Benefits of Combined Climate Metrics

Past studies show that the climate benefit of transitioning from coal to gas depends on the amount of methane leakage from the natural gas supply chain, claiming that the transition is only beneficial in certain scenarios. A key factor responsible for this outcome is the large uncertainty in methane leakage which can negate the emission reduction from the combustion of natural gas (natural gas generally releases less than half of the CO_2 upon combustion compared to coal); in addition, it is important to account for methane emissions associated with coal production.

The typical approach to measure the climate impact of greenhouse gases is to convert non-CO_2 emissions into CO_2 using global warming potential (GWP) for a time horizon (for example, 100 years), thus generating equivalency among different greenhouse gases. GWP is defined as time-integrated radiative forcing of an emission of a gas relative to a CO_2 emission of equal mass for a given time horizon. GWP as an emission metric is sensitive to the time horizon selected and the relationship between radiative forcing and temperature change is complex and may not be linear (Fuglestvedt et al., 2003). In a previous white paper, we discussed this in detail (CMR, 2019). The purpose of this white paper is to briefly discuss the benefits of using combined climate metrics to more fully understand the impacts of methane on climate.

The GWP of methane, a greenhouse gas with substantially shorter atmospheric lifetime compared to CO_2, will increase quickly in the shorter term (up to year 50) and then decrease relative to CO_2 as atmospheric methane breaks down and the time horizon increases from 50 to 100 years. A paper by Allen et al. (2016) indicates that GWP, even with a 100-year time horizon, is well-suited to evaluate the impact of climate warming in the next 20 - 40 years but not for longer time scales.

An alternative approach is to use the global temperature change potential (GTP), in which emissions are compared with respect to the resultant temperature change at the end of the time horizon. The main difference is not so much the choice of radiative forcing implemented by GWP or temperature change used by GTP, but it is between the time-integrated (GWP) and the end-point (GTP) perspectives of the two methods. While GWP integrates the radiative forcing along the time path up to the chosen time horizon, and puts equal weights on all times, the GTP focuses on one particular chosen point in time and gives the temperature effect at that time (Tanaka et al., 2010).

As mentioned in a recent paper by Tanaka et al. (2019), an emerging idea is to combine the GWP and GTP metrics to address both short- and long-term climate impacts in parallel. Different combining methods have been proposed within the five metrics (GWP20, GWP100, GTP20, GTP50, and GTP100) available in the IPCC Fifth Assessment Report (AR5; IPCC, 2014). Tanaka et al. (2019) advocate for a multi-metric approach that uses GWP100, GWP20, and GTP20 to capture the short-term climate impact while utilizing GTP100 to assess the long-term climate impact of greenhouse gases. This approach is in line with the consensus from United Nations Environmental Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC) to use GWP100 and GTP100. GWP20 and GTP 20 are supplemented to provide additional insights (Cherubini et al., 2016; Levasseur et al., 2016).

Tanaka et al. (2019) finds the case to shift from coal to gas is consistent with climate stabilization objectives for the next 50-100 years and is stronger than previously found. By using GWP and GTP complementarily, the authors find that natural gas power plants have smaller short- and long-term impacts than coal power plants, a trend that is consistent across different plant locations (US, China, Germany, India). The combined use of GWP and GTP metrics shows that for leakage rates from 2 to 9%, the shift from coal to natural gas power plants has smaller short- and long-term climate impacts. The differences between coal and natural gas power plants are shown in Figure 1 and Figure 2. One important note, the two major sources of emissions from power plants are fuel extraction & transport to the plant, and fuel combustion at the plant; of which emissions from fuel combustion is dominant. Out of the different gases emitted by coal and natural gas power plants, CO_2 is released in the largest quantity and has the greatest short- and long-term climate impacts as shown in the charts below. The benefits of the coal-to-gas shift are unambiguous and not sensitive to other factors such as methane leakage rates.

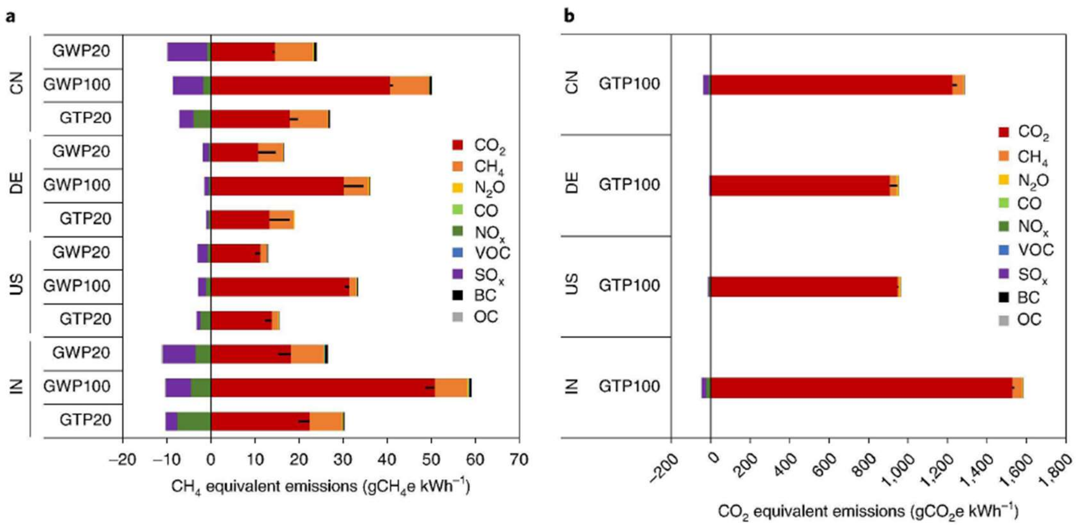

Figure 1. Short-term (left) and long-term (right) climate impacts of a coal power plant. Short term impacts are assessed using GWP20, GWP100, and GTP20 while long-term impacts are measured with GTP100. Figure from Tanaka et al., (2019).

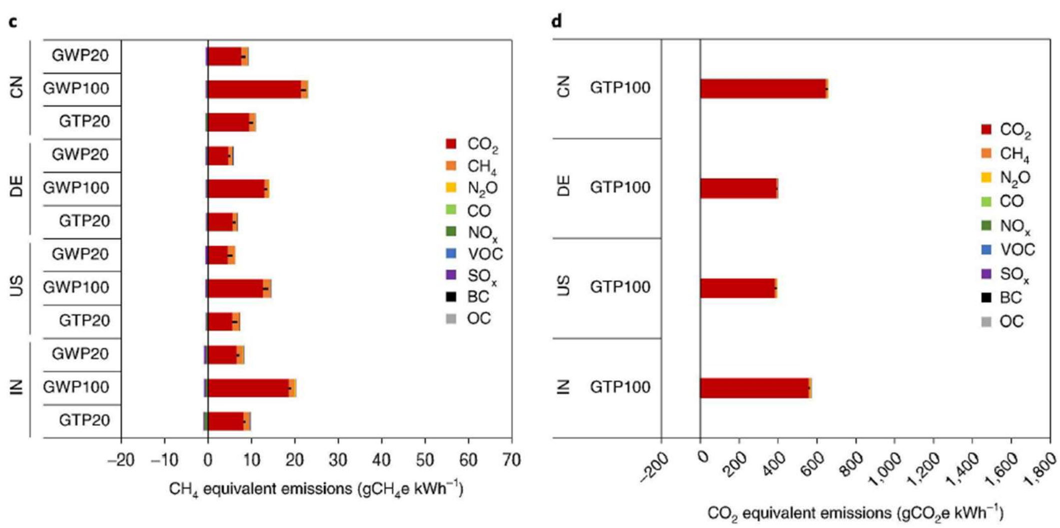

Figure 2. Short-term (left) and long-term (right) climate impacts of a natural gas power plant. Short term impacts are assessed using GWP20, GWP100, and GTP20 while long-term impacts are measured with GTP100. Figure from Tanaka et al., (2019).

If only a single metric such as GWP20 is used, the conclusions by Tanaka et al. (2019) change slightly. Natural gas power plants have lower impacts than coal power plants only when methane leakage rate is below certain location-dependent thresholds. This is because -- in the short-term -- impact from methane is emphasized, penalizing gas plants on systems with high leakage rates. In addition, the importance of CO_2 emissions is significantly reduced due to its long atmospheric lifetime, causing non-CO_2 components such as SOx and NOx to gain more prominence. Therefore, when GWP20-only is used, for natural gas power plants to be favorable, methane leakage rates need to be lower than 3, 9, 5 and 5% in China, Germany, United States, and India, respectively. This is in line with the conditional outcomes from previous studies using GWP20 to study the climate benefits of the coal-to-gas shift.

This shows that the selection of metrics has a major influence on the interpretation of climate assessment outcomes, underlining the importance of a clear understanding and critical reflection on the emission metrics used. A combination of GWP100 and GTP100 addresses both short time scales and century-long time scales which is aligned with the climate stabilization objectives requiring approximately 50-100 years to be achieved. Merely using GWP is not sufficient since it implies short-term climate impacts. The likely implication of using only GWP is that methane emissions from the natural gas industry will be dramatized while carbon dioxide emissions from the other industries will appear less consequential. This is despite the fact that carbon dioxide in the long term is a more problematic greenhouse gas because of its longevity in the atmosphere (for hundreds or thousands of years).

The use of combined metrics to examine climate impacts of natural gas is imperative to be able to have a nuanced understanding and to be able to continue using natural gas for efficient and cost-effective energy production. Specifically, there are climate benefits of the coal-to-gas shift regardless of methane leakage rate up to 9% when long-term metrics are used. When only short-term metrics are considered (GWP20), a natural gas power plant only has less climate impacts than coal power plants when the gas leakage rate is below 5% in the U.S.

There are additional factors, however, to consider such as air quality which further strengthens the case for the coal-to-gas shift. In fact, annual emissions of 1,900 tons of NOx, 3,900 tons of SO2, and 5,200 tons of particulates are prevented from entering the atmosphere for every 10,000 U.S. homes powered with natural gas instead of coal (Spath and Mann, 2000; Spath et al., 1999). These reductions have a direct human health benefit since these pollutants have been linked to asthma, bronchitis, lung cancer, and heart disease (CARB, 2019).

The shift from coal-to-gas has been in motion globally and is gaining momentum. Driven by government mandates to improve air quality, China and India are more aggressively promoting the use of natural gas. In Europe, the low price of natural gas-fired power generation and the high price of carbon are making natural gas more attractive than coal. A recent paper from the National

Bureau of Economic Research (NBER) actually finds that fewer people die each year when home heating is more affordable (Chirakijja et al., 2019). According to the authors, "lower heating prices reduce mortality in winter months…[and] that the drop in natural gas prices in the late 2000s, induced largely by the boom in shale gas production, averted 11,000 winter deaths per year in the US." Home heating can be a matter of life or death in many situations.

Domestically, the Energy Administration Information (EIA) forecasts that U.S. coal-fired power plants will generate 25% of electricity this summer compared to 28% last year (or a 13% decline). This marks the fifth consecutive year of decline for coal as coal-fired power plants continued to be displaced by newer, more efficient natural gas and renewable power generation sources (EIA, 2019).

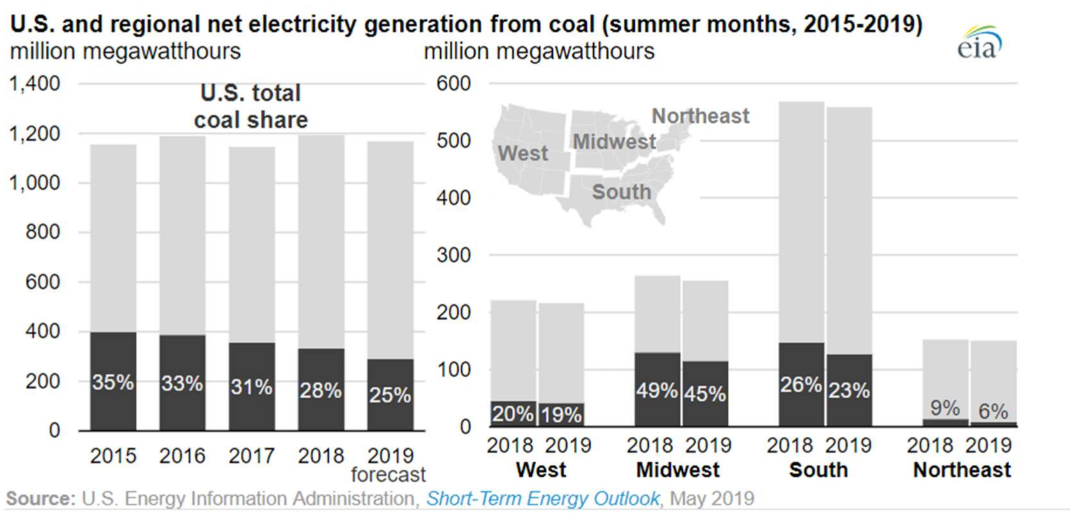

Figure 3. U.S. electricity generation from coal during summer months from 2015-2019

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