TO: The President of the United States, Secretary of State, Special Envoy to COP21 of the UNFCCC.

EXECUTIVE SUMMARY

The UNFCCC 21 Conference of the Parties is underway in Paris. Unfortunately current UNFCCC conventions are based on flawed application of scientific information, which results in misleading estimates of effective levels of greenhouse gas emissions. This communication presents a brief explanation of the flaws and resulting errors by examining data presented primarily by the Fifth Assessment Report (2013) of the International Panel on Climate Change.

The current convention on greenhouse gas inventories requires use of outdated 100-year global warming potentials for greenhouse gases. This convention masks the global warming potential of methane. Use of more appropriate, up-to-date 10-year global warming potentials shows current methane emissions have greater short term global warming impacts than emissions of any other greenhouse gas, including carbon dioxide. Since human-caused emissions of methane are much easier to reduce than those of carbon dioxide, serious efforts to control methane emissions should be undertaken immediately. Current greenhouse gas inventory and reporting rules of the UNFCCC are causing the climate impacts of short-lived greenhouse gases such as methane to be functionally ignored. Ignoring the short term warming impacts of methane does not prevent or mitigate those impacts. If climate change mitigation efforts are to be effective, the short term impacts of potent, short-lived greenhouse gases, especially methane, must be considered. Doing so leads to the following conclusions:

1. Short term climate impacts of anthropogenic methane emissions are five times greater than the current UNFCCC reporting rules suggest.

2. Methane emissions estimates should be based on actual field measurement data. Unlike CO2 emissions that can be reasonably estimated from fossil fuel consumption data and inventori es, methane emissions cannot.

3. Greenhouse gas emissions inventories reported to the UNFCCC are misleading because they fail to accurately reflect the short-term impacts of methane emissions, and other potent, short-lived greenhouse gases.

4. It is inappropriate to consider natural gas as a transition or bridge fuel with re spect to climate change.

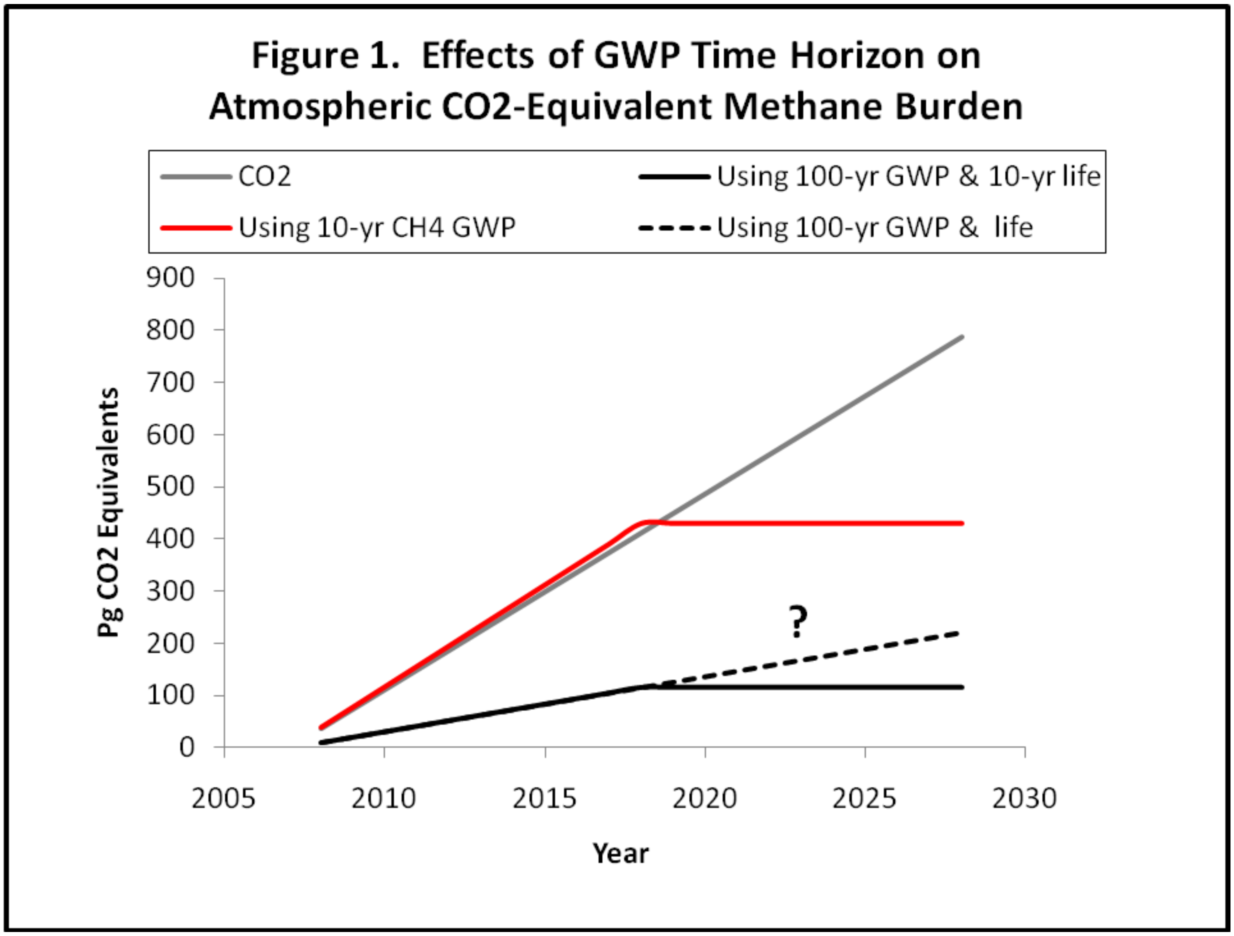
5. Climate change benefits from reduction of methane emissions will accrue rapidly.

6. Conversely, failure to control anthropogenic methane emissions will result in greater short-term climate impacts than the current UNFCCC emissions accounting system anticipates.

7. Similarly, any increases in natural methane emissions will have rapid climate impacts.

8. Atmospheric greenhouse gas concentrations will increase at current, or likely higher rates, until realistic, effective, sustained emissions reduction efforts begin. Specific efforts to control methane

emissions should be part of a broad effort to reduce, preferably end, anthropogenic GHG emissions at the earliest possible date.



SITUATION IN BRIEF

It is essential that all UNFCCC Parties and the global citizenry be as clearly informed as possible with respect to potential climate change and what is being done to mitigate anthropogenic forcing of the climate compared to what is actually necessary if disruptive climate change is to be minimized. If climate change mitigation efforts are to be effective, the short term impacts of potent, short-lived greenhouse gases, especially methane, must be considered. In the near term, methane emissions due to human activity have a stronger global warming impact than the much larger emissions of carbon dioxide. Current greenhouse gas inventory and reporting rules of the UNFCCC are causing the climate impacts of greenhouse gases such as methane to be effectively ignored.

At present the Convention metric for reporting emissions of greenhouse gases other than carbon dioxide is Global Warming Potential (GWP). More specifically the current Convention is to use the 100-

year GWP for all non-CO2 greenhouse gases, regardless of the functional lifetimes of those gases. An improved approach for determining CO2-equivalence for greenhouse gases with life times substantially shorter than the convention time frame is needed. Use of 10-year instead of 100-year GWPs, a relatively simple change discussed in more detail below and presented in Figure 1 above, provides some important lessons regarding the impacts of methane that are overlooked or hidden by the current UNFCCC greenhouse gases inventory and reporting system.

A better understanding of the role of methane and other potent, but short lived greenhouse gases can be achieved by considering two critical points. One of the two critical points is a simple, objective accounting of foreseeable short term future anthropogenic emissions of greenhouse gase s under existing or anticipated commitments of different countries, and whether that accounting accurately presents the climate change mitigating adequacy of such commitments. Such an accounting will be, however, neither objective nor reliable without an adequately clear and reliable means of comparing the effects of different GHGs, which brings forward the second point, how to compare the climate effects of different greenhouse gases. The following more detailed discussion is an attempt to bring the current situation to your attention as well as to the attention of other leaders, scientists, and citizens who are involved in or concerned about the effectiveness of the UNFCCC and national and international efforts to mitigate disruptive climate change.

A MORE DETAILED DISCUSSION – Global Warming Potentials and Their Use with Respect to Climate Impacts of Short-Lived Greenhouse Gases.

According to AR5[1], Global Warming Potential (GWP) has become the default metric by which one greenhouse gas is compared to another. It was codified in the Kyoto Protocol by the UNFCCC as the only conversion factor to be used by nations to convert and report annual GHG emissions. Briefly, as most commonly used, the GWP compares the radiative forcing caused by a one-time emission of a mass unit (e.g., a kilogram) of a selected greenhouse gas to the radiative forcing caused by a similar emission of an equal mass of carbon dioxide (CO2). Since the GWP is based on radiative forcing it is useful to provide a reasonable description of radiative forcing, which in turn requires a prerequisite description of the relationships among energy flows between the earth and surrounding space, and within the earth system, including the greenhouse effect. AR5 presents a diagram (Figure 2-11, accessible at http://www.ipcc.ch/report/graphics/images/Assessment%20Reports/AR5%20-%20WG1/Chapter%2002/Fig2-11.jpg) of the complex energy flows that drive our climate. The following discussion is based on that diagram.

Climate: dynamic equilibrium among energy flows.

What we observe collectively as weather patterns and related longer term conditions is known generally as the earth climate. The earth climate is the result of energy flows and distributions in space and time among the atmosphere, lithosphere, and hydrosphere, as affected by biological activity, including human activity and external energy inputs, which for practical purposes is only solar energy, and losses, radiation from the earth out into space. Figure 2-11 in AR5 provides a simplified depiction of those

[1] The primary reference document for this discussion is *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

energy flows for present day climate conditions. The numerical values in that image indicate energy flow rates and have units of watts per square meter, which are the same as joules per second per square meter, or about 0.24 calories per second per square meter. Each of the components (depicted in the diagram as atmosphere, land surface, clouds, water,…) stores energy, absorbing or releasing it in accord with changing energy distribution in the other components in the earth climate system. The redistribution of energy changes land, air and ocean conditions which we typically observe as changes in temperature, atmospheric pressure, wind, cloudiness, precipitation, ocean currents, and many other conditions, some obvious to direct human observation, some much more subtle.

A look at AR5 Figure 2-11 shows that the incoming solar energy flow at the top of atmosphere (TOA) is 340 W/m^2. In the figure to the right of the incoming solar energy flow are the outgoing reflected solar energy flow of 100 W/m^2 and, further to the right, the outgoing thermal energy flow of 239 W/m^2. That is, the figure indicates that at the top of the atmosphere under present day climate conditions, there is 1 W/m^2 more energy flowing into the earth system than is flowing out. That energy is being retained by the earth system, and will result in an imbalance in the distribution of energy among the many parts of the system. The energy flows in the system will change until a new energy equilibrium[2] among the various parts is established. There are natural variations in solar energy inflow to the earth, and in the speed with which and amount of energy that the various parts of the earth system can absorb, store and release over any selected time interval. Such natural variations result in natural climate variability. When changes in the energy flows result in a sustained energy imbalance that is outside the natural variability, there will be changes in temperature, pressure, wind, etc., which, when considered collectively, will cause the climate to vary outside the range of natural variability, i.e., that will cause climate change.

Along the bottom of the figure are depicted the inputs to and losses from the earth (land, water) surface. The surface loses 84 W/m^2 through evaporation, 20 W/m^2 as sensible heat, and 398 W/m^2 as thermal radiation, for a total of 502 W/m^2. The surface gains 161 W/m^2 of solar energy and 342 W/m^2 of thermal energy returned to the surface a large portion of which is due to the greenhouse effect, i.e., the scattering or absorption and net downward re-radiation of thermal energy by greenhouse gases[3] in the atmosphere. It is important to recognize that the atmosphere regulates by far the largest energy flow to the earth surface, and that this regulating effect is in large part a consequence of greenhouse gases present in the atmosphere. The total input to the land surface is 503 W/m^2. Deducting the total

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[2] It can be argued that the earth climate system is never at energy equilibrium since if the distribution of energy were fully equilibrated, there would be no energy flows to cause and drive the phenomena we recognize collectively as climate. In the context of this discussion of the earth climate system it should be understood that equilibrium does not mean uniform distribution of energy throughout the earth climate system, but a dynamic condition in which energy flows and distributions occur within a consistent recognizable range over time, giving rise to what we observe and experience as the climate resulting from that dynamic equilibrium of energy flows and distributions.

[3] Greenhouse gases have molecular characteristics that cause them to scatter or absorb certain forms of radiant energy, and resulting in net re-emission of that energy in a slightly different radiant form. Consequently, GHGs in the atmosphere prevent thermal energy radiating up from the earth surface from being transmitted directly out into space. Instead, the GHGs scatter or absorb the energy flowing up toward space, then transfer or re-radiate it in all directions. This absorption and re-radiation reduces the direct loss of energy to space (which would cool the climate) by sending some back down toward the earth surface (which results in more energy being retained in the atmosphere and surface and warms the climate).

energy flows away from the surface, 502 W/m^2, from the total energy flows to the surface, 503 W/m^2 , gives a difference of 1 W/m^2 of energy that is being retained by the surface (and lower atmosphere). That is, the 1 W/m^2 energy flow imbalance at the top of the atmosphere is due to the 1 W/m^2 that is not flowing back out from the surface (and lower atmosphere).

Most of the energy absorption or release mechanisms depicted in the figure are not directly or consistently altered by human activities, except greenhouse gases, which are accumulating in the atmosphere to levels that are without precedent for hundreds of millennia. Human activity is changing a key energy redistribution mechanism (the greenhouse effect) in the earth system causing the system to retain energy it previously released, resulting in an energy imbalance among the parts of the system, causing changes in patterns of temperature, pressure, wind, etc., i.e., changing the earth climate.

It is also important to consider that, to date, there is no indication that humans will in the near term stop or even substantially reduce activities that increase GHG concentrations in the atmosphere. Consequently, if substantive climate change begins before anthropogenic GHG emissions have been reduced sufficiently to stabilize GHG concentrations in the atmosphere, the energy imbalance will continue to grow even as the earth system is adjusting to the already unprecedented conditions. Under continuously changing conditions, a new energy equilibrium may not develop, resulting in relatively sudden or severe adjustments in the energy distribution among the parts of the earth system. If that should occur, the course of climate change could follow unanticipated, sudden or severe paths.

<u>Climate: measurement challenges</u>

It should also be noted that the figure indicates the present day energy imbalance on typically measured time scales is small, and challenges the limitations of current measurement capabilities. In the lower left corner of the figure the energy imbalance is provided more accurately as 0.6 W/m^2, less than 0.2% of the energy flows incoming to and outgoing from the top of the earth atmosphere. Also, the numbers in parentheses indicate "the range of values within observational constraints". That is, the actual imbalance could be somewhere between 0.2 and 1.0 W/m^2, a five-fold difference implying that current observational constraints do not allow evaluation of short term energy imbalances with sufficient resolution and reliability to confidently predict when or how severe climate change is likely to be. This effect of current observational constraints can be functionally overcome by looking at the cumulative effects of small, instantaneous energy imbalances over much longer time frames, which brings us, finally, to radiative forcing.

There are numerous definitions of radiative forcing. AR5 section 8.1.1 describes radiative forcing as

> "the net change in the energy balance of the Earth system due to some imposed perturbation. It is usually expressed in watts per square meter averaged over a particular period of time and quantifies the energy imbalance that occurs when the imposed change takes place."

To simplify for this discussion, radiative forcing may be regarded as how much does a change in the amount of a forcing agent, e.g., a greenhouse gas in the atmosphere, change the rate at which the earth system radiates energy away into space. An increase in greenhouse gas concentration will cause stronger re-radiation of energy back down toward the earth surface and thereby reduce the rate at which the earth system radiates energy away into space. Because climate is the consequence of continuous energy flows and redistribution of energy within the earth climate system, any agent that can alter those flows might alter the climate if its effects are strong enough, and if its effects are not countered by other agents that have or cause an opposite radiative forcing. Generally, radiative forcing describes changes in energy flows and, therefore, uses the same units as the flows depicted in AR5 Figure 2-11, i.e., W/m^2, and is discussed with respect to a given time frame because the radiative forcing due to a change in a given agent may be affected by other changes in the earth climate system. For example, clouds, which generally have a cooling effect (negative radiative forcing) may increase in a warmer world due to higher moisture levels in a warmer atmosphere. In a cloudier world, less solar energy reaches the earth surface, so less is re-radiated upward, so the radiative forcing due to greenhouse gases is reduced. Radiative forcings have a cumulative effect, and the overall forcing is the sum of all the forcings of all the agents in the system. Using the common time frame for climate change from 1750 to (near) present, AR5 reports total radiative forcing due to anthropogenic changes in the earth climate system since 1750 to be around 2.3 W/m^2, or almost 4 times the imbalance from short term measurements depicted in Figure 2-11.

Climate metrics: Global Warming Potentials and time dependence

Global warming potential (GWP) is the metric used to account for the impacts of specific GHGs on radiative forcing in the climate system. There are Absolute Global Warming Potentials (AGWPs) and conventional GWPs. The AGWP is the cumulative radiative forcing (W/m^2) over a selected time interval (usually in years) for a 1 kilogram pulse emission of the selected GHG. AGWP units are year W/m^2 per kilogram. AGWPs are calculated using radiative transfer models. The currently conventional GWP is the ratio of the AGWP of, for example, methane, divided by the AGWP of CO2 for a selected time frame, 100 years under the current UNFCCC GHG emissions reporting convention. The relationships among the GWP for methane and the AGWPs for methane and CO2, from which the GWP is calculated, are illustrated in AR5 Figure 8-29 (accessible at http://www.ipcc.ch/report/graphics/images/Assessment%20Reports/AR5%20-%20WG1/Chapter%2008/Fig8-29.jpg).

The GWP is convenient and appealingly simple in appearance, but appropriate application is not straightforward. A prominent difficulty arises from the fact that different greenhouse gases do not force radiative processes in the same ways, and do not have the same functional lifetimes in the atmosphere (see again AR5 Figure 8-29). Both of these in turn complicate the selection of which time frame is appropriate for comparing the effects of different greenhouse gases. A common approach to address this difficulty has been to compare the GWPs of different greenhouse gases over different time frames, most commonly 20, 100, and 500 years (Myhre et al. 2013, Chapter 8 in the AR5). Myhre et al. remarked on related cautionary comments with regard to selecting an appropriate time frame over which to consider GWPs to compare the impacts of different greenhouse gases.

> "Note, however that Houghton et al. *(in the First IPCC Climate Assessment)* presented these time horizons as 'candidates for discussion [that] should not be considered as having any special significance'."

> "The choice of time horizon has a strong effect on the GWP values — and thus also on the calculated contributions of CO2 equivalent emissions by component, sector or nation. There is no scientific argument for selecting 100 years compared with other choices (Fuglestvedt et al., 2003; Shine, 2009). The choice of time horizon is a value judgement because it depends on the relative weight assigned to effects at different times. …"

The 100-year time frame was specifically mentioned by Myhre et al. because in the 1997 Kyoto Protocol the UNFCCC confirmed the 100-year GWPs for greenhouse gases presented in Climate Change 1995 (http://unfccc.int/ghg_data/items/3825.php) were to be used for purposes of calculating and reporting annual inventories of emissions of greenhouse gases. Since that convention was established much related scientific, policy and reporting work has used the UNFCCC 100-year GWP convention (see especially Montzka et al., 2011, doi:10.1038/nature10322). As foreseen by the admonitions of Houghton et al. and others (Myhre et al.), general use of the 100-year GWP GHG inventory convention appears to have resulted in a functional misperception of the implications of greenhouse gas emissions over time frames shorter than 100 years, particularly for gases with shorter atmospheric lifetimes than carbon dioxide. The most prominent among those shorter lived gases is methane.

Myhre et al. used the 10-, 20- and 100-year GWPs of 8 different anthropogenic emissions – CO2, methane, nitrous oxide, other nitrogen oxides (NOx), carbon monoxide, sulfur dioxide, black carbon and organic carbon – to convert emissions levels in 2008 to Petagrams (gigatons, or billions of tons) of carbon dioxide equivalent (per year). They presented the results in their Figure 8.32 accessible at http://www.ipcc.ch/report/graphics/images/Assessment Reports/AR5 - WG1/Chapter 08/Fig8-32.jpg. The GWPs of the minor anthropogenic emissions, NOx, sulfur dioxide and organic carbon, are negative, that is, they have a cooling effect on the atmosphere. Coincidentally, and conveniently for this discussion, the sum of CO2 equivalents of the minor anthropogenic emissions with positive GWPs (nitrous oxide, carbon monoxide, black carbon) and the minor emissions with negative GWPs is reasonably close to zero. That is, for the 8 anthropogenic emissions addressed by Myhre et al., the 3 positive- and 3 negative-GWP minor emissions collectively cancel each other out in the net CO2 equivalent emissions, leaving the net effective GHG emissions as the total of only methane and CO2.

Further consideration of Myhre et al. Figure 8.32 shows that in the 10-year GWP, CO2 emissions in 2008 amounted to about 37.5 gigatons, while methane emissions amounted to about 39 gigatons CO2 equivalent. That is, from 2008-2018, the cumulative warming effect of anthropogenic methane emitted in 2008 would exceed the warming effects of CO2 emitted in 2008. In contrast, using the 100-year GWP, or the warming impacts of the 2008 emissions over the time from 2008-2108, CO2 emissions amount to about 37.5 gigatons but the impact of the 2008 methane emissions declines to about 10.5 gigatons CO2 equivalent. It is fundamentally important to understand why the methane impact appears to decline while the CO2 impact remains the same.

The conventional GWP rates the warming impacts other gases in relation to the warming impact of CO2 over a selected time frame. Consequently, the warming impacts of CO2 are always equal to the warming impacts of CO2, and, so, the GWP of CO2 is always 1 (i.e., 1 kg of CO2 emissions = 1 kg of CO2 equivalent emissions). This is, of course, not true for other greenhouse gases, which can differ from CO2 in how long they remain in the atmosphere and in how they cause warming effects. For the sake of brevity, let us consider only the effects of differences in atmospheric lifetimes.

A gas emitted into the atmosphere today will be removed by natural processes over time. Those natural processes begin working as soon as the gas is emitted into the atmosphere, and continuously reduce the remaining amount of the emitted pulse of gas until it is eventually effectively gone. A pulse emission of CO2 emitted today, or functional portions of it, will remain in the atmosphere for centuries. One hundred years is less than the functional lifetime of a pulse CO2 emission. Consequently, the currently conventional 100-year GWP is reasonable for CO2, as it is for nitrous oxide, which also has a functional atmospheric lifetime of more than 100 years. In contrast, methane has a much shorter atmospheric lifetime, somewhere in the range of 8-12 years. The lifetime of a pulse emission of methane is variable due to the range of mechanisms of removal, and the variability of those mechanisms with atmospheric and other environmental conditions. For convenience in this discussion 10 years is used as a reasonable approximation of the functional atmospheric lifetime of a pulse emission of methane.

So, for nitrous oxide compared to CO2, which both have lifetimes over 100 years, a 100-year time frame GWP is reasonable, and changing to shorter time frames has little effect. For example, the nitrous oxide 100-year GWP is 265 while the 20-year GWP is 264. In contrast, for methane with a 10-year functional atmospheric lifetime, a similar change in time frame has a large effect: the 100-year GWP for methane is 34, while its 10-year GWP is 104, or 3 times greater than the 100-year. Why? Simply put, with a functional lifetime of 10-years, all the warming impacts of methane occur in that first ten years[4] during which time methane is converted to CO2 and continues warming as CO2 thereafter. Use of a shorter time frame GWP indicates more closely the actual impact of a pulse emission of methane while it is actually present in the atmosphere (relative to the impact of a pulse of the same mass of CO2 emitted at the same time). Use of a longer time frame, say, 100 years, will effectively look at the impact of 10 years of actual methane warming effect plus 90 following years of warming due to residual CO2 from decomposition of that pulse of methane, then compares the sum of those two impacts to the impact of a similar first year pulse emission of CO2 over the entire 100 years.

Now, if the primary concern is only an accounting of one year's greenhouse gas emissions over an abstractly long term, then the currently conventional use of the 100-year GWP may be reasonable. Unfortunately, use of a 100-year GWP leads to a false impression regarding the actual, near term impacts of methane, and, consequently, the likely short term warming impacts on the atmosphere. One means of illustrating the nature and potential of the resulting misperception is to use the GWP to look at the effects of a series of annual pulse emissions of methane. That is, consider an annual emission of methane as a pulse, and look at the warming effects over multiple years, as in the Figure 1 (above).

This graph uses emissions data from Myhre et al. Figure 8.32 to project the warming impacts of methane emissions (as CO2 equivalents) over the 20-year period from 2008-2028, assuming annual emissions are constant over those 20 years. The reference (starting) condition in Figure 1 is the year 2008, already well above pre-industrial levels of methane and CO2, but a convenient starting point since data for that year could be borrowed directly from Myhre et al. Figure 8.32. The gray line projects the accumulating CO2 levels for continued annual emissions at the 2008 rate. The black (based on 100-year GWP) and red (based on 10-year GWP) lines project the warming effects (CO2 equivalents) of methane if annual methane emissions continued at the 2008 rate. Minor year-to-year variations in the size of annual emissions have only minor effects in the near term.

The red (10-year GWP) methane line is above the CO2 line for the first ten years. That is, the actual warming impacts of methane emissions exceed those of CO2 emissions for the first ten years. When the 100-year GWP is used to convert methane emissions to CO2 equivalents (black line), this impact is

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[4] Neither the functional life of a pulse of a greenhouse nor the warming impacts actually suddenly ends at the end of a specific number of years after its emission, but that is the approximation utilized for preparation of GWPs. As put by Shindell et al. (2009, Science, 326:716-718). "There are many limitations to the GWP concept (25). It includes only physical properties, and its definition is equivalent to an unrealistic economic scenario of no discounting through the selected time horizon followed by discounting to zero value thereafter. The 100-year time horizon conventionally chosen strongly reduces the influence of species that are short-lived with respect to CO2."

underestimated by almost 4-fold. That is, policy based on use of the 100-year GWP to convert methane to CO2 equivalent emissions inherently amounts to effectively ignoring over 70% of climate warming impacts of anthropogenic methane emissions over the first ten years of such policy. Numerically, using the 100-year GWP convention leads to the conclusion that methane emissions from 2008-present have amounted to 84 gigatons (about 16 ppm) CO2 equivalent, when the actual warming impact (using 10-year GWP) would be 312 gigatons (about 60 ppm). Given in 2008 the concentration of atmospheric CO2 was around 385 ppm, use of the 100-year GWP indicates that the near term warming impact of 2008-2015 methane emissions would have added the warming equivalent of about 4% to that of the initially present CO2, while the actual near term impact based on the 10-year GWP was more like a 16% increase.

The red (10-year GWP) line in Figure 1 becomes horizontal after 10 years because each new annual methane emissions pulse compensates the disappearance of the impact of the pulse that occurred 10 years earlier. Due to the longer life of CO2, the effects of pulses from prior years accumulate and the gray line continues to rise, indicating the accumulating long term warming impacts of CO2 emissions. The strong near term impact of methane emissions and the leveling off of methane impacts due to its short pulse life time has provided a basis for proposals that aggressive efforts to reduce anthropogenic methane emissions can be more easily accomplished, and more productive in the near term than near term efforts to reduce CO2 emissions (Montzka et al., doi:10.1038/nature10322*;* Shindell et al., DOI: 10.1126/science.1210026; and others). However, Montzka et al. and others have typically used a 100-year GWP to present implications of methane emissions reduction efforts. Consequently, those presentations understate the likely near term climate impact, and, consequently, benefit to be obtained from reduction of methane emissions.

It is unclear how the life time of a pulse methane emission should be handled when using a 100-year GWP. If the 100-year GWP is used, then it would seem appropriate to extend the implied life time of a methane pulse to 100 years. Doing so causes the warming impact of residual CO2 from the decomposition of the pulse emission of methane to accumulate, increasing the 100-year (2008-2108) cumulative emissions impact from 429 billion tons using the 10-year GWP to 976 billion tons using the 100-year GWP. This further clarifies the difficulty presented by using only one GWP for all gases, and only one policy directed time frame. Using the 10-year GWP better indicates the actual near term warming impacts of methane. However, the residual CO2 from oxidation of that methane continues to warm the atmosphere long after the pulse of methane has been eliminated. Hence, using the 10-year GWP would underestimate the long term warming impacts.

IMPLICATIONS

An improved approach for determining CO2-equivalence for GHGs with life times substantially shorter than the preferred policy time frame is needed. At present the commonly used metric is the GWP and the simplified depiction of the time course of atmospheric CO2-equivalents based on the GWP in Figure 1 provides some important lessons regarding its use (this list is expanded from the list of 8 condensed conclusions presented at the beginning of this document).

1. If GHG impacts are real and effective in the short term, then the currently wide spread use of the 100-year GWP is effectively masking likely actual warming impacts of methane emissions. Use of a GWP with a time frame that more reasonably reflects the atmospheric life time of a specific GHG provides a better indication of the actual time distribution of the warming effects of that GHG. For methane

emissions, the more appropriate 10-year GWP indicates current methane emissions account for half or more of total near term climate warming impacts.

2. Current UNFCCC reported GHG inventories use the 100-year GWPs from the Second IPCC Climate Assessment Report (1995). The 1995 GWP for methane is 21. That GWP has been revised upward in subsequent IPCC Assessment Reports, most recently in Assessment Report 5 (2013) to a value of 28 or 34, depending on which indirect effects are considered. Effective this year the UNFCCC is updating the GWPs used for reporting GHG inventories from those in the Second Assessment Report (1995) to those in the Fourth (2007), that is, from 21 to 25, beginning this year. This has and will continue to result in substantial underreporting of likely warming effects of methane emissions, as well as those of the short-lived but extremely potent GHG hydrofluorocarbons, emissions of which may increase in the near future.

3. Atmospheric concentrations of both CO2 and methane continue to increase, indicating that globally no effective reductions in net GHG emissions have been achieved despite 20 years of negotiations and efforts. Efforts at emissions reductions to mitigate anthropogenic climate change cannot be effective if those efforts are based on an accounting system that fundamentally misrepresents the climate impacts of the target GHG emissions.

4. GHG inventories reported using 100-year GWPs contribute to inappropriate inferences of relatively benign climate impacts from development of natural gas (primarily methane), as well as its proposed role as a transition or bridge fuel.

5. Due to the 10-year life time of a pulse emission of methane, a reduction in rate of increase of GHG warming effects will begin 10 years after an effective effort to control anthropogenic methane emissions begins. Even if that effort only stabilizes instead of decreasing emissions, a real reduction in the rate of accumulating GHG warming effects will occur within 10 years.

6. Conversely, the 10-year life time of a pulse emission of methane also implies that allowing methane emissions to continue to increase may result in substantially greater near term anthropogenic warming (or related weather/climate events) than presently anticipated.

7. The strong near term warming impacts of methane also imply that changes in natural methane emissions could cause rapid changes in overall GHG warming impacts. Destabilization or stimulation of large, sequestered pools of methane (or methanogenic potential) in permafrost soils, tropical wetlands or methane hydrates on cold sea floors due to climate warming could have rapid climate impacts.

8. Atmospheric GHG concentrations will increase at current, or likely higher rates, until realistic, effective, sustained GHG emissions reduction efforts begin. The relative increase in CO2 concentration is increasing faster than that of methane. Consequently, the relative "value" of a methane emissions control effort can be expected to decrease over time, i.e., the best time for such efforts is now.

9. Due to massively larger emissions and longer atmospheric life time than methane, CO2 is and will remain the dominant GHG with regard to climate warming. Reducing methane emissions provides a more likely achievable opportunity to quickly, albeit temporarily, slow the rate of increase of GHG-related warming, but will not stop the increase. Efforts to control methane emissions should be part of a broad effort to reduce, preferably end, anthropogenic GHG emissions at the earliest possible date.

Sincerely,

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