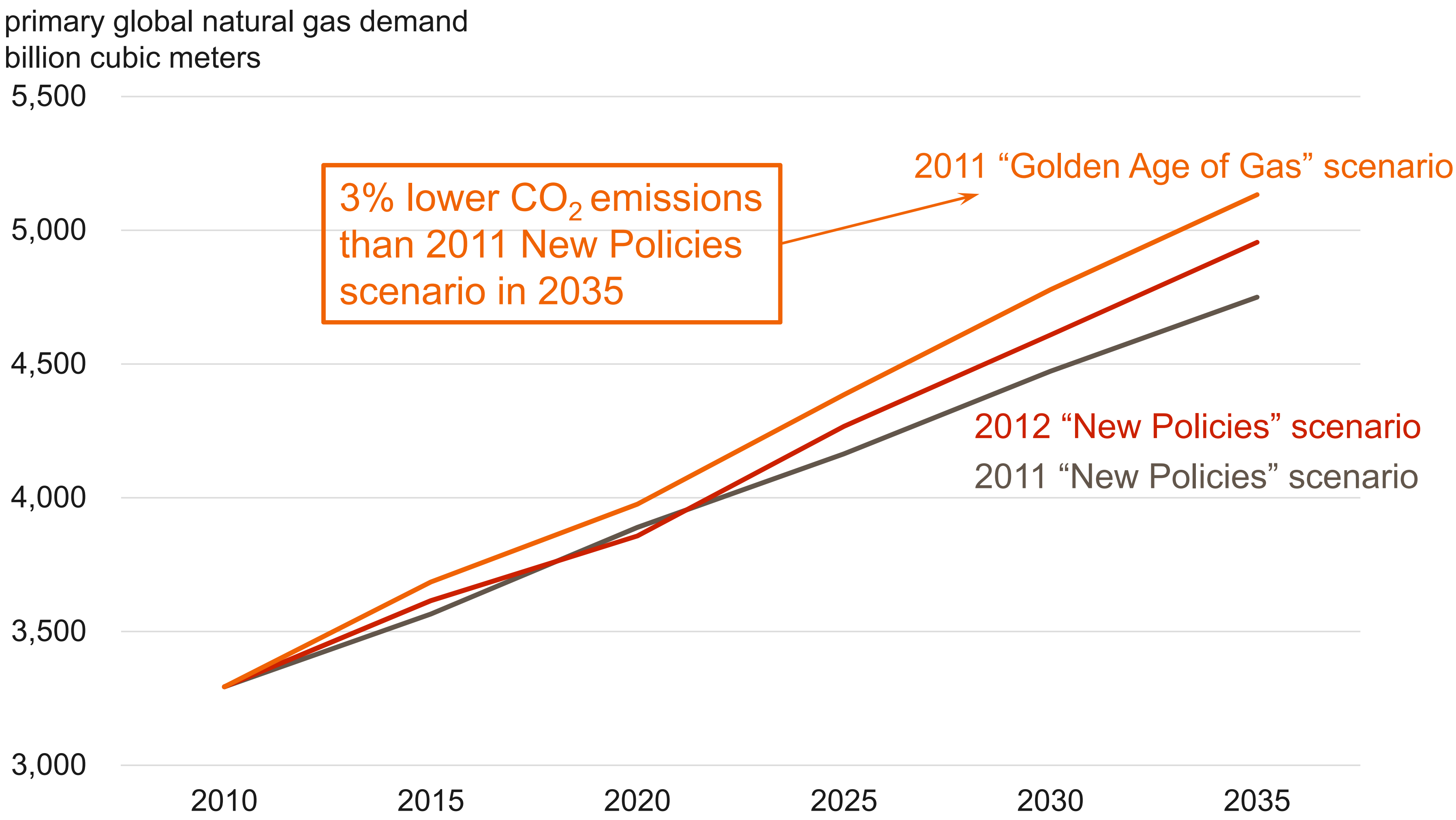
Greater shale gas leads to more industrial energy use and slightly higher GHG emissions in EIA projections

Scenario (for 2040)	Industrial natural gas prices	Aggregate industrial energy* consumption	Natural gas consumption by industry	Coal consumption by industry	Electricity* consumption by industry	Cumulative industrial CO_2e emissions** 2010-2040
Reference	9.09 \$/mmBtu	28.7 QBtu	10.4 QBtu	1.6 QBtu	3.9 QBtu	52 billion tonnes
Percent and absolute difference relative to reference scenario						
High oil and gas	-39%	+7% (+2.1 QBtu)	+18% (+1.8 QBtu)	-3% (-0.05 QBtu)	+2% (+0.1 QBtu)	+0.3%
Low oil and gas	+28%	-4% (-1.1 QBtu)	-8% (-0.9 QBtu)	-5% (-0.1 QBtu)	-1% (-0.02 QBtu)	-1.4%

*Data source: U.S. Energy Information Administration, 2013 Annual Energy Outlook. Notes: *Does not include electricity-related losses. **CO_2e emissions computed by augmenting EIA CO_2 emission estimates for coal, oil, and natural gas by 3.3%,1.5%, and 12.7% respectively to account for non-combustion CO_2 and CH_4 emissions, based on EPA Greenhouse Gas Inventory 2013.*

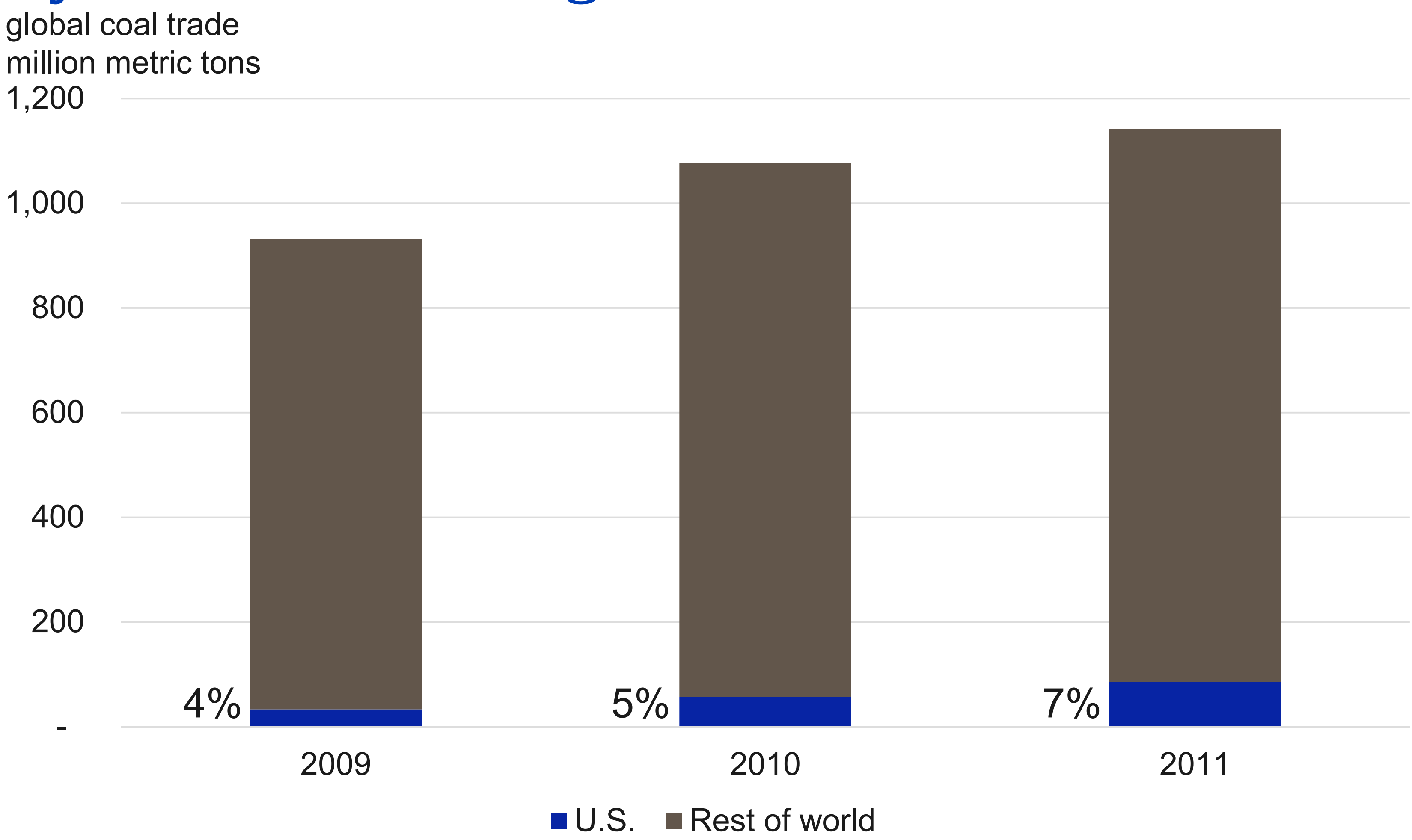
International implications

Projections for global natural gas use are rising



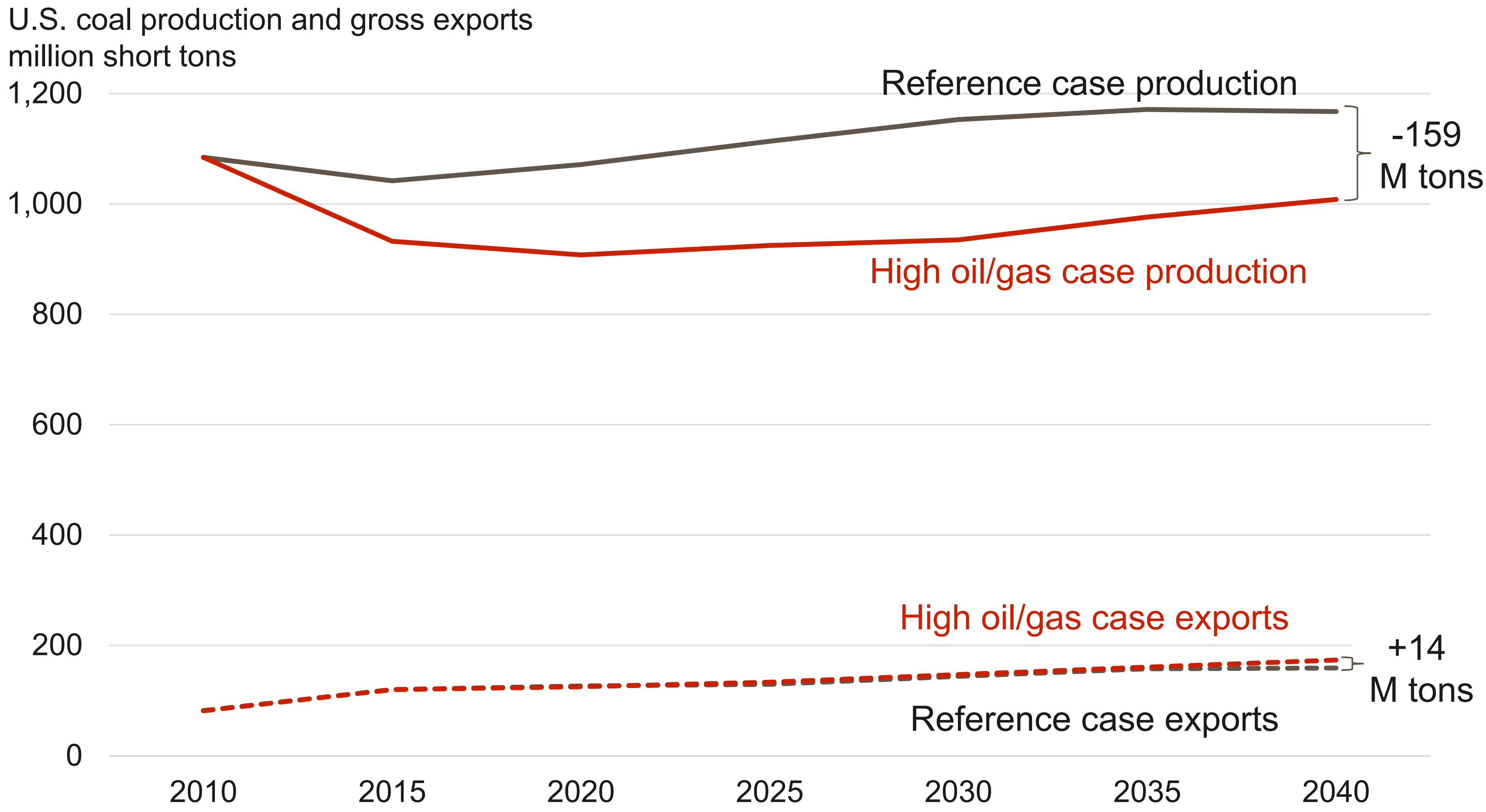
Data source: International Energy Agency 2011 and 2012 World Energy Outlook and 2011 “Golden Age of Gas” report.

U.S. coal exports have increased, but represent a fairly small share of global trade



Data source: U.S. Energy Information Administration and the World Coal Association. Calculated as U.S. net exports as a share of global coal trade.

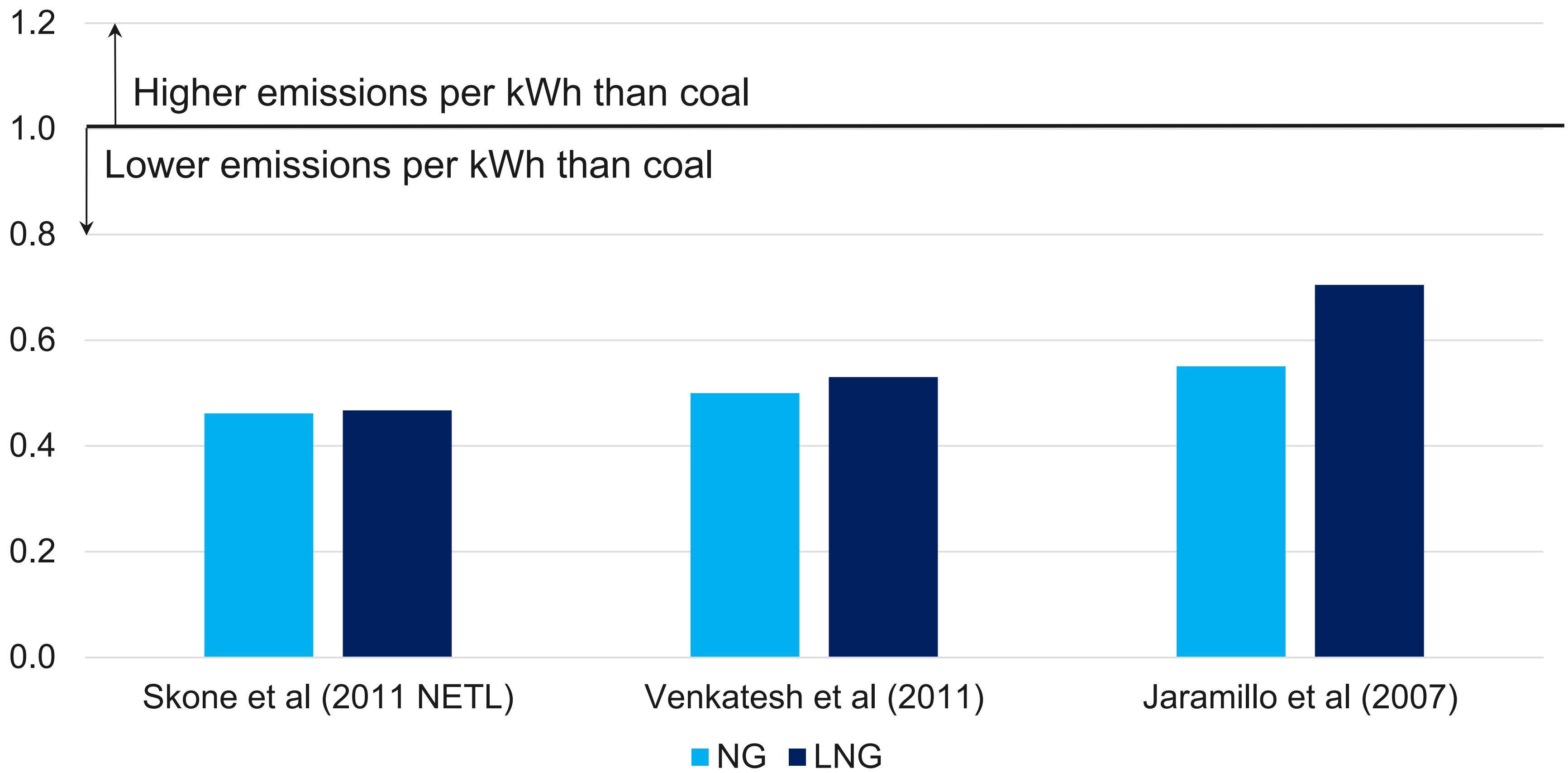
Greater shale gas resources lead to lower U.S. coal production and negligible effects on coal exports in EIA projections



Data source: U.S. Energy Information Administration 2013 Annual Energy Outlook.

LNG tends to have higher GHGs than domestic natural gas for electricity, but still lower than coal

life cycle emissions for electricity generation
ratio of CO_2e emission estimates for electricity from natural gas relative to coal



Data source: Listed authors.

Policy interactions and implications

How does abundant natural gas interact with and affect climate/energy policy?

- Lower natural gas prices make the cost of some policies lower and other policies higher
  - lowering the cost of options with relatively low GHG intensity will tend to make achievement of climate goals less costly
    - e.g., in current *baseline* scenarios no new US coal power is built in part due to low natural gas prices; as a result, regulations that would regulate new coal plant GHG emissions have no apparent impact
    - e.g., under an emissions constraint, lower natural prices lower the cost of meeting emission targets and (by design) do not affect emissions (e.g., EIA AEO 2013, Jacoby et al. 2011, Brown and Krupnick 2010)
  - in the context of renewable energy standards, however, lower gas prices will tend to increase the incremental cost of maintaining those standards
- With substantial long-term GHG reductions, natural gas would need to incorporate carbon capture and storage at reasonable cost to continue as a competitive option

Concluding thoughts

- The GHG emissions intensity of natural gas has fallen; further reductions in non-combustion emissions and improved combustion efficiency could further this trend
  - upstream emission estimates have fluctuated, but not sufficiently to alter the main conclusions
- Thus far, shale gas has lead to decreased GHG emissions by lowering prices and displacing more coal than renewables/nuclear
- Using current lifecycle GHG estimates, natural gas tends to lower GHG emissions relative to coal electric power, gasoline personal vehicles, and electricity for space/water heating
- Natural gas abundance alone will probably not have a substantial effect on future GHG emissions; policy is the key factor
  - but could influence relevant policy in ways that have a substantial effect

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