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S. B. No. 9: An Act Concerning Connecticut Energy Future Testimony

We are living in a volatile time of human social upheaval, conflict, and environmental change. Major international and national fossil fuel polluters are continuing their practices, because of undue influence in government, manipulation of law, public disenfranchisement, strong arming, and deception. Here is an example. A recent gas methane leak study completed in Hartford under the sponsorship of Martha Klein of the Connecticut Sierra Club found over 716 leaks emitting 313 metric tons of gas = 214 US households of consumption/year= over $330,000.00 of lost gas value/annum (Appendix 1). A fraction of these leaks were self reported to PURA. Can you imagine what this might be state wide?

Changes in environmental chemistry, temperature, and numerous other conditions are accelerating at an alarming pace. We cannot dicker and fiddle while Rome goes up in smoke. Thousands of scientists are sounding the alarm (Appendix 2). The earth is rapidly reverting to a former warmer more acidic state and ecosystems and species diversity are in collapse. The worlds most important Oxygen producer, the oceans are acidifying and large areas cannot produce Oxygen. If oxygen levels drop, we are in real trouble. Currently the earth is experiencing a massive 6 mass extinction and there is no where to go!

In writing this law, please bear in mind these issues. When referencing national institutions such as the EPA add "or current environmental agency/institution." In referencing CES also add "or current documents of concern." Allow language in the document to change with the times. Include deferment of knowledge in the law to scientists and academic institutions found here in New England. This is as insurance policy with provision for robustness against unexpected and unplanned for change. I applaud this effort, but make sure this law has teeth, because these most likely will be needed.

Sincerely yours,
Gale E. Ridge

Appendix 1

Hartford, CT Mobile Methane Leak Survey

Report for the Connecticut Chapter, Sierra Club July 18, 2016

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Summary:

We conducted a mobile methane leak survey on all public streets in Hartford, CT, from February 25 through March 31, 2016. We detected a total of 716 distinct methane leaks over 225 road miles in Hartford, resulting in a leak frequency of 3.2 leaks per road mile. This leak frequency compares to 4.3 leaks per mile we previously found in Boston, MA. We preliminarily estimate methane leaks in Hartford to amount to 0.86 metric tons of methane leaked per day (or 313 metric tons per year), equivalent to 42,840 cubic feet per day of natural gas. This leakage rate represents an equivalent daily gas consumption of about 214 US households. The data from this report, if it can be supplemented with an inventory map of leak prone pipe and information on pipeline operating pressures, will provide a spatial database that facilitates strategic repair and replacement of leak prone pipe in Hartford. Accompanying this report is a worksheet of the leak locations and concentrations of methane detected in the air (in parts per million), and a google map file (.kml) of leak locations.

Introduction

This study was conducted at the request of the Connecticut Chapter of the Sierra Club to quantify the number of natural gas leaks in Hartford, Connecticut. Methane, the largest constituent of natural gas, is a powerful greenhouse gas (IPCC 2013), and when leaked from natural gas pipelines damages air quality, kills trees, and can become an explosion hazard. The amount of natural gas leaked in cities and its climate and economic impacts can be substantial. Our recent study in Boston (McKain et al. 2015) estimated a gas loss rate from greater Boston at 2.7% of the total consumed natural gas, which resulted in an annual loss of about $90 Million borne by ratepayers, and about 10% of Massachusetts' greenhouse gas emissions inventory. Estimates of tree damage from gas leaks in mid-sized municipalities in Massachusetts range from hundreds of thousands to millions of dollars.

Urban natural gas pipelines are mostly made up of 'distribution' pipelines operating at low pressures (below 100 psi) compared to the high pressure interstate transmission pipelines that bring natural gas into cities and the "upstream" pipelines in production areas. In older cities, especially in the eastern US, leak-prone cast iron, wrought iron, or bare steel gas pipelines can be up to a century old or older. These pipes can leak at decaying joint connections (typically spaced at 12-foot intervals), or due to corrosion or mechanical disturbance created by freezing conditions. While we did not have the inventory of leak-prone pipe for Hartford, we know that among states, Connecticut has some of the highest total miles and percentage of leak prone pipe (PHMSA, 2016).

There are three investor-owned natural gas utilities in Connecticut serving urban and suburban communities (and a fourth municipal utility in Norwich). Gas service in Hartford is supplied by Connecticut Natural Gas (CNG; cngcorp.com), the smallest of the three in terms of miles of pipeline mains (with 329 miles of leak-prone cast iron and wrought iron mains in 2015). Hartford is the largest city within CNG's service area. For this study we did not have a pipeline inventory for Hartford specifically. There were 225.45 road miles in Hartford as of December 31, 2014 (Connecticut Dept of Transportation).

Strictly speaking, this study detected methane (CH_4) leaks as a broader category than natural gas leaks. Methane may come from sources other than natural gas pipelines, including broken sewer mains, landfills, and wetlands. Our prior work in Boston showed that the vast majority of leaks detected from under streets and sidewalks bore a distinct chemical signature of natural gas methane. Moreover, the spatial signature of wetland and landfill leaks is distinctly different from that of pipeline leaks. Pipeline leaks are recognizable as abrupt and highly localized spikes in methane concentration, whereas wetland and landfill methane emissions are more sloping, gradual deviations from a baseline methane concentration. To perform a simple check of the source of leaks detected in our mobile survey, we re-checked five leaks from the mobile survey to verify that they were associated with natural gas pipelines.

Materials and Methods

We used a mobile Picarro G2301 Cavity Ring-Down Spectrometer (Picarro, Inc., Santa Clara, CA) installed in a van, equipped with a geographic positioning system (GPS), and drove all 225.45 miles of public roads in Hartford, in both directions for all two-way streets. A filtered inlet tube was placed outside the passenger side window at a height of 30 cm above pavement. We periodically tested the analyzer with 0 and 5 ppm CH_4 test gas (Spec Air Specialty Gases, Auburn, ME; reported precision ±10%) periodically throughout the sampling campaign.

To determine discrete leaks from the spatially continuous, raw methane concentration

data, we used Thompson's modified Tau approach (Olewuezi et al., 2015) to perform outlier detection on the raw spatial methane concentration data. This method is a statistical method for deciding whether to keep or discard suspected outliers in a population sample. A threshold methane level that meets the outlier category, indicating a leak, is calculated by the data set's standard deviation and average. The modified Thompson tau technique was used on our data set to determine the threshold because it is applicable to any statistical distribution, and average and standard deviations of the data set are easily calculated.

To avoid double-counting leaks that were driven by multiple times, we used a procedure to eliminate multiple outliers within a spatial window of 30 meters radius from the highest peak methane concentration in the vicinity. We tested the spatial window from as small as 5 m up to 30 m and found relative insensitivity of the total leak count to this range of window sizes, while the apparent leak count decreased substantially at window sizes above 30 m. Since lane widths are generally about 10 m or less, the 30 m window is large enough to prevent double-counting but small enough to avoid incorrectly combining separate actual leaks into one.

We performed a quality control check by auditing 5 randomly selected leaks from the driving survey and verifying and pinpointing subsurface methane concentrations using a ‘bang bar’ to penetrate the surface and a combustible gas indicator (Gas Sentry, Bascom-Turner, Inc. Norwood, MA).

Results and Discussion

We detected a total of 716 distinct methane leaks over 225.45 road miles in Hartford, resulting in a leak frequency of 3.2 leaks per road mile. This leak frequency compares to 4.3 leaks per mile we previously found in Boston, MA. A preliminary estimate of the leakage rate from these leaks can be made using the leak size distribution data from our recent study in Boston (Hendrick et al. 2016). Assuming leak sizes in the leak prone pipe in Hartford are distributed as they are in Boston (with a log-normal average of 1.2 kg CH4 per day), a preliminary estimate of methane leakage rate in Hartford is 0.86 metric tons of methane leaked per day (or 313 metric tons per year), equivalent to 42,840 cubic feet per day of natural gas. The 0.86 metric tons methane per day in Hartford compares to our estimate of 4.0 metric tons per day methane leakage in Boston (which has about three times the road miles). The Hartford leakage rate represents an equivalent daily gas consumption of about 214 US households. This is a minor fraction of the total households in Hartford, (almost 45,000 according to the 2000 US Census), but the co-benefits of fixing gas leaks to air quality, tree health, and safety to people and property add impetus for Hartford to address this problem.

Five randomly selected leaks observed from the mobile survey were re-visited and pinpointed with subsurface probes. We found all five of these leaks. Leak reports for

these five leaks are available on request.

From data in provided to the US Energy Information Administration (EIA 2016), in 2015 Connecticut ranked 7th among states in the total number of miles of leak-prone, cast iron and wrought iron gas distribution pipeline, and 3rd among states in miles of cast iron and wrought iron pipe as a percentage (16.9%) of total miles of distribution pipeline. By comparison, Massachusetts ranked 3rd and 4th in these categories, respectively.

From 2005-15, according the the US Energy Information Administration (EIA 2016) CNG reduced its inventory of leak-prone, cast iron and wrought iron pipe by 24%, about the same as the reduction attained by Yankee Gas Services Co, and at twice the rate over the same period by the largest gas utility in the state, Southern Connecticut Gas Co. (12% reduction from 2005-15).

The data here indicates that Hartford is substantially less leaky than Boston, and may be in better shape than cities served by Southern Connecticut Gas Co, which may be attributed to better efforts by CNG to repair and replace leak prone pipe in Hartford compared to National Grid, the gas utility serving most of Boston, or Southern Connecticug Gas, which has reduced its leak prone pipe miles by half the rate of CNG over the last decade.

Future improvements on this study would include obtaining the complete pipeline inventory and map, and a map of the operating pressures of the pipes in Hartford, from CNG. These data would help explain why certain roadways in Hartford had a higher spatial density of leaks than others, and would allow for an estimate of the likely rankings of leak rates from particular lengths of pipeline. Among the low pressure distribution pipelines, operating pressures can vary substantially, from 0.5 psi to 60 psi or more. All things being equal, a leak in a pipe will leak at a rate that is proportional to the pipeline operating pressure, so leaks we found in zones of higher operating pressure will be expected to leak at higher rates. Although peak methane concentrations observed from the mobile survey offer a rough indication of leak size, it is itself not a reliable indicator of leak sizes because of the vagaries of wind speed and direction that make the peak concentrations vary from second to second, and from one drive-by to another.

Data files accompanying this report are available below:

Excel file with all 716 leak locations and peak methane concentrations, and Google Earth (.kml) file of all leak locations: https://www.dropbox.com/sh/hjlin942vut8cq7/ AACXbSsCjWLv_1RBX68JAeXEa?dl=0

Raw data of methane concentrations and Google Earth files of the raw methane concentration data: https://www.dropbox.com/home/Hartford%20CT%202016

Any computer running Google Earth can open the .kml leak file or .kml methane

concentration files to explore the spatial data set. Acknowledgements

This report and study was prepared for the Connecticut chapter of the Sierra Club. Funding was provided by the Connecticut Chapter to Gas Safety, Inc. to perform the mobile survey and collect raw data. Mr. Yufeng Yang and Nathan Phillips analyzed the data and wrote up the results on a pro bono basis.

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Pipeline Hazardous Materials and Safety Administration. Bare Steel Pipeline Inventory (2016) http://opsweb.phmsa.dot.gov/primis_pdm/gd_bare_steel.asp

Appendix 2

World Scientists' Warning to Humanity: A Second Notice

WILLIAM J. RIPPLE, CHRISTOPHER WOLF, THOMAS M. NEWSOME, MAURO GALETTI, MOHAMMED ALAMGIR, EILEEN CRIST, MAHMOUD I. MAHMOUD, WILLIAM F. LAURANCE, and 15,364 scientist signatories from 184 countries

Twenty-five years ago, the Union of Concerned Scientists and more than 1700 independent scientists, including the majority of living Nobel laureates in the sciences, penned the 1992 "World Scientists' Warning to Humanity" (see supplemental file S1). These concerned professionals called on humankind to curtail environmen- tal destruction and cautioned that "a great change in our stewardship of the Earth and the life on it is required, if vast human misery is to be avoided." In their manifesto, they showed that humans were on a collision course with the natural world. They expressed concern about current, impending, or potential damage on planet Earth involving ozone depletion, freshwa- ter availability, marine life depletion, ocean dead zones, forest loss, biodiver- sity destruction, climate change, and continued human population growth. They proclaimed that fundamental changes were urgently needed to avoid the consequences our present course would bring.

The authors of the 1992 declara- tion feared that humanity was pushing Earth's ecosystems beyond their capac- ities to support the web of life. They described how we are fast approach- ing many of the limits of what the biosphere can tolerate without substantial and irreversible harm. The scientists pleaded that we stabi- lize the human population, describing how our large numbers—swelled by another 2 billion people since 1992, a 35 percent increase—exert stresses on Earth that can overwhelm other efforts to realize a sustainable future (Crist et al. 2017). They implored that we cut greenhouse gas (GHG) emis- sions and phase out fossil fuels, reduce

deforestation, and reverse the trend of collapsing biodiversity.

On the twenty-fifth anniversary of their call, we look back at their warn- ing and evaluate the human response by exploring available time-series data. Since 1992, with the exception of stabilizing the stratospheric ozone layer, humanity has failed to make sufficient progress in generally solv- ing these foreseen environmental chal- lenges, and alarmingly, most of them are getting far worse (figure 1, file S1). Especially troubling is the current trajectory of potentially catastrophic climate change due to rising GHGs from burning fossil fuels (Hansen et al. 2013), deforestation (Keenan et al. 2015), and agricultural production— particularly from farming ruminants for meat consumption (Ripple et al. 2014). Moreover, we have unleashed a mass extinction event, the sixth in roughly 540 million years, wherein many current life forms could be annihilated or at least committed to extinction by the end of this century.

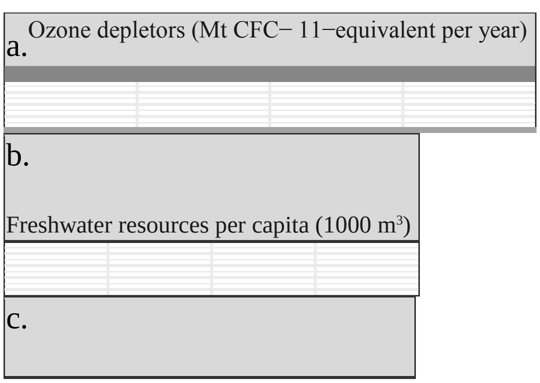
Humanity is now being given a second notice, as illustrated by these alarming trends (figure 1). We are jeopardizing our future by not reining in our intense but geographically and demographically uneven material consumption and by not perceiving continued rapid population growth as a primary driver behind many ecological and even societal threats (Crist et al. 2017). By failing to adequately limit population growth, reassess the role of an economy rooted in growth, reduce greenhouse gases, incentivize renewable energy, protect habitat, restore ecosystems, curb pollution, halt defaunation, and constrain invasive alien species, humanity is not taking

the urgent steps needed to safeguard our imperilled biosphere.

As most political leaders respond to pressure, scientists, media influencers, and lay citizens must insist that their governments take immediate action as a moral imperative to current and future generations of human and other life. With a groundswell of organized grassroots efforts, dogged opposition can be overcome and political leaders compelled to do the right thing. It is also time to re-examine and change our individual behaviors, including limiting our own reproduction (ideally to replacement level at most) and drastically diminishing our *per capita* consumption of fossil fuels, meat, and other resources.

The rapid global decline in ozone- depleting substances shows that we can make positive change when we act decisively. We have also made advancements in reducing extreme poverty and hunger (*www.worldbank. org*). Other notable progress (which does not yet show up in the global data sets in figure 1) include the rapid decline in fertility rates in many regions attributable to investments in girls' and women's education (*www. un.org/esa/population*), the promising decline in the rate of deforestation in some regions, and the rapid growth in the renewable-energy sector. We have learned much since 1992, but the advancement of urgently needed changes in environmental policy, human behavior, and global inequities is still far from sufficient.

Sustainability transitions come about in diverse ways, and all require civil-society pressure and evidence- based advocacy, political leadership, and a solid understanding of policy



Reconstructed marine catch (Mt per year)

1.5 1.2 0.9 0.6 0.3

600 400 200

30 20 10

12 10 8 6

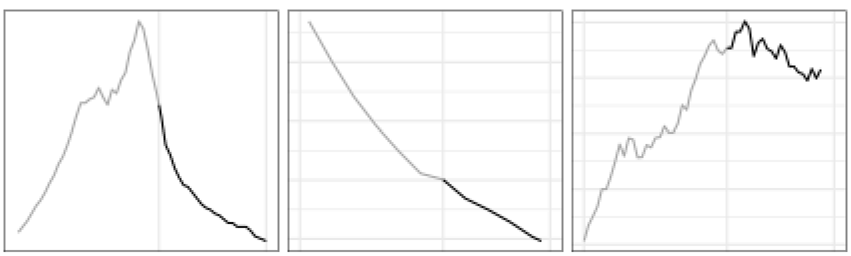
4.10 4.05 4.00

1.00 0.75 0.50 0.25 0.00

130
110
90
70
50

100 80 60 40

7 6 5 4 3



d.

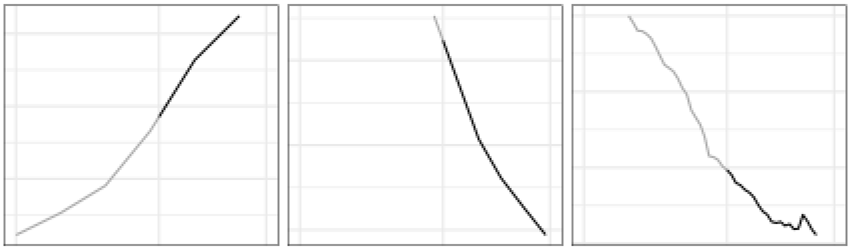
Dead zones (number of affected regions)

e.

Total forest (billion ha)

f.

Vertebrate species abundance (% of 1970)



g.

CO_2 emissions (Gt CO_2 per year)

h.

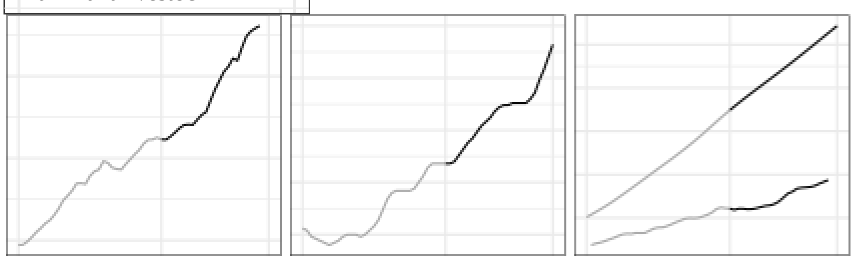
Temperature change (°C)

i.

Population (billion individuals)

Humans

Ruminant livestock



1960

1992 2016

1960

1992 2016

Year

1960 1992 2016

Figure 1. Trends over time for environmental issues identified in the 1992 scientists' warning to humanity. The years before and after the 1992 scientists' warning are shown as gray and black lines, respectively. Panel (a) shows emissions of halogen source gases, which deplete stratospheric ozone, assuming a constant natural emission rate of 0.11 Mt CFC- 11-equivalent per year. In panel (c), marine catch has been going down since the mid-1990s, but at the same time, fishing effort has been going up (supplemental file S1). The vertebrate abundance index in panel (f) has been adjusted for taxonomic and geographic bias but incorporates relatively little data from developing

countries, where there are the fewest studies; between 1970 and 2012, vertebrates declined by 58 percent, with freshwater, marine, and terrestrial populations declining by 81, 36, and 35 percent, respectively (file S1). Five-year means are shown in panel (h). In panel (i), ruminant livestock consist of domestic cattle, sheep, goats, and buffaloes. Note that* y*-axes do not start at zero, and it is important to inspect the data range when interpreting each graph. Percentage change, since 1992, for the variables in each panel are as follows: (a) –68.1%; (b) –26.1%; (c) –6.4%; (d) +75.3%; (e) –2.8%; (f) –28.9%; (g) +62.1%; (h) +167.6%; and (i) humans: +35.5%, ruminant livestock: +20.5%. Additional descriptions of the variables and trends, as well as sources for figure 1, are included in file S1.

instruments, markets, and other driv- ers. Examples of diverse and effective steps humanity can take to transition to sustainability include the follow- ing (not in order of importance or urgency): (a) prioritizing the enact- ment of connected well-funded and well-managed reserves for a significant proportion of the world's terrestrial, marine, freshwater, and aerial habi- tats; (b) maintaining nature's ecosys- tem services by halting the conversion of forests, grasslands, and other native habitats; (c) restoring native plant communities at large scales, particu- larly forest landscapes; (d) rewilding regions with native species, especially apex predators, to restore ecological processes and dynamics; (e) devel- oping and adopting adequate policy instruments to remedy defaunation, the poaching crisis, and the exploi- tation and trade of threatened spe- cies; (f) reducing food waste through education and better infrastructure; (g) promoting dietary shifts towards mostly plant-based foods; (h) further reducing fertility rates by ensuring that women and men have access to education and voluntary family-plan- ning services, especially where such resources are still lacking; (i) increas- ing outdoor nature education for children, as well as the overall engage- ment of society in the appreciation of nature; (j) divesting of monetary investments and purchases to encour- age positive environmental change; (k) devising and promoting new green technologies and massively adopting renewable energy sources while phas- ing out subsidies to energy production through fossil fuels; (l) revising our economy to reduce wealth inequality and ensure that prices, taxation, and incentive systems take into account the real costs which consumption pat- terns impose on our environment; and (m) estimating a scientifically defen- sible, sustainable human population size for the long term while rallying nations and leaders to support that vital goal.

To prevent widespread misery and catastrophic biodiversity

loss, humanity must practice a more environmentally sustainable alternative to business as usual. This prescription was well articulated by the world's leading scientists 25 years ago, but in most respects, we have not heeded their warning. Soon it will be too late to shift course away from our failing trajectory, and time is running out. We must recognize, in our day- to-day lives and in our governing institutions, that Earth with all its life is our only home.

Epilogue

We have been overwhelmed with the support for our article and thank the more than 15,000 signatories from all ends of the Earth (see supplemental file S2 for list of signatories). As far as we know, this is the most scientists to ever co-sign and formally support a published journal article. In this paper, we have captured the environmental trends over the last 25 years, showed realistic concern, and suggested a few examples of possible remedies. Now, as an Alliance of World Scientists (scientists.forestry.oregonstate.edu) and with the public at large, it is important to continue this work to document chal- lenges, as well as improved situations, and to develop clear, trackable, and practical solutions while communicat- ing trends and needs to world leaders. Working together while respecting the diversity of people and opinions and the need for social justice around the world, we can make great progress for the sake of humanity and the planet on which we depend.

Spanish, Portuguese, and French versions of this article can be found in file S1.

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Viewpoint

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Supplemental material

Supplementary data are available at BIOSCI online including supplemental file 1 and supplemental file 2 (full list of all 15,364 signatories).

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