**Ambitious Methane Emissions Reductions Needed**

The content of this discussion paper is largely from the work of Todd Shuman of Wasteful, Unreasonable Use and the Ventura County Climate Hub Methane Working Group and Ara Marderosian of Sequoia Forestkeepers.

Their analyses explain why it is time for ARB to stop discounting their calculations and use the higher, more accurate global temperature potential for methane. It is time to recognize that methane emissions are a decisive factor driving runaway catastrophic climate change. California’s dairy industry, as by far the largest in the nation, should not have the power it has over national and state SLCP reduction policy.

California must be a model for the world in standing up to industrial animal producers and immediately require that methane emissions be slashed, especially from enteric dairy sources. For EJAC to recommend a policy whereby 60 percent of current levels will still be emitted after 2030 is unconscionable.

For starters, ARB has been refusing to take a hard look at the cumulative impacts dimension of livestock-related enteric emissions in the SLCP Reduction Strategy. The associated Draft EA currently constitutes violation of CEQA and is holding back California’s leadership as an incubator for effective climate policy.

The warming potential must be dealt with now if ARB wants to call itself a leader in emissions reduction policy. Cumulative anthropogenic livestock-related and cattle-related methane emissions likely increased the 2015 average global temperature by 0.0044 and 0.0033 degrees C (respectively), beyond what the 2015 global average temperature would otherwise have been. The year 2011 anthropogenic livestock-related and cattle-related methane emissions can be expected to increase the 2021/2022 average global temperature by 0.0061 and 0.0045 degrees C (respectively) beyond what the 2021/2022 global average temperature would otherwise likely be. [See Appendix B in the attachment]

This is relevant for California since it is by far the largest dairy production state in the country. To improve the quality of life around dairies and reduce greenhouse gas emissions while maintaining a sustainable environmentally and socially responsible dairy industry, this highly significant “global temperature forcing” effect of enteric methane from ruminants must be aggressively regulated. Besides a 60 percent reduction in emissions by 2030, you must specifically recommend

* mandatory livestock herd size reduction; and
* gas-collecting, plastic-bag-expanding backpack technology for all grazing cattle in order to capture emitted enteric methane, so methane can be burnt rather than belched into the atmosphere.

*Dispersed*, pasture-based livestock as a source of enteric fermentation methane emissions should also be considered for incorporation within cap and trade, with auctioned pollution permits or offset credit purchase costs based on one of the following alternative values for ARB calculations of environmental impact:

* a short-term interval methane Global Warming Potential [GWP] value;
* a short-term interval Global Temperature Potential [GTP] value;
* an alternative measure based upon the radiative forcing/efficiency value of methane.1

Concerning the third bulleted point above, we refer you to the summary language from two recent analyses by Laudner et al. (2013) and Pierrehumbert and Eshel (2015).2 The authors of these studies propose scientifically-derived CO2 sequestration/CH4-N2O emission ratiosthrough which the internalization of the social and environmental costs of methane and nitrous oxide emissions might be realized through compensatory CO2 sequestration.

“In the case of Midwest feedlot beef, for example, the CH4 and N2O emissions associated with a sustained production of 1 kg yr−1 of beef would need to be offset by a reduction of 1460 kg in cumulative carbon from fossil fuel burning, in order to keep within an agreed climate objective.” (See page 8 and Table 2 on page 7, Pierrehumbert and Eshel [2015].)

Pierrehumbert (2014) has also proposed mechanisms (involving carbon taxes and tax credits) through which the internalization of the social and environmental costs of methane and nitrous oxide emissions might also be realized.1 CARB has to consider these mechanisms as an alternative and disclose the analysis concerning these mechanisms.

There should be meaningful, mandatory reduction targets established for enteric emissions from all livestock, such that a 60 percent reduction in enteric emissions, statewide, will be *required* by year 2030. Shuman and Marderosian propose a staged *mandatory 20 percent reduction target for year 2020*, 40 percent target for year 2025, and a 60 percent target for year 2030.

In addition, a substantial tax should be imposed on all other sources of uncaptured, unburnt methane emitted into the atmosphere that are not included in cap and trade. A methane tax could be based on the use of short-term interval methane GWP or GTP. Since the best scientific estimate for the *effective* lifetime of methane in the atmosphere is a little over 12 years (12.4 years, IPCC AR5th 2013, Chapter 8, Table 8.7, page 714), **a methane GWP of 100 should be used, as that is the approximate methane GWP associated with the 12.4 year time interval** (see Figure 8.29, page 712, chapter 8, IPCC AR5th). A methane tax could also be based upon analysis produced by Dr. Drew Shindell in *The social cost of atmospheric release*, Drew T. Shindell, Climatic Change (2015) 130:313–326, DOI 10.1007/s10584-015-1343-0, page 319, Table 2, Median total; declining rate. Finally, a methane tax could be based on the CO2 sequestration/CH4-N2O emission ratios that Laudner et al. (2013) or Pierrehumbert and Eshel (2016) have derived.

From a comment to Governor Brown on November 23, 2015, my colleagues Shuman, Marderosian, and Gallagher explained Dr. Shindell’s conclusion: “We believe that a 100 percent methane fee or fine based upon Dr. Shindell’s $4700 methane finding is reasonable and accords with the best available science concerning methane and carbon dioxide. A fee value of $4700/CH4 ton is approximately 43 times greater than the $110 damage value presented in Dr. Shindell’s published paper for one ton of carbon dioxide. This ratio of 43 to 1 is in reasonable proximity to the IPCC 100-yr interval methane Global Warming Potential (34 w/ cc fb) and far below the 20-year interval methane Global Warming Potential (GWP) of 86 (w/ cc fb). (Source: Intergovernmental Panel on Climate Change, Climate Change 2013: The Physical Science Basis, 714, Table 8.7, https://www.ipcc.ch/report/ar5/wg1/ (accessed 13 July 2015)). Dr. Shindell’s methane “damage” value also factors in other adverse impacts associated with methane (primarily, methane as a pathway to the formation of surface ozone-related air pollution).”

The results of these rigorous analyses should be factored/incorporated into a framework so that livestock and dairy product producers would be compelled to internalize (or "absorb") into the cost of their products the social and environmental costs of CH4 and N20 emissions per kg of beef or dairy product based upon honest cumulative carbon equivalency ratio rates.3 Finally, the ARB must address *indirect* methane reduction *alternatives* concerning enteric emissions in the SLCP Reduction Strategy and the associated draft EA.

Your current draft recommendation in alignment with SB 1383 (Lara) is far too low. Regardless of the pressure from the Farm Bureau and dairy industry lobbyists, your response must be that it is unthinkable to still allow 60% of the methane emitted from animal agriculture in California to continue after 2030! ARB should have cut all emissions years ago. Anything less than 80 percent reduction by 2030 shows a lack of understanding of what enteric methane is doing to our world. The biggest recommendation you can make to the 2030 scoping for the salvation of life on this planet is for ARB to show the world how and why to get real and get tough about methane.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Footnote 1**: “Based on background values of 378 ppm for CO2 and 1.75 ppm for CH4 prevailing circa 2005, the radiative efficiency of CO2 is 1.4 × 10−5 W/m2/ppb while that of CH4 is 3.7 × 10−4 W/m2/ppb, or a factor of 26 greater . . . .” (Page 349, Pierrehumbert, see below.)

“A novel approach to multi-gas climate protection protocols, quite different from that used in the Kyoto Protocol, is required to properly deal with SLCP. In the context of a carbon tax, an emitter would pay a tax for each GtC of CO2 emitted but would be given a one-time tax credit for each Gt/year of methane emissions rate reduction, weighted according to the corresponding radiative forcing. If the emitter ever increased the methane emissions rate again, the tax credit would need to be paid back with interest . . . Related approaches to SLCP mitigation are discussed in Lauder et al. (2013).”

*Short-Lived Climate Pollution,* R.T. Pierrehumbert Annu. Rev. Earth Planet. Sci. 2014. 42:341–79, page 374-375

**Footnote 2:** “[A] one-off sequestration of 1 t of carbon would offset an ongoing methane emission in the range 0.90–1.05 kg CH4 per year . . . The conversion factors are more conveniently used in terms of carbon mass, giving 1.1 t C (4.07 t CO2) offsetting 1 kg CH4 per year with Reff = 0.3… Larger values of Reff mean more weight is given to the effect of CO2 on radiative forcing, and so the rate of ‘equivalent’ CH4 emissions must be correspondingly higher, giving 0.95 t C (3.5 t CO2) offsetting 1 kg CH4 per year if Reff is set to 0.35.”

*Offsetting methane emissions — An alternative to emission equivalence metrics,* A.R. Lauder, I.G. Enting, J.O. Carter, N. Clisby, A.L. Cowie, B.K. Henry, M.R. Raupach, International Journal of Greenhouse Gas Control 12 (2013) 419–429, quotes taken from pages 419, 422.

RT Pierrehumbert and G Eshel, *Climate impact of beef: an analysis considering multiple time scales and production methods without use of global warming potentials,* Environ. Res. Lett. 10 (2015) 085002

(Pierrehumbert [2014] also notes, on page 374: “Specifically, using Equation 2 we find that a permanent reduction of SLCP emission rate corresponding to 1 W/m2 is equivalent to a reduction of cumulative carbon emissions by 407 GtC, with regard to long-term radiative forcing . . .]

**Footnote 3:** Beef and dairy product producers should also be compelled to internalize [or “absorb”] additional meat/dairy-production-related *CO2* emission costs. Such costs, as documented by Pierrehumbert and Eshel [2015], are quite dramatic for certain meat production modes [Feedlot Midwest and Pastured Midwest] that are likely similar to meat/dairy production modes in California. Soil-related carbon emission environmental costs due to livestock feed row crop production (which were not documented by Pierrehumbert and Eshel [2015]) should also be “internalized” by beef and dairy product producers.

­­­­­­­­­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Leakage is not an issue in state methane regulation**

This section will explain why EJAC should recommend that ARB not be influenced by claims of potential leakage. The CARB stated its perspective explicitly on page 67 of the SLCP Reduction Strategy, CARB, 04/11/2016:

“If regulations impose costs on the industry that cannot be recouped, a result could be emissions leakage, if some dairies relocate outside of California or herd sizes grow elsewhere. This could include places where milk production efficiencies are lower and associated enteric fermentation emissions are higher and could increase mobile source emissions from heavy duty vehicles associated with transport of dairy products to established processing facilities and distribution centers.”

We believe that Dairy Cares, the Environmental Defense Fund (EDF), and the CARB have politically deployed the concept of “leakage” to ignore and/or block initiatives that would compel an “internalization” of significant enteric-emission-related environmental costs.

To start, we are not aware of any studies that indicate leakage would occur, if animal-based agricultural industries were incorporated into a climate policy regime as we recommend above, and no studies concerning animal agriculture and potential leakage have been cited by CARB either.

Second, leakage is a cry of wolf by such industries. Regulators must not be swayed by the immense political power of concentrated economic interests in California such as is happening.

Third, even if some of our proposed policies above were implemented and enforced and some leakage did then occur, such a result would not necessarily constitute a violation of AB 32. The state courts have applied broadly deferential review standards when CARB's policies have been challenged in the past leaving it to CARB to prioritize among the competing objectives in AB 32.

Most significantly, agriculture-emissions-related leakage, if there is any, must be placed in historical context. A much larger type of leakage, known as resource shuffling, occurred a few years ago, and the massive leakage associated with it had a pronounced impact on carbon market prices. Yet CARB enabled and authorized such large-scale leakage, and no legal violation of AB 32 was ever recognized by either CARB or a court of law. Why should it now be a barrier to moving ahead to deal with enteric methane?

In short, we interpret the discourse promulgated by Dairy Cares, EDF, and CARB as an attempt to shift the economic burden of SLCP regulation away from the dairy industry. There is no legal reason to hold back on capping and taxing enteric methane. Compulsory inclusion of livestock-associated enteric emissions within California’s GHG emission control and reduction system would far outweigh any risk of or actual leakage that might occur.

In other words, EJAC can make sure that the economic concept of leakage, as enshrined in AB 32, is not used to prevent California from exerting global leadership with regard to compulsory agricultural/livestock-related business internalization of ACD pollution costs associated with livestock enteric and manure-related methane emissions. California cannot wait for other states or the nation to enact similar “internalization” policies at the same time. That is not going to happen soon enough; the radiative-forcing rate is aggravating and intensifying climate disruption on our already rapidly-heating planet.

**Our responses to selected quotes from ARB’s SLCP Reduction Strategy, 04/11/2016, with Appendices A, B and C**

ARB Quote A: “The long-term operational impacts associated with the Proposed Strategy would reduce emissions of black carbon, methane, and HFCs, thereby reducing GHG emissions in the State. Thus, the Proposed Strategy would result in a long-term beneficial effect and no significant cumulative effect would occur . . . Thus, short-term construction related GHG emissions impacts associated with reasonably-foreseeable compliance responses to the Proposed Strategy would be less-than-significant, when compared to the overall GHG reduction associated with implementation of the Proposed Strategy. Thus, the Proposed Strategy **would not make a considerable contribution (i.e., would be beneficial) such that a significant cumulative impact would occur** on GHG emissions.” (Appendix C, 5-13/14 Draft EA for the Proposed SLCP Reduction Strategy, CARB, April 11, 2016.)

**Our Response:** The premise underlying the Draft EA text above is fallacious. Significant cumulative effects associated with livestock-associated enteric methane emissions have already been occurring, are continuing to occur, and will likely continue to occur unless meaningful mitigation measures are adopted, enacted, and enforced to reduce SLCP emissions from *all* *significant* anthropogenic SLCP emission sources. Without effective mitigation, adverse global surface and ocean temperature change-related impacts will continue. CARB has proposed no mitigation measures concerning enteric emissions generated in California -- the single largest methane emission source in California. This failure constitutes a violation of CEQA.

ARB Quote B: “California has the most dairy cows in the country and the highest aggregated dairy methane emissions. The State also has higher per-milking cow methane emissions than most of the rest of the United States, due to the widespread use of flush water lagoon systems for collecting and storing manure. Milk production feed efficiency at California dairies, however, is among the best in the world; California dairy cows produce low enteric fermentation emissions per gallon of milk. So if dairy farms in California were to manage manure in a way to further reduce methane emissions, a gallon of California milk might be the least GHG intensive in the world.”

Page 65, SLCP Reduction Strategy, CARB, April 11, 2016

**Our Response:** Utilizing a conservative estimate, we note that each milking cow – ***no matter how efficient a milk producer it is*** -- still emits approximately 240 lbs. of methane into the atmosphere per year. ARB must stop imagining a premise of “low-GHG intensive milk”. The entire dairy industry must be held responsible to drastically reduce enteric emissions by 2020, 2025, and 2030. Low GHG-intensive milk production helps generate significant global temperature change effects that are having, and will continue to have, adverse impact on native biodiversity, human populations, and the very fabric of life on this planet.

ARB Quote C: “ARB and CDFA staff will establish a working group with other relevant agencies and stakeholders to focus specifically on solutions to barriers to dairy manure projects. The group will aim to ensure and accelerate market and institutional progress. It may cover several topics, including: project finance, permit coordination, CEQA, feed-in tariffs, simplified inter-connection procedures and contracts, credits under the LCFS, *increasing the market value of manure products,* and uniform biogas pipeline standards. This group will be coordinated with similar working group efforts related to anaerobic digestion, *composting,* energy, *healthy soils*, and water.” (*Italics* added, Page 68, SLCP Reduction Strategy, CARB, April 11, 2016.)

**Our Response:**  The results of composting depend on the assumptions about sequestration and GWP values used to compute the results. If the compost is plant-based, then definitely we want to invest in composting programs. With cow-based compost, if one uses mean range sequestration values and the much higher methane GWPs associated with shorter-time intervals, there is a rationale. However, if one uses high end range values and much lower methane GWPs associated with long-time intervals, then this is a false promise for carbon sequestration.

A manure composting approach would work best for chicken, turkey, and pig-based manure (as there are no methane emissions due to enteric fermentation. However, with cow manure, it takes a large quantity (78,000 lbs) to produce the amount of composted manure (62,400 lbs) needed for an acre of land to achieve a net soil sequestration of atmospheric carbon in the range of 150-990 lbs/yr/acre (converting from the original 51-333g/m2/of C results for all three years presented in Ryals and Silver, [2013]). Since carbon is 27.291 percent of CO2 by mass, the amount of net atmospheric CO2 that is sequestered on this acre of land is likely in the range of 553-3627 lbs. per year.

Now consider that it takes 3.616 years for a beef cow to produce 78,000 lbs. of manure. Over that time, the beef cow will emit 477.3 pounds of methane (at 60 KG/yr). At GWP 34 (100 year interval), that is 16,228 CO2 equivalents, at GWP 86 (20 year interval), that is 41,047 equivalents.  It takes a lactating dairy cow 2.6712 years to produce that much manure. Over that time, a lactating dairy cow will emit 641.1 pounds of methane (at 109 KG/yr). At GWP 34, that is 21,796 CO2 equivalents, at GWP 86, that is 55,133 CO2 equivalents.

The cost/benefit analysis must take account for the number of years before the soil organic carbon sequestration levels from the compost treatment counterbalance the CO2 equivalency emissions associated with the enteric fermentation methane emissions from the cows. It depends on the GWP value you use!

It is not really known what the soil carbon sequestration levels will be over time, though DeLonge argues elsewhere that it might continue for 20 years. If one uses the GWP of 34 and the maximum number in the soil sequestration range, the counterbalanced point occurs in 4.47-6.00 years (beef cow-lactating cow). If one uses the maximum range number and the GWP of 86, the equalization point occurs in 11.32-15.20 years (beef cow-lactating cow). In other words, when planners are honest about the amount of heat forcing from methane, the compost from beef and dairy cattle does not pencil out as a method for carbon sequestration.

Wherever there are large concentrations of manure, the manure should be composted and applied to the land. However, the people of California should not invest in compost production associated with ruminants that emit copious amounts of methane via enteric fermentation as a method to sequester carbon. Paying carbon credits to cattle and sheep farmers for creating concentrations of ruminant manure risks fosters a widespread ruminant-based manure compost production industry. It is time to question further investments in this as an approach for carbon sequestration unless methane is captured or the numbers otherwise account for the GWP of the associated methane emissions.

(See Ryals, Rebecca and Whendee L. Silver, *Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands*, Ecological Applications, 23(1), 2013, pp. 46–59; Marcia S. DeLonge, Rebecca Ryals, and Whendee L. Silver, *A Lifecycle Model to Evaluate Carbon Sequestration Potential and Greenhouse Gas Dynamics of Managed Grasslands,* Ecosystems(2013) 16: 962–979. Note: the Ryals, Silver, and DeLonge-authored California Soil Carbon Sequestration/ Composted Manure studies form the foundation upon which the ACR composted manure carbon sequestration protocol is based.)

**Appendix A: Calculations for animal agriculture as a major source of GHG emissions**

**1**: FAO Cattle-Related Statistics for 1962 and 2012

Country Item Element Unit Y1962 Y2012

World Cattle Emissions (CH4) (Enteric) Gigagrams 50,491.3724 72,289.6713

Food and Agriculture Organization of the United Nations, Statistics Division (FAOSTAT) <http://faostat3.fao.org/download/G1/GE/E>

*Year 1962*

50,491.3724 Gg of CH4 emitted

5.04913724 \* 104 Gg \* 2.20462262 \* 106lbs./Gg  = 11.13144217 \* 1010 lbs.

1.113144217 \* 1011 lbs., or 111,314,421,700 lbs. of CH4, or 111.314 billion lbs. emitted

*Year 2012*

72,289.67 Gg of CH4 emitted

7.228967 \* 104 Gg \* 2.20462262 \* 106lbs./Gg  = 15.93714417 \* 1010 lbs.

1.593714417 \* 1011 lbs., or 159,371,441,700 lbs. of CH4, or 159.371 billion lbs. emitted

**2**: For the 1962–2012 period: +0.90/+0.67 degree Celsius rise for land/land-ocean combined

1958-1965 (1962) 1988-1995 (1992) 2008-2015 (2012) relative to 1880-1920 (1900)

0.36/0.27 0.80/0.62 1.26/0.94 relative to 1900 land/land-ocean value of 0 degrees C

1962-1992 increase: +0.44/+0.35; 1992-2012 increase: +0.46/+0.32;

1962-2012 increase +0.90/+0.67

Source: <http://data.giss.nasa.gov/gistemp/maps/>. [Note: Todd Shuman consulted with Dr. Ron Miller, Deputy Chief of Lab, NASA Goddard Institute of Space Studies concerning proper parameters for input. Dr. Miller recommended “smoothing” anomalies over 7-year time frames; use Anomalies, not Trend; define Mean Period as Annual (Jan-Dec); defined base period 1880-1920 was considered reasonable. Use 1200 KM Smoothing Radius, and Robinson Map Projection. For Land: use GISS analysis; For Ocean: use ERSST v.4.]

**3**: “[NASA recently released data](http://data.giss.nasa.gov/gistemp/graphs_v3/) showing that the planet has just seen seven straight months of not just record-breaking, but record-shattering heat. It is clear, through the space agency's data, that this year we are already well on track to see what will likely be the largest increase in global temperature a single year has ever seen.

The NASA data also show that April was the hottest April ever recorded, as well as the fact that it crushed the previous April record by the largest margin of increase ever recorded. That makes it [three months in a row](http://www.theguardian.com/environment/2016/apr/15/march-temperature-smashes-100-year-global-record) that the monthly record has been broken, and easily at that, by the largest margin ever.” Dahr Jamail, May 23, 2016,

<http://www.truth-out.org/news/item/36133-atmospheric-carbon-dioxide-concentration-has-passed-the-point-of-no-return>

**Appendix B: Calculations of various anthropogenic methane emissions sources**

The relationship between CH4 mass emission and global temperature change values in Figures 2a and 2d of Allen et al. (2016) appears to be largely linear and directly proportional (i.e. 110 Mt of CH4 generates X degrees of change, 330 Mt of CH4 generates 3X degrees of change, 1320 Mt generates 12X degrees of change, 1360 MT generates 12.36X degrees of change.) [Email communication with Dr. Myles Allen, May 15, 2016)

Todd Shuman extracted global mass emission estimates for the different anthropogenic methane emission sources and linked these values with the global temperature change (GTC) values in Figure 2d. For the mass values for the different sources, the “bottom up” methane source mass values in IPCC AR5, Chapter 6, page 507 are used. For enteric emissions for total livestock and for cattle, the Food and Agriculture Organization numbers (FAOSTAT) for year 2011 are used. Here are the numbers for the year 2011:

 Enteric - 98 Mt (with the cattle subcomponent at 72 Mt)

Fossil Fuel – 96 Mt

Landfill/Waste – 75 Mt

Rice – 36 Mt

Biomass Burning – 35 Mt

From Allen et al. (2016), the total cumulative anthropogenic 2011 CH4 mass emission estimate (330 Mt, email communication with Myles Allen, May 11, 2016) is associated with a GTC value (in degrees C) of 0.015 for year 2015, 0.02066 for year 2021-2022, 0.016 for year 2031-2032,  0.005066 for year 2050, and 0.0005 for year 2100.

Todd Shuman performed some simple cross-multiplication arithmetic calculations to derive CH4-related sectoral GTC estimates below. Using the fossil fuel number as an example, here is the arithmetic method used:

For year 2015: 330/0.015=96/x=0.00436 degrees GTC; for year 2021/2022, 330/0.02066=96/x=0.006 degrees GTC; for year 2050, 330/0.005066=96/x=0.0015.

(The GTC for the total CH4 value in Year 2031/2032 is just slightly larger than for year 2015 GTC value, so Todd Shuman just added a plus sign (+) to the 2015 sectoral GTC values below to serve as the 2031/2032 sectoral GTC values.)

 Below are the sectoral GTC values (in degrees Celsius) proportionally associated with the 330 Mt methane emission pulse in 2011 for years 2015, 2021/2022, 2031/2032, and 2050.

 Livestock enteric: 0.0044, 0.0061, 0.0044+, and 0.0015

     (Cattle enteric: 0.0033, 0.0045, 0.0033+, and 0.0011)

Fossil fuel: 0.0044, 0.006, 0.0044+, and 0.0015

Landfill waste: 0.0034, 0.0047, 0.0034+, and 0.0012

Rice: 0.0016, 0.0023, 0.0016+, and 0.00056

Biomass Burning: 0.0016, 0.0022, 0.0016+, and 0.00054

(For reference, the corresponding GTC values for the CO2 emission pulse for those years [based upon a mass of 38,000 Mt] are approximately 0.015, 0.024, 0.026, 0.024, and 0.021.)

Myles R. Allen, Jan S. Fuglestvedt, Keith P. Shine, Andy Reisinger, Raymond T. Pierrehumbertand Piers M. Forster*, New use of global warming potentials to compare cumulative and short-lived climate pollutants,* Nature Climate Change, PUBLISHED ONLINE: 2 MAY 2016 | DOI: 10.1038/ NCLIMATE2998

**Appendix C: Calculations of Methane Fees and Effects on Wholesale Milk Prices**

One milking cow produces 240 lbs. of methane per year [1]. 8.3333 milking cows produce 2000 lbs. of methane per year (1 ton). One milking cow produces 2500 gallons of milk/year [2].

8.3333 cows produce 20,832.5 gallons of milk per year.

The wholesale price of milk paid to the dairy producer is currently16.93 dollars per hundredweight (cwt) [3]. 11.63 gallons are in a cwt [4]. $16.93 per cwt/11.63 gallons per cwt equals $1.45/gallon of milk. The dairy producer therefore currently receives just over 30,000 dollars (20,832.5 gallons X $1.45 per gallon = $30,207.12) from the wholesale milk buyer for the milk production produced by those 8.333 milking cows.

If the dairy producer has to pay an additional $4700/ton CH4 produced by those 8.3333 milking

cows, the overall amount he must receive in the future from the milk buyer must now increase to nearly 35,000 dollars (30,207.12 + 4700 = 34,907.12) in order to cover his costs and maintain the same level of profit.

To maintain the same pre-fee “wholesale milk price per pound to total dollar amount received from the milk buyer” ratio, the wholesale price/lb. of milk received by the dairyman must rise from $1.45/lb. to 1.68/lb. Such a price rise would constitute a 15.86 percent (approx. 16%) increase, relative to the pre-fee wholesale milk price. (1.45/30207.12 = x/34907.12 = 1.6756;

0.23/1.45 = 0.1586.)

It is therefore reasonable to assume that a 16 percent rise in the wholesale price of milk may occur if the methane fee is instituted and rigorously enforced. This may lead to commensurate increases in the wholesale and retail prices of related milk and cheese commodities.

Sources:

1: Each milking cow emits CH4: 109 kg/cow/yr., or 239.8 pounds per year. See K. A. Johnson and D. E. Johnson, “Methane Emissions from Cattle,” Journal of Animal Science 73(8) (1995): 2483–92.

2: “The average cow in the U.S. produces about 21,000 lbs. of milk per year, that’s nearly 2,500 gallons a year! On a daily basis, most cows average about 70 lbs. of milk per day, or about 8 gallons per day. 8 gallons is about 128 glasses of milk per day.”

http://www.dairymoos.com/how-much-milk-do-cows-give/

3: DAIRY MARKET NEWS, VOLUME 82, REPORT 45, WEEK OF NOVEMBER 9 - 13,

2015, p 15 of 27, http://www.ams.usda.gov/market-news/dairy/mnweekly-2015

4: http://www.experts123.com/q/how-many-gallons-are-in-a-hundredweight-of-milk.html