ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

What Influence Will Switching to Natural Gas Have on Climate?
USER GUIDE FOR NATURAL GAS LEAKAGE RATE MODELING TOOL

Background

Although natural gas burns cleaner than either coal or oil, methane leakage throughout the natural gas supply chain — including production, processing, distribution, and vehicle end-use — reduces and sometimes eliminates the potential climate benefits of switching. Methane, the main constituent in natural gas, is a greenhouse pollutant many times more potent than carbon dioxide. In fact, pound for pound, methane is 72 times more potent as a heat-trapping pollutant than carbon dioxide in the first 20 years.

U.S. Environmental Protection Agency (EPA) estimates current leak rates across the natural gas supply chain to be 2-3%. However, there are significant uncertainties associated with this estimate and intense disagreement over which leak rates are correct. The climate advantage of natural gas over coal could be considerably diminished or eliminated depending on what leak rates actually are and how we respond to them.

A shift of one-third of the power sector's coal fleet towards natural gas would almost certainly produce climate benefits if EPA is right about current leak rates. But what would happen if, on top of that, we also reduced the leak rate to 1%? And if leak rates are higher than current EPA estimates, will the shift to natural gas eat up all the climate gains achieved by shutting down coal plants?

Answering questions

To help answer these kinds of questions, Environmental Defense Fund (EDF) has developed a natural gas leakage modeling tool to explore the climate implications of reducing emissions from natural gas systems in the context of a switch towards natural gas-fueled technologies.

The tool will allow you to create scenarios comparing a hypothetical "policy case" to the baseline case by adjusting leak rates, fuel mix (power and transport sectors), and efficiency in the power sector (see appendix 1 for sample scenarios).

First, you can vary the natural gas leakage rates across three levels of the supply chain:

- **well to city gate**: from the well through the production, processing, transmission, and storage to delivery of natural gas to the city
- **local distribution**: from the city gate through distribution of natural gas to houses, commercial users or the fueling pump for vehicles

- **pump to wheels**: from the natural gas pump to vehicle use

Second, you can adjust the policy case fuel mixes for the power sector (coal, natural gas and zero emission fuels) and for the transportation sector (gasoline and natural gas in the light-duty fleet and diesel and natural gas in the heavy-duty fleet). Finally, you can adjust the efficiency of coal and/or natural gas power plants in your policy case, which varies the level of CO2 emissions that the added capacity produces.

Note that the model assumes that all changes occur immediately, providing a "snapshot" of the climate impacts resulting from the user inputs. It also takes into consideration the warming potential and atmospheric life span of methane, which degrades relatively quickly compared to carbon dioxide — so that you can see how your choices affect short- and long-term climate impacts.[1]

The results of your choices are depicted in both a graph and a table over time. These results show the potential change in "climate influence" — or, more precisely, the change in cumulative radiative forcing relative to total 2010 U.S. greenhouse gas emissions over 100 years. A negative value indicates that your choices are resulting in climate benefits. A positive value indicates that your choices are resulting in climate damages. If you care about climate change, you would want to find policy choices that start in negative territory and remain there, but different sets of choices have short-and long-term consequences that need to be weighed.

How to use the modeling tool (beta testing version 1.2)

Step 1: Define a policy case by changing light blue cells in the scenario inputs box of the control panel

Enter the desired values for natural gas leak rates and sector fuel mixes for your scenario. Power plant efficiencies can be modified as well. When you change the percentage in a light blue box, the associated grey box will automatically adjust so the sum equals 100% for each sector.

Step 2: Determine the impact of the policy case on the climate

The control panel displays results in the form of a graph and a summary table. Results are represented as a percentage change in net radiative forcing relative to 2010 U.S. emissions. You can find a larger version of the graph in the summary chart tab. The cross-over leak rate tab estimates the natural gas leak rate below which your fuel mix scenario becomes beneficial to the climate at a given time frame.

Things to consider when defining your policy case

At the start, we encourage you to change one variable at a time, then set it back to the defaults and change another variable. This allows you to see the impact of each action by itself. From there, you can see how combining actions interact with each other to provide synergistic effects

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[1] On a 20-year horizon, a methane molecule has 72 times more heat trapping capacity than a carbon |dioxide molecule. Over 100 years, that capacity shrinks to 25 times more capacity.

— such as reducing natural gas leakage rates while increasing the percentage of gas-fired generation.

Electric sector fuel mix

- The 2010 baseline power sector fuel mix is 46% coal, 24% natural gas, and 30% other (all of which is comprised of near zero-carbon emission sources such as hydro, wind, solar, and nuclear).[2] Estimates vary on how many coal-fired power plants will be retired in the U.S. between now and 2020; their current total capacity is approximately 300 GW. The U.S. Energy Information Agency currently predicts a 3% decline in energy production from coal by 2020 (EIA AEO 2012 Early Release). But predicting generation trends is complex and dynamic, and in 2012, in the face of rising coal prices and falling natural gas prices, the power sector fuel mix stands at 37% coal, 27% natural gas, and 36% other (US EIA Electric Power Monthly, January 2012).

- There have been many thoughtful studies to predict — or set goals for — the electric sector fuel mix. Predictions must take into account coal use, and expectations about whether reductions in coal use will be made up by natural gas, deployment of energy efficiency, renewables, nuclear or other technologies. One analysis prepared in 2010 for the American Public Power Association gives you a sense of the range of possibilities (in 2030): the range for coal generation was 8%-38%; the range for natural gas was 12%-43%, and the range for zero carbon sources (not including efficiency) was 33%-49%.[3] The model provides you the flexibility to test these scenarios or any others that you think may be possible or desirable.

- The model assumes demand for electricity to be constant, but you can approximate the impact of increased energy efficiency by increasing the amount of zero carbon generation relative to coal and natural gas.

- The model assumes that all changes occur immediately, providing a "snapshot" of the climate impacts resulting from the user inputs. In the power sector fuel mix, the model excludes petroleum (which makes up only approximately 1% of power generation).

- "Zero emissions alternatives" include efficiency, hydro, wind, solar and nuclear.

Natural gas leak rate

- The natural gas leak rate is defined as the natural gas lost in the atmosphere as a percentage of gross production.

- Well to city gate includes production, processing and interstate pipelines.

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[2] Based on EIA's Annual Energy Outlook 2012 Early Release. http://www.eia.gov/forecasts/aeo/er/

[3] http://www.publicpower.org/files/PDFs/ImplicationsOfGreaterRelianceOnNGforElectricityGeneration.pdf, p. 18

- Natural gas is assumed to consist of 90% methane.

- "Other sectors" include non-electricity demand for natural gas from residential, commercial and industrial users. Approximately two-thirds of the U.S. consumption of natural gas is in these other sectors. Reductions in the leak rate of natural gas overall includes these sectors and thus will add to the climate benefits derived.

- U.S. EPA data was used as the basis for baseline leakage rates from the U.S. natural gas supply (2% from well to city gate and 0.3% in the local distribution system). In 2011, EPA increased its estimate of methane leakage in the natural gas supply chain by a factor of two based on new data indicating its prior estimate underestimated actual emissions. Specifically, EPA revised emission factors for gas well cleanups, condensate storage tanks, and centrifugal compressors. In addition, EPA added emissions for unconventional gas well completions and workover venting. Debate exists over the accuracy of these EPA estimates. Industry representatives insist that they are too high, pointing to data collected from the 59% of the industry participation in EPA's Gas Star program, a voluntary effort to encourage methane emission reductions.

- Howarth et al[4] argue that leak rates for shale gas from well to city gate are 3.6-7.9% and 1.7-6.0% for conventional gas, but as with industry assertions, there are few actual measurements. The model allows for a total leak rate as high as 12% — but this is considered extremely unlikely to be the actual case.

- The pump to wheels default leak rate is assumed to be 0.5%, but there is almost no data available. Pump to wheels leakage includes emissions that occur from refueling, from the use of the fuel and incomplete combustion. There are few data from in-use vehicles, as opposed to new vehicles, and what little does exist suggests that it adds roughly 20% to well-to-pump methane losses.

Climate influence summary of results

"Climate influence" is shorthand for the relative change in the cumulative radiative forcing (in W/m2) due to U.S. greenhouse gas emissions over specific time horizons depending on user-defined adjustments to the U.S. natural gas leak rate and technology switch scenarios. Positive values represent an increase in radiative forcing, while negative values represent a decrease. Short-term increases in net radiative forcing will determine the rate at which the climate changes, determining ecological impacts and potentially trigger climate surprises, while long-term changes determine the overall change in global temperatures. We need to address both short- and long-term net radiative impacts if we are going to minimize social and ecological disruption.

[4] Howarth, Robert W., Renee Santoro, Anthony Ingraffea. "Methane and the greenhouse-gas footprint of natural gas from shale formations," *Climatic Change*, DOI 10.1007/s10584-011-0061-5, (2011). http://www.sustainablefuture.cornell.edu/news/attachments/Howarth-EtAl-2011.pdf

Power plant efficiency

Our model assumes that coal and natural gas power plants in the baseline are running at 2010 average heat rates (Btu/kWh; EIA's Electric Power Annual 2010).[5] Baseline coal assumes a heat rate of 10,415 Btu/kWh; baseline natural gas assumes a heat rate of 8,185 Btu/kWh. The user can adjust the policy case heat rates in order to capture different efficiency potentials for coal and natural gas in the future. For example, the 2011 National Petroleum Council Report, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," lists a range of possible heat rates for natural gas (6,563 Btu/kWh – 12,289 Btu/kWh) and coal (9,000 Btu/kWh to 11,377 Btu/kWh). Whatever you choose, the user-defined policy case heat rates are applied only to any additional coal or natural gas above the baseline share.

Transportation sector fuel mix

The model assumes a current fuel mix of 97% gasoline and 3% natural gas for the light-duty vehicle fleet – in this sector, the model excludes diesel for simplicity. In the future, we hope to include an option for electric vehicles. The model assumes 97% diesel and 3% natural gas in the heavy-duty vehicle fleet.[6] The International Association for Natural Gas Vehicles projects that natural gas vehicles will represent 9% of vehicles on the road globally in 2020.[7] The U.S. Energy Information Administration projects that the natural gas light-duty and heavy-duty sector in the U.S. will grow by less than <1%.[8]

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[5] EIA, Electric Power Annual 2010. http://205.254.135.7/electricity/annual/pdf/table5.3.pdf

[6] Based on EIA's Annual Energy Outlook 2012 Early Release. http://www.eia.gov/forecasts/aeo/er/

[7] Objectives of the International Association for Natural Gas Vehicles, from a speech by John Lyon, IANGV President 2006-2008 (IANGV website, available at http://www.ngvglobal.com/65-million-ngvs-by-2020-iangv-projection-0603).

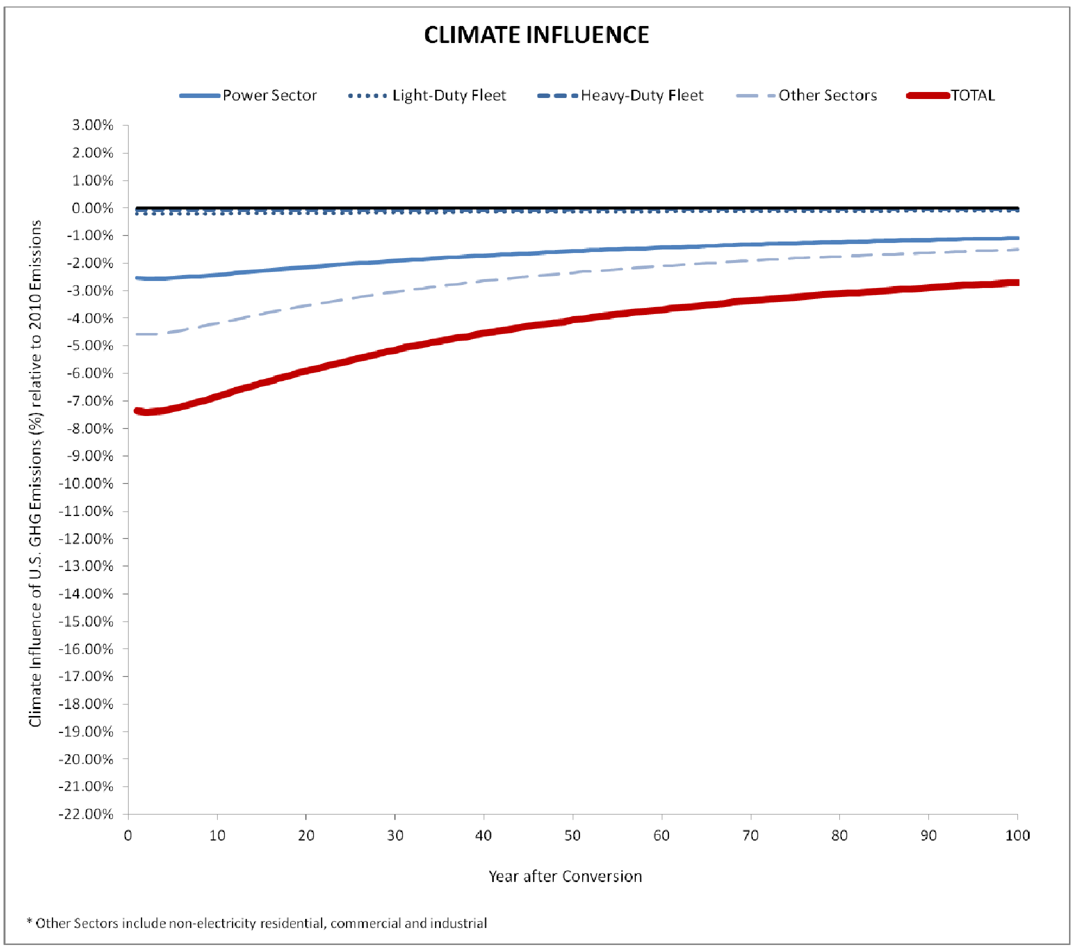
[8] As pointed out in a study by the OECD, the 2011 NAT GAS Act (New Alternative Transportation to Give Americans Solutions), if adopted, could encourage the further penetration of natural gas vehicles by extending for 10 to 15 years the existing $0.50/gasoline-gallon-equivalent tax credit for the use in vehicles of compressed or liquefied natural gas, as well as the income tax credit that comes with the purchase of a natural gas vehicle (Michel Nijboer, 2010. The Contribution of Natural Gas Vehicles to Sustainable Transport, Paris: OECD).

Appendix 1. Sample scenarios

What follows are five example scenarios. While the model allows users to modify current (baseline) leak rates, the first four scenarios assume that current well-to-wheels leak rates sum to 2.8% (2.3% from the well through the local distribution system based on EPA estimates plus an additional pump-to-wheels increment of 0.5%).[9] The last scenario assumes a higher starting leak rate of 6%. All five scenarios assume that new natural gas plants (above the baseline share) will run more efficiently than the current average at a heat rate of 7,000 Btu/kWh vs. 8,185 Btu/kWh.

Scenario 1: Reducing natural gas supply chain (well-to-wheels) leakage to 1%

EDF has set a goal of reducing natural gas leakage rates to 1% across the supply chain. Reductions of that magnitude from our assumed leak rate of 2.8% would have substantial climate benefits across all time frames: from a 5.9% to 2.7% reduction in net radiative forcing relative to 2010 U.S. greenhouse gas emissions over 20 and 100-year time horizons respectively. Climate benefits are attributable mostly to the non-electricity residential, commercial and industrial sectors—although some is also attributable to the power sector.

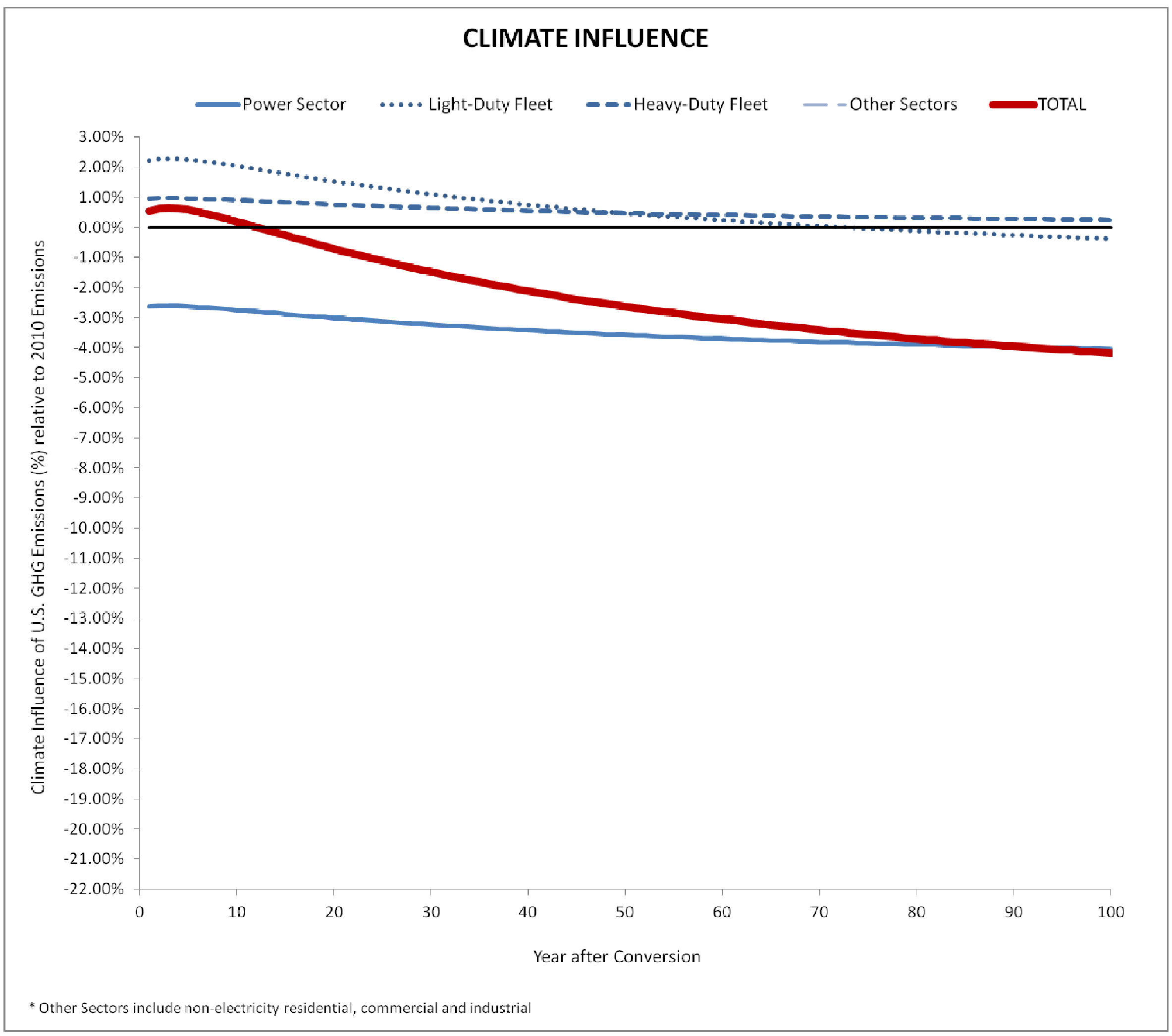


[9] The well to wheels leak rate applies to the transport sector; non-electricity residential, commercial and industrial sectors emissions are affected by the leak rate from the well through the local distribution system; power sector emissions are affected by the well to city gate leak rate.

Scenario 2: Fuel switch to natural gas

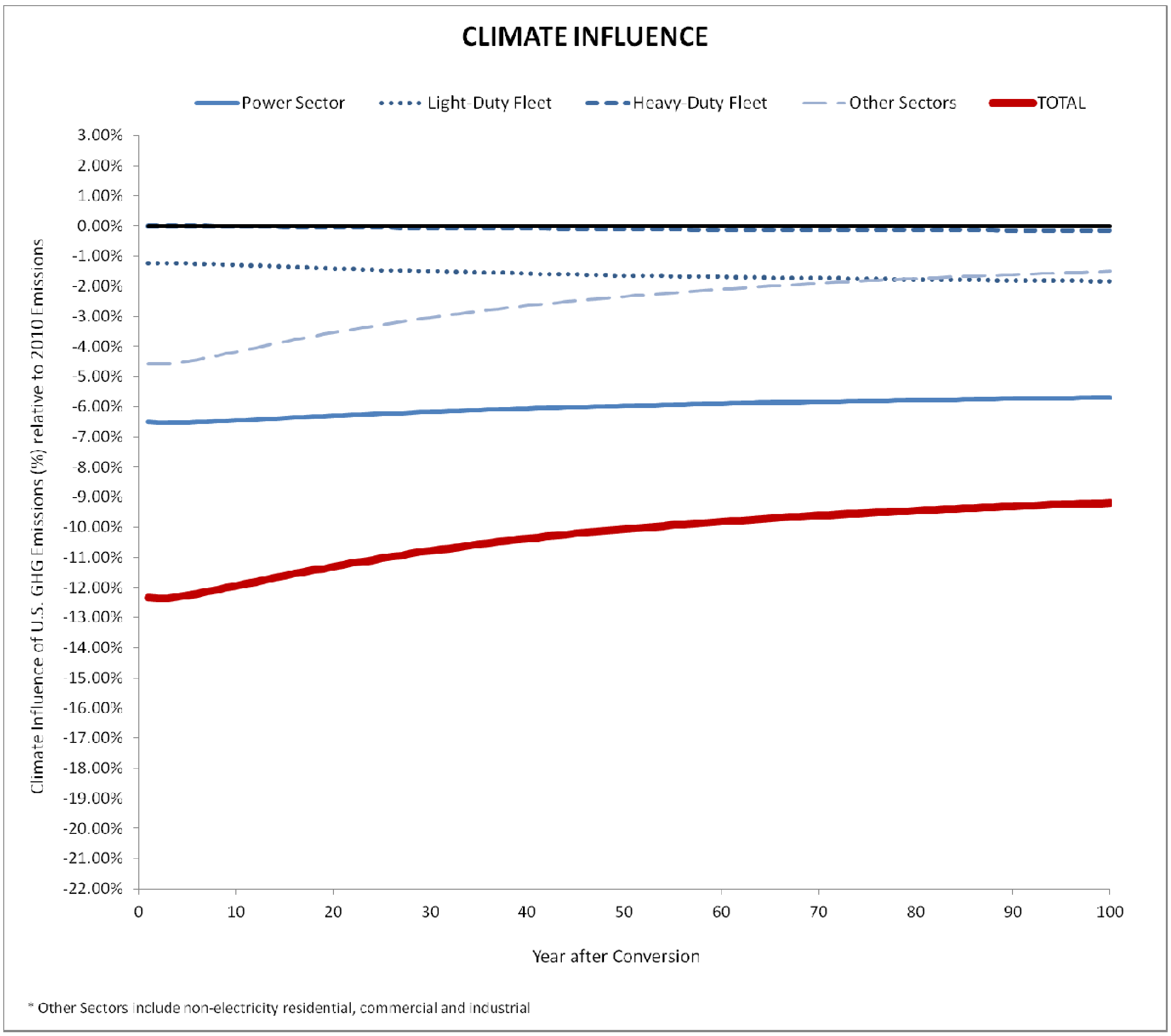
In this scenario, coal-fired power generation is reduced by one-third and entirely replaced by natural gas-fired generation. In the transport sector, the share of natural gas is increased to 50% in both light-duty and heavy-duty vehicle fleets. There is no reduction in the leak rate, which stays at 2.8%. The model shows that for the first 13 years, the switch to natural gas would result in climate damage. After that, there would be slight benefits that increase over time, from a 0.7-4.2% reduction in net radiative forcing relative to 2010 U.S. greenhouse gas emissions over 20- and 100-year time horizons, respectively. While there are climate benefits from the power sector switch across all time frames, the initial climate damages result from the fuel switch in the transport sector. The light-duty switch only becomes beneficial around 72 years after conversion, while the switch in the heavy-duty fleet results in climate damages over the entire 200-year time frame examined.

The model also allows the user to determine the "cross-over leak rate," or the leak rate at which a fuel switch would be beneficial to the climate across all time frames. For the fuel switch in the light-duty and heavy-duty fleets to be beneficial across all time frames, the well-to-wheels leak rates would need to be below 1.6% and 1%, respectively.



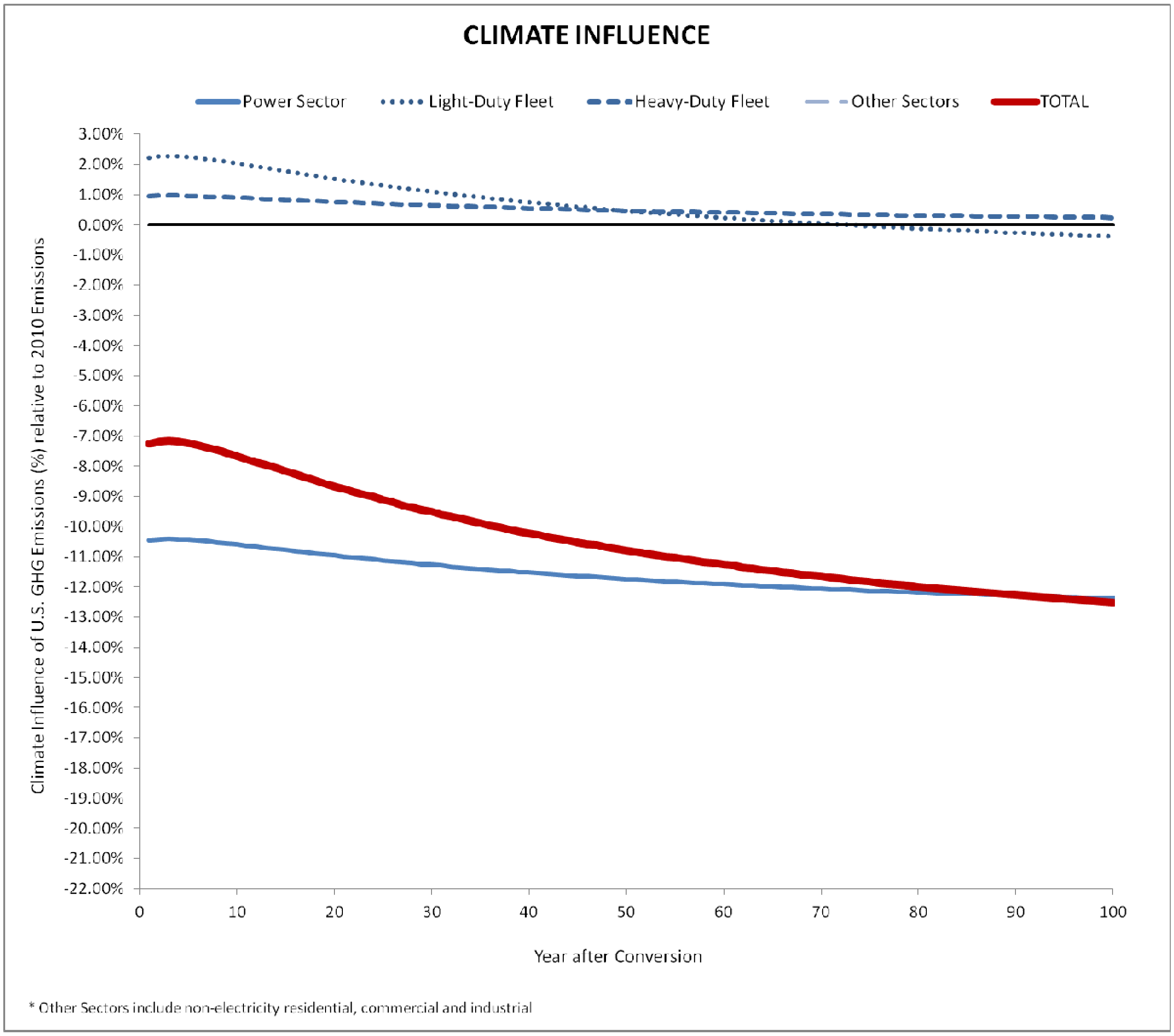
Scenario 3: Fuel switch to natural gas plus leak rate reduction

This is a combination of Scenarios 1 and 2. As in Scenario 2, coal-fired generation is reduced by a third and replaced entirely by natural gas; transport sector fuel mixes are shifted to 50% natural gas. However, in this scenario, the well-to-wheels leak rate is reduced from 2.8% to 1%, as in Scenario 1. This scenario illustrates the importance of reducing leak rates in the context of a fuel mix shift to natural gas. With leak rates reduced, the fuel switch provides large climate benefits across all time frames, from a 11.3% to 9.2% reduction in net radiative forcing relative to 2010 U.S. greenhouse gas emissions over 20 and 100-year time horizons, respectively. The transport sector fuel switch now results in climate benefits as well, though very small (between 0.1 and 0.2%) for the heavy-duty fleet.



Scenario 4: Fuel switch to natural gas and renewables

In this scenario, a third of coal-fired power generation is replaced by natural gas and another third is replaced by renewable energy. As in Scenarios 2 and 3, transport sector fuel mixes shift to 50% natural gas in both fleets. There is no reduction in leak rate, which stays at 2.8%. In this scenario, there are high climate benefits across all time frames. Net radiative forcing is reduced by 8.7% and 12.5%, assuming 20 and 100-year time horizons, respectively. As in Scenarios 2, the fuel switch in the transport sector brings climate damages, but these are more than offset by the increased use of renewables.



Scenario 5: Fuel switch to natural gas and renewables plus leak rate reduction

This is a combination of Scenarios 1 and 4. As in Scenario 4, a third of coal-fired generation is replaced by natural gas and a third is replaced by renewables. Transport sector fuel mixes switch to 50% natural gas in both fleets. Additionally in this scenario, we assume a 6% starting leak rate, which is significantly higher than the 2.8% leak rate based on EPA data (4.9% from the well through the local distribution system plus an additional pump-to-wheels increment of 1.1%). This leak rate of 6% is reduced to 1% across the supply chain. This scenario again illustrates the dramatic increase in climate benefits that results from the reduction of the leak rate, particularly if leak rates are actually higher than those based on EPA data. Net radiative forcing relative to 2010 U.S. greenhouse gas emissions is reduced by 28% and 22% over 20 and 100-year time horizons, respectively. The fuel shift in the transport sector is beneficial to the climate across all time-frames as well, and there are substantial benefits from reducing the leak rate in the non-electricity residential, commercial and industrial sectors.