ROADMAP FOR U.S.-CHINA METHANE COLLABORATION: TECHNICAL APPENDIX

Sha Yu[1,2*], Jenna Behrendt[1], Mengye Zhu[1], Xinzhao Cheng[1], Wenli Li[1], Baobao Liu[1], Jared Williams[1], Haiwen Zhang[1], Ryna Cui[1], Meredydd Evans[1,2], Nathan Hultman[1], Haewon McJeon[1,2], Steve J. Smith[1,2], Qimin Chai[3], Minpeng Chen[4], Fei Guo[5], Lena Höglund Isaksson[5], Nina Khanna[6], Jiang Lin[6], Yazhen Wu[7]

1 Center for Global Sustainability, School of Public Policy, University of Maryland, College Park, USA
2 Joint Global Change Research Institute, Pacific Northwest National Laboratory, College Park, USA
3 Tsinghua University, Beijing, China
4 Renmin University of China, Beijing, China
5 International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria
6 Lawrence Berkeley National Laboratory, Berkeley, USA
7 Peking University, Beijing, China

* Corresponding Author: sha@umd.edu

S1: Emissions Inventory Methodology

We collected data from several inventories for the analysis included in the full report. Summary and preliminary underlying information from inventories included in the full report are noted below (Tables S1.1 through S1.4). These summaries are for the versions of inventories collected, and thus may not represent the latest inventory information. They are based on information we collected, and our interpretation of inventory underlying assumptions and data sources. The information below is not meant to be comprehensive for all inventories but can provide some high-level information across inventories to understand results in the report. Please refer to the literature linked in the **Source** column of the tables for the most complete and up to date information on each respective inventory. Tables S1.1 and S1.2 include details on the bottom-up and top-down inventories, respectively. Tables S1.3 includes coal sector-specific adjustments used in bottom-up inventories in China. Table S1.4 outlines the gridded inventories used in our spatial analysis policy brief.

Table S1.1: Summary of Bottom-up Inventories

Inventory Abbreviation	Inventory Name	Sectors	Years Reported	Activity Data	Emission Factors	Spatial Resolution	Source
CEDS v2021_04_21 (CEDS)	Community Emissions Data System	Coal Mining, Abandoned Coal Mine Methane (AMM), Oil and Gas, Solid Waste, Wastewater, Livestock (Manure Management, Enteric Fermentation), Rice Cultivation	1750 - 2019	Calibrated to national inventories, EDGARv5.0 or FAO emissions data for most sectors	Calibrated to national inventories, EDGARv5.0 or FAO emissions data for most sectors	0.5° * 0.5°	(McDuffie et al., 2020; Hoesly et al., 2018, O'Rouke et al., 2021a)
China NCCC	Initial/ Second/ Third National Communication on Climate Change of The People's Republic of China, The People's Republic of China First/Second Biennial Update Report on Climate Change	Coal Mining, AMM, Oil and Gas, Solid Waste, Wastewater, Livestock (Manure Management, Enteric Fermentation), Rice Cultivation	1990, 2005, 2010, 2012, 2014	China Coal Industry Yearbook, Sinopec Group Statistical Yearbook	Country-specific parameters; IPCC default emission factors with some sector adjustments		(UNFCCC, 2004, 2012, 2017, 2019a, 2019b)
EDGARv6.0 (EDGAR)	Electronic Data Gathering, Analysis, and Retrieval system v6.0	Coal Mining, AMM, Oil and Gas, Solid Waste, Wastewater, Livestock (Manure Management, Enteric Fermentation), Rice Cultivation	1970 - 2018	IEA World Energy Balances, FAOSTAT, UNFCCC, USGS, World Coal Association	EMEP/EEA or IPCC default emission factors	0.1° * 0.1°	(Crippa et al., 2021a; Crippa et al., 2021b; Janssens-Maenhout et al., 2019)

EPA v2019_10_31 (EPA)	U.S. Environmental Protection Agency Non-CO_2 Projections & Mitigation Potential Report	Coal Mining, AMM, Oil and Gas, Solid Waste, Wastewater, Livestock (Manure Management, Enteric Fermentation), Rice Cultivation	1990 - 2015	EIA International Energy Outlook, UNFCCC country reported emissions, BP Statistical Review of World Energy	IPCC Tier 1 default emission factors		(EPA, 2019)
FAO v2021_11_5 (FAO)	Food and Agriculture Organization	Livestock (Manure Management, Enteric Fermentation), Rice Cultivation	1961 - 2019	UN Statistics, U.S. Geological Survey, and other sources	IPCC Tier 1 default emission factors		(FAOSTAT, 2014)
GAINS v2019_09_30 (GAINS)	Greenhouse Gas and Air Pollution Interactions and Synergies and ECLIPSEv6b current legislation for air pollution	Coal Mining, AMM, Oil and Gas, Solid Waste, Wastewater, Livestock, Rice Cultivation	1990 - 2015	IEA World Energy Outlook, World Bank, UNFCCC, EUROSTAT, FAOSTAT	Sector-specific emission factors	0.5° * 0.5°	(Höglund-Isaksson et al., 2020)
GFEIv2 (GFEI)	Global Fuel Exploitation Inventory	Coal Mining, AMM, Oil and Gas	2010 - 2019	For Annex I countries, use emissions as reported to the UNFCCC, For non-Annex countries, use activity data from the U.S. Energy Information Administration	IPCC emission factors	0.1° * 0.1°	(Scarpelli et al., 2022)
U.S. GHGI	Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020	Coal Mining, AMM, Oil and Gas, Solid Waste, Wastewater, Livestock (Manure Management, Enteric Fermentation), Rice Cultivation	1990- 2020	See United States of America Common Reporting Format (CRF) Table in EPA, 2022	IPCC emission factors; U.S. NIR		(EPA, 2022)

Table S1.2: Summary of Top-down Inventories

Top-down Source	Sectors	Years Reported	Uncertainty	Atmospheric Transport Model	Prior Estimate	Observational Data	Spatial Resolutions	Source
Chen et al. 2022b	Total, Coal Mining, AMM, Livestock, Rice Cultivation	2019	2 standard deviations	GEOS-Chem	EDGAR v4.3.2, GFEI	TROPOMI, GOSAT	0.25° * 0.3125°	(Chen et al., 2022b)
Deng et al. 2022	Total (average of years reported)	2010 - 2017	No regional uncertainty estimate or range found	Multiple models	UNFCCC	GOSAT, in situ observations	1° * 1°	(Deng et al., 2022)
GMBv2020	Total (average of years reported)	2000 - 2009, 2008 - 2017, 2017 (actual year data)	No regional uncertainty estimate or range found	Multiple models	A series of datasets are used such as EDGAR v4.3.2 and GFED	GOSAT-TANSO-FT, in situ observations	Varies from 0.1° * 0.1° to 6° * 4°	(Saunois et al., 2020)
Lu et al. 2021a	Total, Coal Mining AMM, Oil and Gas, Livestock, Rice Cultivation (average of years reported)	2010 - 2017	50% standard deviation	GEOS-Chem	GFEI, EDGAR v4.3.2 and other literature	GOSAT and GLOBALVIEW plus in situ observations	4° * 5°	(Lu et al., 2021a)
Miller et al. 2019	Total, Coal Mining, Livestock, Rice Cultivation	2010 - 2015	95% confidence interval	GEOS-Chem	EDGAR v4.2	GOSAT	2° * 2.5°	(Miller et al., 2019)
Qu et al. 2021	Total	2019	50% standard deviation	GEOS-Chem	EDGAR v4.3.2, GFEI and other literature	TROPOMI, GOSAT	2° * 2.5°	(Qu et al., 2021)
Sheng et al. 2021	Total, Coal Mining, AMM, Oil and Gas, Livestock	2010 - 2017	1 standard deviation	The UK Met Office NAME	EDGAR V4.2, SENSPrior	GOSAT, NIES	0.352° * 0.234°	(Sheng et al., 2021)

Stavert et al. 2021	Total (average of years reported)	2000 - 2009	95% confidence interval	Multiple models	Gridded EDGAR v4.3.2, GAINS ECLIPSE v6 and other literature	GOSAT-TANSO-FT, in situ observations	1° * 1°	(Stavert et al., 2021)
Wang et al. 2021	Total (average of year reported)	2014 - 2018	30%	Multiple models	EDGAR v5.0	GOSAT, WDCGG	0.1° * 0.1°	(Wang et al., 2021)
Worden et al. 2022	Total, Coal Mining, Oil and Gas, Livestock, Rice Cultivation	2019	Annex 1 regions - 15%, Annex 2 regions - 30%	GEOS-Chem	EDGAR v4.3.2	GOSAT	2° * 2.5°	(Worden et al., 2022)
Zhang et al. 2021b	Total (average of years reported)	2010 - 2018	20%-50% standard deviation	GEOS-Chem	EDGAR v4.3.2 and other literature	GOSAT	4° * 5°	(Zhang et al., 2021b)

Table S1.3: Inventory Approaches for Estimating Coal Emissions in China

Inventory	Sector-specific Adjustments for Coal Emissions in China	Sources
CEDSv2021_ 04_21 (CEDS)	Fossil-related emissions for China are based on EDGARv5.0 through 2015. Post-2015 trend for coal production emissions was scaled forward using coal production data.	(McDuffie et al., 2020; Hoesly et al., 2018; O'Rouke et al., 2021a)
EDGARv6.0 (EDGAR)	Used the lower end of the range of emission factors recommended by EMEP/EEA for coal mines in Europe, in accordance with literature observance that mines in China are most often low-quality coal.	(Crippa et al., 2021a; Crippa et al., 2021b; Janssens-Maenhout et al., 2019)
EPAv2019_10_31 (EPA)	EPA projections are based on literature estimates of China-specific emissions by production type (surface versus underground) and from different stages of production (VAM, mining, and post-mining). Nationally reported data and EIA activity data are used for years without reported data (including projected trend).	(EPA, 2019)
GAINSv4_ 2019_09_30 (GAINS)	Emissions were aligned with several regional studies that calculated bottom-up emissions from existing coal mines and verified estimates with top-down measurements from existing literature. Assumed that AMM emissions correspond to 10% active hard coal mine emissions, as derived from previous research on U.S. estimates.	(Höglund-Isaksson et al., 2020)
GFEIv2 (GFEI)	Uses regional bottom-up information for the distribution of coal emissions in China from previous literature and nationally reported data for scaling gridded emissions.	(Scarpelli et al., 2022)
Sheng et al. 2021	Uses distribution of coal emissions in China from previous literature, based on Chinese State Administration of Coal Mine Safety (SACMS) data on reported methane emissions from operating mines.	(Sheng et al., 2021)

Table S1.4: Gridded Inventories Summary. If subsector data was not available for inventories, only the sector is listed below.

Inventory Name	Sectors	Subsectors Included	Proxy Datasets	Spatial Resolution	Year of Data	Source
CEDSv2021_04_21 (CEDS)	Total, Agriculture, Energy, Waste	• Electricity and heat production, fossil fuel fires, fuel production and transformation, oil and gas fugitive/flaring	Agriculture, transportation, energy, industry, and solvent production and application: EDGAR International shipping: ECLIPSE and additional data Waste: HYDE population, GPWv4 (modified rural population)	0.5° * 0.5°	2018	(McDuffie et al., 2020; Hoesly et al., 2018; O'Rouke et al., 2021b)
EDGARv6.0 (EDGAR)	Total, Agriculture, Energy, Waste	• Agricultural soils, agricultural waste burning, enteric fermentation • Power industry, fuel exploitation (coal, oil, gas), oil refineries and transformation • Solid waste incineration, solid waste landfills, wastewater handling	See Janssens-Maenhout et al., 2019 for more information	0.1° * 0.1°	2018	(Crippa et al., 2021a; Crippa et al., 2021b; Janssens-Maenhout et al., 2019)
GAINSv4/ECLIPSEv6b (GAINS)	Total, Agriculture, Energy, Waste	• Agriculture, agriculture waste burning on fields • Power plants, energy conversion, extraction		0.5° * 0.5°	2020	(Höglund-Isaksson, 2020)
GFEIv2 (GFEI)	Energy	• Coal exploitation, oil exploitation, gas exploitation	For the U.S. and China, coal, oil and gas spatial distribution are based on previous literature	0.1° * 0.1°	2018	(Scarpelli et al., 2022; Scarpelli et al., 2020)

S2: Policy Mapping Methodology

To evaluate existing methane mitigation policies in the U.S. and China for our full report, a total of over 4,000 policy documents from several policy databases were identified, which contain the keywords methane or methane emissions. Coalbed methane, coal mine methane and biogas, which are certain types of methane gas, were also considered as keywords as we found that they were particularly important to identify relevant Chinese policy documents (Table S2). From these over 4,000 documents, around 270 policy documents for each country were selected for further analysis based on the level of relevance and importance to methane mitigation. These policies were largely categorized based on policy instrument type and sector. Some of the policies address methane emissions in overarching contexts instead of specific sectors. In this case, they were either categorized in the climate change category (methane-specific or methane-included) if it was a policy document for climate change issues, or categorized in general sectoral categories including energy, agriculture, waste sectors or other. The sector for the policies did not often overlap. However, there were some overlaps in the policy instrument dimension because the same policy document can be categorized into different policy instrument types if multiple policy types exist in the same policy document.

Table S2: Data Sources and Selection

	U.S.	China
Total policies collected and reviewed*	>1,500	>3,000
Policies selected based on the level of relevance and importance	275	270
Policy types	• Acts, rules, executive orders, action plans, government-sponsored programs etc.	• Laws, administrative regulations, Five-Year Plans, other strategic plans, normative legal documents etc.
Data sources	• Proquest Congressional • U.S. Government Information (Govinfo) • Regulations.gov • Government websites	• PKU (Peking University) law database • Government websites
**Federal or central government policies. Keywords for screening and selection: methane, methane emissions, coalbed methane, coal mine methane, biogas. Bills were reviewed but not included in the current analysis.*		

S3: U.S.-China Methane Collaboration Readiness and Potential

Our analysis evaluated key methane mitigation sectors and opportunities for collaboration across the U.S. and China. We evaluated five major categories: climate change, energy, agriculture, waste and other. The major categories are further divided into subsectors, including coal mine, oil and gas, manure management, enteric fermentation, rice cultivation, landfills and wastewater, and/or by the level of relevance and importance to methane emissions reduction. For example, policies that directly and specifically address methane mitigation as a climate challenge are considered as the most relevant and important government actions to tackle this issue, such as the U.S. Methane Emissions Reduction Action Plan announced in 2021. It implies that methane has officially entered the national climate policy agenda and indicates a high level of national ambition. There are also policies that incorporate methane emissions content but are less specific to methane mitigation, such as the National Plan for Tackling Climate Change (2014 - 2020) of China.

Formula S3: Evaluating U.S.-China Collaboration

$$\text{Score} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \quad (1)$$

$$R_{score} = \frac{X_{i,r} - \min(X_r)}{\max(X_r) - \min(X_r)} \quad (2)$$

$$P_{score} = \frac{X_{i,p} \times EPA_{weighted} - \min(X_p \times EPA_{weighted})}{\max(X_p \times EPA_{weighted}) - \min(X_p \times EPA_{weighted})} \quad (3)$$

$$I_{score} = \frac{(X_{i,wb} + X_{i,cdm}) \times Coalition_{weighted} - \min[(X_{wb} + X_{cdm}) \times \text{Coalition}_{\text{weighted}}]}{\max[(X_{wb} + X_{cdm}) \times Coalition_{weighted}] - \min[(X_{wb} + X_{cdm}) \times Coalition_{weighted}]} \quad (4)$$

$$E_{score} = \frac{(X_{i,us} + X_{i,cn}) - \min(X_{us} + X_{cn})}{\max(X_{us} + X_{cn}) - \min(X_{us} + X_{cn})} \quad (5)$$

$$\text{Total}_{\text{score}} = \text{Sum}\ (R_{score}, P_{score}, I_{score}, E_{score}) \quad (6)$$

Where i refers to the sectoral dimension and j refers to the measurement dimension including research collaboration (r), GMI partnership (p), World Bank projects of China (w), CDM projects of China (c), U.S. sectoral methane emissions (us) and China sectoral methane emissions (cn). $EPA_{weighted}$ refers to whether the given sector had projects with EPA and $EPA_{weighted}$=2. $Coalition_{weighted}$ refers to whether the given sector is involved in any global industrial coalition and $Coalition_{weighted}$ =2.

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