Integrated Modeling & Development of Emission Scenarios for Methane and Key Indirect Greenhouse Gases

Final Report

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Final Technical Report

This report outlines main accomplishments to date on the development of Emission inventories and Scenarios for Key Indirect Greenhouse Gases (CO, VOCs, NOx) and methane supported by the Office of Science (BER), U.S. Department of Energy, Grant No. DOE-DE-FG02-02ER63463.

This research produced 3 journal articles, 1 book chapter, and 4 research articles/abstracts in conference proceedings. In addition, this grant supported two Ph.D students and one undergraduate student at UIUC

Tasks Accomplished

As originally proposed, first, we compared model-estimated direct emissions for CO, NMVOC and NOx emissions for recent years with the latest data available in the open literature concerning individual trace gas emission factors and emissions by source. This initial step helped us to define the areas most urgently requiring improved understanding of the actual magnitude of current emissions and our understanding of the forces driving those emissions. Then we reviewed the basic socio-economic and technological driving forces used in the development of the SRES storylines, as well as other prominent regional and global scenarios, and assessed their application to projections of CH_4, CO, NOx and NMVOCs. In this step we also reviewed the literature for new empirical studies that relate directly to understanding changes in the driving forces that affect emissions of methane and other short-lived gases that impact climate. Based on this literature research, we identified following areas that could give rise to inconsistencies and/or uncertainties in the emission estimates for CO, VOCs and NOx at the regional and global level:

(1) Energy and land use, the main sources and drivers of CO_2 emissions, are the primary focus of the SRES analysis. In contrast to energy-based CO_2 emissions, little research has been carried out to evaluate the influences of socio-economic and technological driving forces on long-term emission trends of gases, particularly the reactive gases from non-energy sectors.

(2) Energy-economic models used in the SRES analyses projected CH_4 and indirect GHG (CO, VOCs, and NOx) emissions on the basis of simple relationships to aggregate economic or sector-specific activity drivers. This may contribute to findings that SRES scenarios underestimate uncertainties in reactive gas emissions.

(3) Examining the contribution of anthropogenic emissions to uncertainty in future projections for CH_4, CO, NOx and NMHC/VOCs emissions, we found that SRES pathways tend to cover a smaller range of possible futures and be biased towards higher forcings (except for NOx, where the bias is in favor of lower forcings).

(4) Initial premises on which SRES non-CO_2 and indirect GHG projections were made also include two serious inconsistencies that have the potential to significantly alter

the actual climate impact of the scenarios. The first inconsistency is that projections of non-energy emissions were not entirely based on the same underlying factors as energy-related ones. This is due to the fact that the majority of models used in the SRES analysis do not include many of the major non-energy sources of non-CO_2 GHGs. The second inconsistency arises from an agreed-upon property of all SRES scenarios, that there be no intervention to control greenhouse gases. In contrast, regional controls on SO_2 emissions across the illustrative SRES scenarios lead to emissions in the last two decade of the century that are well below those of 1990 levels. There appear to be few controls on NOx, CO and NMHC/VOC emissions across all scenarios. However, the large increases in surface O_3 concentrations in SRES scenarios may be inconsistent with the SRES storylines that underpin the emission scenarios.

(5) Uncertainty in regional emissions and emission factors and activity levels for the major sources for CO, VOCs, and NOx are quite large. Reducing uncertainties in total future emissions can be achieved by: (i) improving data for current day budget; (ii) accounting for the strong dependence of forcing on location and timing of emissions; (iii) improving data for emission factors for indirect GHGs from fossil fuel combustion, in particular from road transport and power plants, and aircrafts; and (iv) improving data for activity data and emission factors for biogenic, soil, ocean, biomass burning, savanna burning, biofuel use, agriculture waste burning and deforestation.

In the following, the significant findings from the DOE-supported studies are outlined:

Determination of Present Day Emissions of Indirect Greenhouse Gases From Aircraft and Evaporative Emissions

Recent trends in aircraft emissions of reactive GHGs prove to be continuously increasing in both developed and developing countries. Current inventories and future scenarios combine aircraft emissions within the non-road transportation sector, however aircraft emissions and the growth of these emissions are quite unique, and grouping them within this sector does not allow for models to appropriately account for the continuing growth in air travel or the importance in altitudinal variations of indirect GHGs. Our study provides specific information on aircraft for 14 geo-political regions, allowing for aircraft emission estimates to be appropriately accounted for. By using information from the IEA Energy database and the MiniCAM model, and applying it to recent research, we have estimated base year emissions for the three reactive gases on a 0.5 x 0.5 grid scale. Our base year results show global NO_X emissions to be 2.98 Tg (NO_2/yr), global CO emissions to be 0.73 Tg (CO/yr), and 0.27 Tg (NMHC/yr). On a regional scale, our estimates are slightly higher than some estimates in developing countries. This is probably due to the fact that air travel is growing fastest in developing countries, and that the studies we are comparing data with have base year estimates around 1990. These inventories are designed to be used as inputs to socio-economics models to develop future emission scenarios and to atmospheric chemistry models for tropospheric chemistry studies for greenhouse gases, particularly for CH4 and tropospheric ozone.