SHORT-LIVED CLIMATE POLLUTANTS SPECIAL EDITION RESEARCH DIGEST

November – December 2020

The Scientific Advisory Panel

of the

CLIMATE & CLEAN AIR COALITION

TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

All SLCP research digests are available on the CCAC website (http://ccacoalition.org/en/research-digest)

Table of Contents

Multiple Benefits/Impacts & Crosscutting

Description: This section includes articles addressing the multiple benefits of action to address SLCPs and implement SLCP measures.

Climate co-benefits of air quality and clean energy policy in India

Sustainable development goals connect policies addressing air quality and energy efficiency with complementary benefits for climate mitigation. However, a typically fragmented approach across these domains hinders effectiveness in addressing short-lived climate forcers (SLCFs)—including methane, carbon monoxide, non-methane volatile organic compounds and black carbon—to supplement CO2 mitigation. Here, to support policy coordination in India, we assess climate co-benefits of air quality and clean energy policies, using multiple metrics (global warming and temperature change potentials). We estimate an emission reduction potential of −0.1 to −1.8 GtCO2e yr−1 in 2030. The largest benefits accrue from residential clean energy policy (biomass cooking) and air pollution regulation (curbing brick production and agricultural residue burning emissions), which cut black carbon. In the next 1–2 decades (using global warming potential—GWP20), emission reduction potentials of warming SLCFs exceed those of CO2, which is not evident on longer timescales. Concurrently, policies in the electricity generation and transport sectors reduce cooling SLCFs (SO2 and NOx), potentially unmasking 0.1–2.4 GtCO2e yr−1. Integrating these interventions into national climate policies can strengthen both climate action and sustainability. The crucial impact of black carbon suggests that it should be included in the international climate accord.

Tibrewal, Kushal, and Chandra Venkataraman. "Climate co-benefits of air quality and clean energy policy in India." Nature Sustainability (2020): 1-9.

Understanding China's biggest sustainability experiment: Atmospheric and climate governance in the Yangtze River Economic Belt as a lens

China's coal consumption has made up more than 70% of China's energy assumption since 1978, and it accounts for approximately 21% of global carbon emissions in 2017. How China reach clean air targets, fulfill its commitment to reduce CO2 emission in the Paris Agreement, and achieve higher targets, such as peak CO2 emissions by 2030 and achieve net-zero emission by 2060? A range of sustainability experiments have been conducted to support China in the sustainability transition. As the biggest one among them, the Yangtze River Economic Belt runs across the middle of the country from east to west, with an area of 2,050,000 km2 or 21.39% of China's territory, and covers 11 provinces and cities. Although many studies have been conducted relevant to the Belt, few studies have described the research landscape, trends, and relevant topics of interest and gaps. To address this gap, we review, synthesize, and analyze the latest publications on the Belt and find environmental governance has been the key topic in current publications. Significantly, atmospheric and climate governance could be used as a lens to understand China's environmental governance, human-environmental interactions and trade-offs between environmental protection and socio-economic development in the Belt. Based on this lens, we find that: I. current research on the Belt has started and increased rapidly in the past five years, but our knowledge on it as a cross-boundary, cross-level and cross-sector sustainability experiments is somewhat limited; II. distribution of risk and responsibility across different regions in atmospheric and climate governance has not been well-addressed; III. new carbon emission accounting methods, especially methods based on a consumption-based approach, could be adopted to offer more comprehensive and just understandings about sectoral differences and environmental benefits; IV. influence of topography and meteorology on ambient air quality in the Belt cannot be ignored and should be included by the following research; and V. trade-offs and competing interests among different actors should be recognized and balanced to facilitate sustainable industrial upgrading, innovation and transforming without compromising individual well-being and regional development.

Peng, Meng, et al. "Understanding China's biggest sustainability experiment: Atmospheric and climate governance in the Yangtze River Economic Belt as a lens." Journal of Cleaner Production (2020): 125760.

Methane

Description: This section includes articles addressing methane source apportionment, emissions factors, impacts and emissions trends.

An Analysis of Abandoned Oil Well Characteristics Affecting Methane Emissions Estimates in the Cherokee Platform in Eastern Oklahoma

Anthropogenic activities increase methane emissions, contributing to greenhouse gas levels and adversely affecting the environment. Abandoned oil and gas wells potentially leak methane, but data are limited. We analyze methane emissions from abandoned wells (n = 179) in the Cherokee Platform in Oklahoma, a previously unaccounted basin, and compare emissions factors (EFs) to those in the Greenhouse Gas Inventory. We compare the contribution of various characteristics to the propensity for leakage. Higher emissions were observed with shallower wells and with unplugged wells. Plugged wells (n = 20) had an average EF of 96 ± 429 g/day and 65 ± 294 g/day for unplugged wells (n = 159). The majority of wells had no detectable leak. We calculated ethane EFs based on geochemical analysis of gas samples, finding higher EFs for unplugged (1.2 ± 5.5 g/day) versus plugged (0.9 ± 4.6 g/day) wells. The data indicate that in addition to the location of abandoned wells, physical characteristics are necessary to consider in estimating methane emissions.

Saint-Vincent, Patricia MB, et al. "An Analysis of Abandoned Oil Well Characteristics Affecting Methane Emissions Estimates in the Cherokee Platform in Eastern Oklahoma." Geophysical Research Letters 47.23 (2020): e2020GL089663.

Multi-satellite imaging of a gas well blowout enables quantification of total methane emissions

Incidents involving loss of control of oil/gas wells can result in large but variable emissions whose impact on the global methane budget is currently unknown. On November 1, 2019, a gas well blowout was reported in the Eagle Ford Shale. By combining satellite observations at different spatial and temporal scales, we quantified emissions 10 times during the 20-day event. Our multi-satellite synthesis captures both the short-term dynamics and total integrated emissions of the blowout. Such detailed event characterization was previously not possible from space, and difficult to do with surface measurements. We present 30-m methane and carbon dioxide plumes from the PRISMA satellite, which let us estimate flare combustion efficiency (87%). Integrating emissions across all satellites, we estimate 4800 ± 980 metric tons lost methane. Blowouts occur across the globe and multi-satellite observations can help to determine their pervasiveness, enable corrective action, and quantify their contribution to global methane budgets.

Cusworth, Daniel H., et al. "Multi-satellite imaging of a gas well blowout enables quantification of total methane emissions." Geophysical Research Letters: e2020GL090864.

Black Carbon

Description: This section includes articles addressing black carbon source apportionment, emissions factors, impacts and emissions trends.

Resolving aerosol mixing state increases accuracy of black carbon respiratory deposition estimates

Black carbon (BC) particles, also known as soot, deteriorate air quality and threaten public health. BC is emitted from the incomplete combustion of fossil fuel, which is a major energy source in the world today. Therefore, evaluating the impact of BC on global public health is vital, especially in the context of growing global population and energy demand. Since the atmospheric lifetime and deposition efficiency of BC after inhalation are governed by the size and chemical composition, realistic representation of those properties in models is required for such evaluation, yet is currently lacking. Here, we show that a simple but commonly found representation of size and chemical composition of BC particles in global models results in globally prevalent underestimation of the respiratory deposited BC mass concentration. The results emphasize that realistic representation of BC particles

is indispensable to the evaluation and hence the mitigation of BC impacts on global public health.

Ching, Joseph, Mizuo Kajino, and Hitoshi Matsui. "Resolving aerosol mixing state increases accuracy of black carbon respiratory deposition estimates." One Earth 3.6 (2020): 763-776.

A shallow ice core from East Greenland showing a reduction in black carbon during 1990–2016

This study reports on the measurements of ion and refractory black carbon (rBC) concentrations in a shallow (10.96 m) ice core sample which was drilled from the field site of the East Greenland Ice Core Project (EGRIP) in July, 2016. The results provide a recent record of rBC deposition in the East Greenland ice sheet from 1990 to 2016. The annual variability in oxygen (δ18O) and hydrogen (δD) isotopic compositions indicated that notably warm events occurred since 2008. Peaks in rBC occurred during summer seasons, which may be attributed to the burning of biomass in boreal summer. The rBC record and analysis of historical air trajectories using the HYSPLIT model indicated that anthropogenic BC emissions from Russia, North America and Europe contributed to the majority of rBC deposition in the Greenland region, and a reduction in anthropogenic BC consumption in these areas played a dominant role in the decrease in BC concentrations since 2000. This record also suggests that the emissions from the East Asian region (China) contributed very little to the recorded BC concentrations in East Greenland ice core. The model results indicated that radiative forcing due to BC had decreased significantly since 1990, and had remained below 0.02 W m−2 since 2000.

Zhi-Heng, Du, et al. "A shallow ice core from East Greenland showing a reduction in black carbon during 1990–2016." Advances in Climate Change Research (2020).

Tropospheric Ozone

Description: This section includes articles addressing tropospheric ozone impacts and important trends in precursor emissions.

Role of export industries on ozone pollution and its precursors in China

This study seeks to estimate how global supply chain relocates emissions of tropospheric ozone precursors and its impacts in shaping ozone formation. Here we show that goods produced in China for foreign markets lead to an increase of domestic non-methane volatile organic compounds (NMVOCs) emissions by 3.5 million tons in 2013; about 13% of the national total or, equivalent to half of emissions from European Union. Production for export increases concentration of NMVOCs (including some carcinogenic species) and peak ozone levels by 20–30% and 6–15% respectively, in the coastal areas. It contributes to an estimated 16,889 (3,839–30,663, 95% CI) premature deaths annually combining the effects of NMVOCs and ozone, but could be reduced by nearly 40% by closing the technology gap between China and EU. Export demand also alters the emission ratios between NMVOCs and nitrogen oxides and hence the ozone chemistry in the east and south coast.

Ou, Jiamin, et al. "Role of export industries on ozone pollution and its precursors in China." Nature communications 11.1 (2020): 1-12.

1981–2020 winter ozone trends, Erzgebirge, Central Europe

Tropospheric ozone (O3) acts as greenhouse gas and air pollutant. Over the last 100 years, tropospheric O3 levels increased above background by factor 2.5 in the northern hemisphere and by factor 3–4 across Europe. The gas poses a potential risk to forest ecosystems in many mountain areas. There, O3 concentrations result from long-range transport and are influenced by removal processes (dry deposition, gas phase and cloud removal, reduction on wet aerosols). Most trend studies analyzed annual-mean concentrations. We focus on winter O3 trends at high altitudes in the German/Czech Erzgebirge (period 1981–2020) to avoid major noise from photochemical reactions and to better explain recent O3 behavior in Central Europe. Hourly air quality and meteorological data from four stations (Carlsfeld, CAR; Fichtelberg, FIB; Schwartenberg, SWB; Zinnwald, ZIW) were used to analyze O3 trends. The data can explain the complex O3 formation and removal behavior.

Three distinct periods of O3-concentration trends can be discerned: i) Until the late 1980s, characterized by relatively low O3 concentrations. ii) Dramatic transformation in the 1990s with changing air pollution in Central Europe. Strong O3-concentration increase at FIB is corroborated by data from CAR and ZIW. iii) Stabilization as of 1997/98, when O3 concentrations remained at the same level for all four stations, despite general regional air pollution decrease. Key results are:

a) Winter O3 trends mainly depend on O3 concentration of air masses transported to the stations and on the O3-removal potential (ORP) of clouds, not on local formation processes.

b) ORP differs between clouds and fog, depending on droplet chemical composition. Fog from the North Bohemian Basin showed the highest ORP due to reaction with liquid phase S(IV). However, O3 reactions with O2− in fog droplets showed high ORP, too, depending on cloud-water pH values and NOx concentrations.

c) So-called “Bohemian fog” decreased, and with it related ORP, while that of clouds from westerly and northwesterly air masses remained nearly unchanged since 1997/98.

d) Decreasing ORP in clouds and fog (= higher O3 concentration) oppose decreasing O3 concentrations in westerly air masses. Both effects lead to unchanged O3 levels in the Erzgebirge since 1997/98.

Gebhardt, Hannah, Frank Zimmermann, and Jörg Matschullat. "1981–2020 winter ozone trends, Erzgebirge, Central Europe." Geochemistry (2020): 125738.

Hydrofluorocarbons (HFCs)

Description: This section includes articles addressing hydrofluorocarbon emissions, relevant new information about use sectors, alternative refrigerants and relevant analysis of energy efficiency.

Comparative analysis of HFO-1234ze(E) and R-515B as low GWP alternatives to HFC-134a in moderately high temperature heat pumps

This study provides a theoretical comprehensive performance and environmental analysis of the hydrofluoroolefin HFO-1234ze(E) and the mixture R-515B as alternative low global warming potential (GWP) refrigerants to replace the hydrofluorocarbon HFC-134a in heat pumps. Single-stage cycle, including the use of internal heat exchanger (IHX) has been used as a reference configuration. The influence of an IHX has been simulated to present the benefits of this component in vapour compression systems for medium and moderately high temperature heating applications. HFO-1234ze(E) and R-515B provide around 25% lower heating capacity than HFC-134a due to a diminution of latent heat of vaporization and suction density. The heating capacity difference between HFO-1234ze(E) and R-515B becomes not greater than 2%. The heating coefficient of performance (COP) of the alternative low-GWP refrigerants is comparable to the reference HFC-134a in the conditions proposed. The environmental analysis illustrates that HFO-1234ze(E) and R-515B can reduce down to 18% and 15%, respectively, the equivalent CO2 emissions compared to HFC-134a in low-temperature space heating applications, and down to 78% compared to a natural gas boiler as conventional heating technology in moderately high temperature applications (domestic hot water, industrial processes, and radiators). Although HFO-1234ze(E) and R-515B present comparable efficiency and environmental performance, R-515B, exhibits an advantage in installation safety requirements as a non-flammable refrigerant (A1).

Mateu-Royo, Carlos, et al. "Comparative analysis of HFO-1234ze (E) and R-515B as low GWP alternatives to HFC-134a in moderately high temperature heat pumps." International Journal of Refrigeration (2020).

Socio-Economic Impacts

Description: This section includes articles addressing the socio-economic impacts due to air pollutions and SLCP related climate changes

How do socioeconomic factors influence urban PM2.5 pollution in China? Empirical analysis from the perspective of spatiotemporal disequilibrium

PM2.5 pollution has harmed the health and social lives of residents, and although evidence of PM2.5 pollution caused by human activities has been reported in a large body of literature, traditional econometric and spatial models can explain the contribution of a given factor from only a global perspective. Given this limitation, this study quantitatively investigated the effects of the spatiotemporal heterogeneity of various socioeconomic factors on PM2.5 pollution in 273 Chinese cities from 2010 to 2016 by exploratory spatial data analysis (ESDA) and geographically weighted regression (GWR). The spatiotemporal distribution pattern and intrinsic driving mechanism of city-level PM2.5 pollution were systematically examined. The results indicate the following: (1) The cities with high PM2.5 pollution are located north of the Yangtze River and east of the Hu line. A notable positive spatial correlation was observed between these cities, and nearly one-third of the cities are in the Hsingle bondH clustering area. (2) From the global regression point of view, population size and economic development are the main factors causing the deterioration and spread of PM2.5 pollution in Chinese cities, and population size undoubtedly exerts the strongest influence. Industrial structure, economic development, openness degree, urbanization and road intensity also play weak roles in promoting urban PM2.5 pollution. (3) The socioeconomic factors influencing pollution exhibit significant spatial heterogeneity. Specifically, the cities in which pollution is promoted by economic development are mainly concentrated in the northeast and western regions. The cities in which population size exerts a positive driving effect are in most regions, except for a few central and western cities. Three targeted strategies for developing more sustainable cities are comprehensively discussed by building on the understanding of the socioeconomic driving mechanism for PM2.5 pollution.

Yan, Dan, et al. "How do socioeconomic factors influence urban PM2. 5 pollution in China? Empirical analysis from the perspective of spatiotemporal disequilibrium." Science of The Total Environment (2020): 143266.

Biomass Burning & Household Energy

Description: This section includes articles primarily addressing SLCP measures and innovations related to the household energy initiative, open burning of agricultural residue, and SLCP emissions in relevant sectors. Solid waste burning is covered in the waste section.

Particulate matter emissions reduction from residential wood stove using inert porous material inside its combustion chamber

Residential wood stoves are the most important source of air pollution and particulate matter in southern regions of Chile, where the Eucalyptus globulus is the most consumed biomass. In this context, the main objective of this experimental investigation was to evaluate the effect of the use of inert ceramics foams (Silicon carbide) inside the combustion chamber of residential wood stoves on particulate matter emissions. The porous ceramics were disposed in three configurations (floor, walls, and roof) in a single-chamber, and biomass was burned. Preliminary wood stoves combustion test showed that porous ceramics increase firewood burning rates, exhaust gases and external surface temperatures, and carbon dioxide emissions. Final combustion test results showed that for all configurations the particulate matter emission factors decreased at least in 20%. Being the porous ceramics located at the combustion chamber walls the configuration with the highest improvement, achieving a 61% reduction. The positive effect, on biomass combustion, of adding porous ceramics inside the combustion chamber could be attributed to a higher rate of the volatile organic compounds being burned due to heat and mass transfer intensification. Thus, further studies are necessary to identify an optimal design for a combustion chamber incorporating porous ceramics.

Guerrero, Fabián, et al. "Particulate matter emissions reduction from residential wood stove using inert porous material inside its combustion chamber." Fuel (2020): 119756.

Agriculture and Livestock

Description: This section includes articles primarily addressing SLCP measures and innovations related to the Agriculture initiative and SLCP emissions in relevant sectors

Repeatability and ranking of long-term enteric methane emissions measurement on dairy cows across diets and time using GreenFeed system in farm-conditions

The aims of this work were to study on dairy farm conditions: i) the repeatability of long-term enteric CH4 emissions measurement from lactating dairy cows using GreenFeed (GF); ii) the ranking of dairy cows according to their CH4 emissions across diets. Forty-five Holstein lactating dairy cows were randomly assigned to 3 equivalent groups at the beginning of their lactation. The experiment was composed of 3 successive periods: i) pre-experimental period (weeks 1 to 5) in which all cows received a common diet; ii) a dietary treatment transition period (weeks 6 to 10); and iii) an experimental period (weeks 11 to 26) in which each group was fed a different diet. Experimental diets were formulated to generate more or less CH4 production: i) a diet based on ryegrass silage and concentrates, low in starch and lipid, designed to induce high CH4 emissions (CH4+); ii) a diet based on maize silage and concentrates, rich in starch, designed to induce intermediate CH4 emissions (CH4int); iii) a diet based on maize silage and concentrates, rich in starch and lipid, designed to induce low CH4 emissions (CH4-). Gas emissions were individually measured using GF systems. Repeatability of gas emissions, dry matter intake (DMI) and dairy performances measurements was calculated from data averaged over 1, 2, 4, and 8 weeks for each animal. Hierarchical cluster analysis was performed to rank individual animals according to their CH4 emissions. No significant differences were observed for daily CH4 emissions (g/day) among diets, because of lower DMI of CH4+ cows. When CH4 emissions were referred to units of DMI or milk, the differences among diets emerged as significant and persistent over the observed period of lactation. Repeatability values of gas emissions measurements were higher than 0.7 averaged over 8 weeks of measurement, but still higher than 0.6 for CH4 g/day, CO2 g/day, CH4 g/kg milk, and CH4/CO2 even averaging only 2 weeks of measurement. The repeatability of CH4 emissions measurement was systematically lower than those of DMI or dairy performance parameters, like milk and FPCM yield, irrespective of the averaged measurement period. The dairy cow ranking was not stable over time between all individuals or within any of the diets. In our experimental conditions, the GF performance in the long term can be considered reliable in differentiating dairy herds by their CH4 emissions according to diets with different methanogenic potential, but did not allow the ranking of individual dairy cows within a same diet. Our data highlight the importance of phenotyping animals across environment in which they will be expected to perform.

Coppa, Mauro, et al. "Repeatability and ranking of long-term enteric methane emissions measurement on dairy cows across diets and time using GreenFeed system in farm-conditions." Methods (2020).

Beef cattle methane emission estimation using the eddy covariance technique in combination with geolocation

Methane emissions of a grazing herd of Belgian Blue cattle were estimated per individual on the field by combining eddy covariance measurements with geolocation of the cattle and a footprint model. This method allows the measurement of outdoor non-invasive methane emissions but is complex and subject to methodological issues. Estimated emissions were 220 ±35 g CH4 LU−1 day−1 (grams of methane per livestock unit per day), where the uncertainty corresponds to the random error and does not include any possible systematic error. Cattle behavior was also monitored and presented a clear daily pattern of activity with more intense grazing after sunrise and before sunset. However, no significant methane emission pattern could be associated with it, the diurnal emission variation being lower than the measurement precision.

Dumortier, Pierre, et al. "Beef cattle methane emission estimation using the eddy covariance technique in combination with geolocation." Agricultural and Forest Meteorology (2020): 108249.

Improving robustness and accuracy of predicted daily methane emissions of dairy cows using milk mid-infrared spectra

A robust proxy for estimating methane (CH4) emissions of individual dairy cows would be valuable especially for selective breeding. This study aimed to improve the robustness and accuracy of prediction models that estimate daily CH4 emissions from milk Fourier transform mid-infrared (FT-MIR) spectra by (i) increasing the reference dataset and (ii) adjusting for routinely recorded phenotypic information. Prediction equations for CH4 were developed using a combined dataset including daily CH4 measurements (n = 1089; g d−1) collected using the SF6 tracer technique (n = 513) and measurements using respiration chambers (RC, n = 576). Furthermore, in addition to the milk FT-MIR spectra, the variables of milk yield (MY) on the test day, parity (P) and breed (B) of cows were included in the regression analysis as explanatory variables. Models developed based on a combined RC and SF6 dataset predicted the expected pattern in CH4 values (in g d−1) during a lactation cycle, namely an increase during the first weeks after calving followed by a gradual decrease until the end of lactation. The model including MY, P and B information provided the best prediction results (cross-validation statistics: R2 = 0.68 and standard error = 57 g CH4 d−1). The models developed accounted for more of the observed variability in CH4 emissions than previously developed models and thus were considered more robust. This approach is suitable for large-scale studies (e.g. animal genetic evaluation) where robustness is paramount for accurate predictions across a range of animal conditions.

Vanlierde, Amélie, et al. "Improving robustness and accuracy of predicted daily methane emissions of dairy cows using milk mid-infrared spectra." Journal of the Science of Food and Agriculture (2020).

Transportation

Description: This section includes articles primarily addressing SLCP measures and innovations related to the Diesel initiative and SLCP emissions in relevant sectors

Effects of vehicular emissions on the urban environment- a state of the art

A jerky aspect of the pollutants from the road transportation sector is widening swiftly. The utilization of motor vehicles has been expanding day by day due to the intensive raise of the population. Many studies have illustrated that the peak levels of vehicular pollutants contribute to air pollution. On-road motor vehicles such as cars, bikes and trucks are the major source of emissions. The emissions such as chlorofluoro carbons which are introduced into the atmosphere due to different human activities leads to depletion of ozone layer which directly or indirectly effects the climate. Due to these increased emissions the global environment is facing immeasurable changes which can impact the climate as well as the human health. Air quality is one of the leading troubles in our society and there are numerous factors that effect the quality of air and one of them is Vehicular emission. This paper mainly focuses on how vehicular emissions contribute to climate change from a study made through different literature papers. The parameters and the methodologies that influence the environmental change as well as the human health were extracted from the literature survey and are discussed in this paper. The connection between the air quality and the climate change is also mentioned, since the greenhouse gases influences the quality of air and leads to the ozone depletion. Through this study, one can identify the causes of vehicular emissions towards climate change and there by effecting the human health. The main motive of this research is to present a structured analysis of various causes as well as impacts of vehicular pollution on the environment and climate with the help of the available literature. The study concludes that, the reduction of vehicular pollution is not only favourable for cities but also important for improving the global climate change.

Kumar, P. Gireesh, et al. "Effects of vehicular emissions on the urban environment-a state of the art." Materials Today: Proceedings (2020).

Expected impacts on greenhouse gas and air pollutant emissions due to a possible transition towards a hydrogen economy in German road transport

Transitioning German road transport partially to hydrogen energy is among the possibilities being discussed to help meet national climate targets. This study investigates impacts of a hypothetical, complete transition from conventionally-fueled to hydrogen-powered German transport through representative scenarios. Our results show that German emissions change between −179 and +95 MtCO2eq annually, depending on the scenario, with renewable-powered electrolysis leading to the greatest emissions reduction, while electrolysis using the fossil-intense current electricity mix leads to the greatest increase. German energy emissions of regulated pollutants decrease significantly, indicating the potential for simultaneous air quality improvements. Vehicular hydrogen demand is 1000 PJ annually, requiring 446–525 TWh for electrolysis, hydrogen transport and storage, which could be supplied by future German renewable generation, supporting the potential for CO2-free hydrogen traffic and increased energy security. Thus hydrogen-powered transport could contribute significantly to climate and air quality goals, warranting further research and political discussion about this possibility.

Weger, Lindsey B., Joana Leitão, and Mark G. Lawrence. "Expected impacts on greenhouse gas and air pollutant emissions due to a possible transition towards a hydrogen economy in German road transport." International Journal of Hydrogen Energy (2020).

Air pollution & Health Impacts

Description: This section includes articles primarily addressing linkages between air pollution exposure and health impacts

A National Difference in Differences Analysis of the Effect of PM2.5 on Annual Death Rates

Many studies have reported that PM2.5 was associated with mortality, but these were criticized for unmeasured confounding, not using causal modeling, and not focusing on changes in exposure and mortality rates. Recent studies have used propensity scores, a causal modeling approach that requires the assumption of no unmeasured confounders. We used differences in differences, a causal modeling approach that focuses on exposure changes, and controls for unmeasured confounders by design to analyze PM2.5 and mortality in the U.S. Medicare population, with 623,036,820 person-years of follow-up, and 29,481,444 deaths. We expanded the approach by clustering ZIP codes into 32 groups based on racial, behavioral and socioeconomic characteristics, and analyzing each cluster separately. We controlled for multiple time varying confounders within each cluster. A separate analysis examined participants whose exposure was always below 12 µg/m3.We found an increase of 1 µg/m3 in PM2.5 produced an increased risk of dying in that year of 3.85x10-4 (95% CI 1.95 x10-4, 5.76 x10-4). This corresponds to 14,000 early deaths per year per 1 µg/m3. When restricted to exposures below 12 µg/m3, the increased mortality risk was 4.26 x10-4 (95% CI 1.43x10-4, 7.09 x10-4). Using a causal modeling approach robust to omitted confounders, we found associations of PM2.5 with increased death rates, including below U.S. and E.U. standards.

Schwartz, Joel, et al. "A National Difference in Differences Analysis of the Effect of PM2. 5 on Annual Death Rates." Environmental Research (2020): 110649.

Changes in the PM2.5-related environmental health burden caused by population migration and policy implications

Over the past few decades, increasingly serious air pollution has occurred in China, which has led to an increasing number of premature deaths caused by fine particulate matter (PM2.5). Population migration and rapid urbanization may cause a series of changes in premature deaths. In China, there is a scientific consensus on the severity of the environmental health burden caused by PM2.5 pollution in different areas, but changes in the health burden associated with complex migration remain a significant challenge. This study aims to provide a comprehensive assessment of changes in the environmental health burden of different types of migrants and to facilitate policy development to consider more humanely reducing the environmental health burden of migrants.

In this study, we zoned premature deaths based on urban and rural areas extracted by nighttime light data combined with land use data, and analyzed the changes in the environmental health burden associated with intra-provincial urbanization migration and inter-provincial migration. Our research showed that changes in premature deaths caused by intra-provincial urbanization migration and inter-provincial migration accounted for 48.40%–93.38% and 2.61%–34.52% of the total changes in premature deaths, respectively. The highest premature deaths reached 10.16 cases/km2 in Beijing in 2015. By analyzing the changes in the environmental health burden associated with intra-provincial urbanization migration and inter-provincial migration, we found that few people needed to bear a higher environmental health burden after moving to Hainan, Tibet, Ningxia, Xinjiang, and Guangdong. In contrast, more than 50% of the people moving into Beijing, Liaoning, Shanghai, and Jiangsu had to bear a higher environmental health burden. Fujian and Zhejiang had a healthier environment than the other developed coastal provinces, and had a relatively low environmental health burden. Thus, we introduced corresponding policy suggestions for different migration types.

Lin, Anqi, et al. "Changes in the PM2. 5-related environmental health burden caused by population migration and policy implications." Journal of Cleaner Production (2020): 125051.

Long-term exposure to air pollution and mortality in the Danish population a nationwide study

Studies have shown higher mortality in association with exposure to air pollution. We investigated this association with focus on differences between socioeconomic groups. We included all Danes born between 1921 and 1985 aged 30–85 years from 1991 to 2015 (N = 4,401,348). We applied a nested case-control design and identified those who died during follow-up and selected five controls per case. We modelled NO2, fine particulate matter (PM2·5), black carbon (BC) particles, and ozone (O3) as five-year average concentrations at the residential addresses of 672,895 all natural cause mortality cases and 3,426,533 controls in conditional logistic regression with adjustment for individual and neighbourhood level socio-demographic variables. In single pollutant models, a 10 μg/m3 (BC: 1 μg/m3) increase in NO2, PM2·5, BC, and O3 was associated with natural cause mortality rate ratios (MRR) of 1·05 (95% confidence interval 1·04–1·06), 1·08 (1·04–1·13), 1·05 (1·02–1·08), and 0·96 (0·95–0·97), respectively. The patterns were similar for respiratory disease and lung cancer mortality. O3 was associated with higher risk of CVD mortality. The rate differences for a unit increase in PM2·5, NO2, and BC were largest among those with the lowest income; this pattern was not detected when considering the relative risk measure, MRR. Long-term concentration of air pollution at the residence was associated with higher natural cause mortality in the Danish population and the strength of the association differed by socioeconomic group. We recommend that future studies express socioeconomic differences in absolute rather than relative risk.

Raaschou-Nielsen, Ole, et al. "Long-term exposure to air pollution and mortality in the Danish population a nationwide study." EClinicalMedicine 28 (2020): 100605.

Analysis of various transport modes to evaluate personal exposure to PM2.5 pollution in Delhi

Access to detailed comparisons of the air quality variations encountered when commuting through a city offers the urban traveller more informed choice on how to minimise personal exposure to inhalable pollutants. In this study we report on an experiment designed to compare atmospheric contaminants, in this case, PM2.5 inhaled during rickshaw, bus, metro, non-air-conditioned car, air-conditioned (AC) car and walking journeys through the city of Delhi, India. The data collection was carried out using a portable TSI SidePak Aerosol Monitor AM520, during February 2018. The results demonstrate that rickshaws (266 ± 159 μg/m3) and walking (259 ± 102 μg/m3) modes were exposed to significantly higher mean PM2.5 levels, whereas AC cars (89 ± 30 μg/m3) and the metro (72 ± 11 μg/m3) had the lowest overall exposure rates. Buses (113 ± 14 μg/m3) and non-AC cars (149 ± 13 μg/m3) had average levels of exposure, but open windows and local factors caused surges in PM2.5 for both transport modes. Closed air-conditioned transport modes were shown to be the best modes for avoiding high concentrations of PM2.5, however other factors (e.g. time of the day, window open or closed in the vehicles) affected exposure levels significantly. Overall, the highest total respiratory deposition doses (RDDs) values were estimated as 84.7 ± 33.4 μg/km, 15.8 ± 9.5 μg/km and 9.7 ± 0.9 μg/km for walking, rickshaw and non-AC car transported mode of journey, respectively. Unless strong pollution control measures are taken, the high

exposure to PM2.5 levels will continue causing serious short-term and long-term health concerns for the Delhi residents. Implementing integrated and intelligent transport systems and educating commuters on ways to reduce exposure levels and impacts on commuter's health are required.

Maji, Kamal Jyoti, et al. "Analysis of various transport modes to evaluate personal exposure to PM2. 5 pollution in Delhi." Atmospheric Pollution Research (2020).

Mortality Benefits and Control Costs of Improving Air Quality in Mexico City: The Case of Heavy Duty Diesel Vehicles

Diesel vehicles are significant contributors to air pollution in Mexico City. We estimate the costs and mortality benefits of retrofitting heavy-duty vehicles with particulate filters and oxidation catalysts. The feasibility and cost-effectiveness of controls differ by vehicle model-year and type. We evaluate 1985 to 2014 model-year vehicles from 10 vehicle classes and five model-year groups. Our analysis shows that retrofitting all vehicles with the control that maximizes expected net benefits for that vehicle type and model-year group has the potential to reduce emissions of primary fine particles (PM2.5) by 950 metric tons/year; cut the population-weighted annual mean concentration of PM2.5 in Mexico City by 0.90 µg/m3; reduce the annual number of deaths attributable to air pollution by over 80; and generate expected annual health benefits of close to 250 million US$. These benefits outweigh expected costs of 92 million US$ per year. Diesel retrofits are but one step that should viewed in the context of other efforts—such as development of an integrated public transportation system, promotion of the rational use of cars, reduction of emissions from industrial sources and fires, and redesign of the Mexico City Metropolitan Area to reduce urban sprawl—that must be analyzed and implemented to substantially control air pollution and protect public health. Even if considering other potential public health interventions, which would offer greater benefits at the same or lower costs, only by conducting, promoting, and publishing this sort of analyses, we can make strides to improve public health cost-effectively.

Evans, John S., et al. "Mortality Benefits and Control Costs of Improving Air Quality in Mexico City: The Case of Heavy Duty Diesel Vehicles." Risk Analysis (2020).

Urban Air Pollution & Megacities

Description: This section includes articles addressing PM2.5 and air pollution source apportionment, impacts and emissions trends.

Impacts of traffic and street characteristics on the exposure of cycling commuters to PM2.5 and PM10 in urban street environments

Cycling commuters are a large and growing group in China. Cyclists might be exposed to higher than average risks from pollution owing to their proximity to traffic. The factors affecting cyclists' exposure in urban streets include the sources of traffic and the dispersion of pollutants. This study performs cycling mobile monitoring under calm weather conditions in a central business district of Fuzhou, China. Relative exposure concentration (REC) after background correction is proposed to examine exposure level and evaluate the impacts of traffic density and composition and to identify street characteristics (built environment features and roadside vegetation) that determine the exposure level distribution between and within different street segments. The averaged REC of 10 m buffers along the route with a spatial variability between segments ranged from 1.2 to 3.5 µg/m3 and 2.8–4.3 µg/m3 above the background level for PM2.5 and PM10. REC hotspots (>4 µg/m3) not only appeared frequently in wide streets with larger traffic volumes, but also in narrow streets with dense trees owing to the accumulation of particles contributed from emission and road dust re-suspension caused by diesel trucks. In multivariable models, the street aspect ratio H/W and buildings spacing distance are the main factors influencing the REC variation in wide streets, whereas the leaf area index and canopy coverage percentage of the roadside vegetation explained 29–53% of the REC variation in narrow streets with dense trees. Our insights have the potential to inform traffic management and planning strategies designed to reduce cyclists' exposure to pollution in urban streets.

Hu, Haibin, et al. "Impacts of traffic and street characteristics on the exposure of cycling commuters to PM2. 5 and PM10 in urban street environments." Building and Environment (2020): 107476.

Assessing neighborhood variations in ozone and PM2.5 concentrations using decision tree method

Typical air pollution events involving ozone (O3) and PM2.5 occurred frequently in China, while the fine-scale pollution variation, especially at a neighborhood level (2 km*2 km), is complex and still not clear. To assess how urban form and meteorology influence neighborhood air pollution distribution, this study took the Minhang district in Shanghai, as experimental cases, and performed a neighborhood-scale investigation on O3 and PM2.5 by using mobile measurements. Both land-use regression model and decision tree model were used to examine the relationship between air pollutant concentration and influenced variables. As the decision tree model captured the linear and non-linear relationship between variables, it was demonstrated that explained more variations of O3 and PM2.5 concentrations than the LUR model. The results also showed that O3 concentrations were mainly affected by meteorological factors while PM2.5 concentrations were more heavily determined by background level and residential area. Both O3 and PM2.5 showed a significant correlation with air temperature, traffic volume, building height, and green space. Interestingly, green spaces were negatively correlated with the PM2.5 variations, which was almost the opposite to that of O3. With the superiority to the discrete observation, the decision tree model based concentration surfaces clearly revealed the heterogeneity of O3 and PM2.5 distributions. This study not only preliminarily identifies the impacts of land-use type and meteorological factors on the spatial patterns of O3 and PM2.5, but also provides a possible alternative method for assessing the neighborhood air pollution in the future.

Gao, Ya, et al. "Assessing neighborhood variations in ozone and PM2. 5 concentrations using decision tree method." Building and Environment (2020): 107479.

Real-time numerical source apportionment of PM2.5 concentrations over the Yangtze River Delta region, China

A real-time numerical source apportionment system was established based on the operational regional atmospheric environmental modelling system (RAEMS) for eastern China in order to calculate the contribution of emissions from different provincial regions over the Yangtze River Delta (YRD) region to the PM2.5 concentration. The 2019 modelling results showed good and reliable performance of the RAEMS in modelling PM2.5 concentrations over 55 cities in the YRD region. Herein, the analysis results indicated the importance of local emissions on PM2.5 concentration at both provincial and city scales, with contribution rates of 54%–65% and 62.3%–70.7%, respectively. The contribution of mutual inner-regional transport among provinces was clear, contributing varied proportions (1%–22%) among themselves and similar proportions (23%–29%) to the provincial city PM2.5 concentration. The cross-regional transport contributed from regions outside the YRD provided relatively weaker contributions of 3.3%–10.6%. However, this contribution doubled during cold air events. Note that the temporal trend of PM2.5 over Shanghai is largely dominated by the contributions from Zhejiang and Jiangsu, whereas the other provinces are highly self-dominated. In addition to controlling local emissions to decrease the PM2.5 pollution rate, varied effects were found by reducing inner-regional transport. The cross-regional transport contribution found herein was relatively lower throughout the year than that in previous pollution episode studies. The results of this research provide support for both the real-time emergency PM2.5 pollution prevention and joint strategy policy making for anthropogenic emission regulation and control in the YRD region.

Zhou, Guangqiang, Zhongqi Yu, and Yuanhao Qu. "Real-time numerical source apportionment of PM2. 5 concentrations over the Yangtze River Delta region, China." Atmospheric Environment (2020): 118104.

Spatiotemporal assessment of PM2.5 concentrations and exposure in China from 2013 to 2017 using satellite-derived data

Satellite-based estimation of fine particulate matter of 2.5 µm or less (PM2.5) at a high spatiotemporal resolution is important to understand the detailed dynamics of PM2.5 pollution and exposure. Stricter clean air

policies have been enacted in recent years to tackle China's serious problem with PM2.5 pollution, including the implementation of the Air Pollution Prevention and Control Action Plan between 2013 and 2017. However, assessment of the change in national PM2.5 exposure during this period is difficult due to the limitation of high-resolution PM2.5 data. To address this issue, a satellite-based spatiotemporal model was developed to predict daily high-resolution surface PM2.5 concentrations in China during the designated period, and quantitative analysis was then performed regarding the spatiotemporal characteristics of this critical pollutant. The corresponding changes in the population exposure to PM2.5 were also explored at a fine scale. The overall concentrations of PM2.5 declined from 2013 to 2017, with substantial decreases in eastern China but negligible decreases in western China. The national PM2.5 concentration declined remarkably from 2013 to 2014 to 2015–2017. The Beijing–Tianjin–Hebei and Pearl River Delta regions and most cities reached the goals set by the Air Pollution Prevention and Control Action Plan. However, despite the overall reduction in the PM2.5 concentration, by 2017 the vast majority of the Chinese population still lived in areas with sustained levels of high risk from fine particle pollution. The findings from this study have crucial environmental policy implications for the mitigation of PM2.5 pollution and could benefit PM2.5–related health studies in China.

He, Qingqing, et al. "Spatiotemporal assessment of PM2. 5 concentrations and exposure in China from 2013 to 2017 using satellite-derived data." Journal of Cleaner Production (2020): 124965.

Effects of Imports and Exports on China's PM2.5 Pollution

This paper examines the effects of imports and exports on China's PM2.5 pollution using data from 31 provinces during the period 2001–2016. At the aggregate level, our analysis shows that exports have a pollution-generating effect while imports have a pollution-shifting effect on provincial PM2.5 pollution. Cross-sectional analysis reveals that imports and exports exhibit opposite effects on manufacturing and high-tech industries, but demonstrate the same pollution-generating effect for the heavy industry sector. At the regional level, the effects are similar to those at the aggregate level. We also examine the impacts of other factors on PM2.5 pollution. Our empirical evidence shows that PM2.5 pollution is positively correlated with domestic sales, population density, economic growth, urbanization rate, and transportation, but negatively correlated with energy efficiency and industry structure. This paper suggests that reducing exports and increasing imports will help to reduce PM2.5 pollution.

Li, Zhaohua, Ziwei Fang, and Zhuyu Tang. "Effects of Imports and Exports on China's PM2. 5 Pollution." China & World Economy 28.6 (2020): 28-50.

The effect of recent controls on emissions and aerosol pollution at city scale: A case study for Nanjing, China

We selected a typical developed city in east China, Nanjing, to evaluate the effect of recent national and local policies of air pollution control on emissions and air quality at city scale. Using a bottom-up methodology, the annual emissions of SO2, NOX, CO, NH3, primary fine particle matters (PM2.5), black carbon, and organic carbon were estimated to decline 70%, 22%, 49%, 72%, 64%, 65%, and 86%, respectively, while a slight increase was found for the non-methane volatile organic compounds (VOCs) during 2012–2016. The inter-annual change in NOX emissions was consistent with that in tropospheric NO2 column from satellite observation. Using air quality modeling (AQM), the city-scale emission inventory was further evaluated through comparisons between the simulated and observed concentrations of selected species. For SO2, NO2 and PM2.5, the normalized mean bias (NMB) and normalized mean errors (NMEs) for most cases were within 20% and 50% respectively, implying the reliability of the emission inventory. Regarding chemistry species, the modeling performance was better for sulfate and black carbon than nitrate and ammonium. From 2012 to 2016, the average of monthly PM2.5 concentrations for January, April, July, and October in Nanjing was found to decline 28% and 25% with AQM and ground observation, respectively, implying the benefit of emission control on aerosol pollution. Extra simulations with fixed emissions or meteorology conditions for 2012 and 2016 were conducted to understand the effects of emission control and meteorology variation on the reduced aerosol pollution.

Zhao, Yu, et al. "The effect of recent controls on emissions and aerosol pollution at city scale: A case study for

Nanjing, China." Atmospheric Environment (2020): 118080.