Modeling of Methane Mitigation Options in US MARKAL

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Introduction

The US Environmental Protection Agency (EPA) is augmenting the EPA US-national MARKAL[1] model to include the ability to track methane emissions and assess mitigation strategies that interact with the energy system. This methane accounting sub-model includes emission sources and mitigation technologies in the following five methane subsystems:

1) Municipal waste and landfills;
2) Natural gas production, transmission/storage, and distribution;
3) Coal production;
4) Oil production, and
5) Manure management.

This paper describes the methane sub-model, the status of its calibration to historical data and EPA projections of methane emissions, and preliminary results from runs of the sub-model.

Methane Subsystem Descriptions

Data on historical and projected future methane emissions is developed from various EPA documents[2], the AEO 2002[3], and a few other sources[4]. The approach employed for modeling each of the five methane sectors is described below. In each sectors, the model simulates activities that produce methane, derives emission estimates from these activities, provides alternatives for handling the produced methane, and implements methane mitigation technologies as appropriate, based on least-cost and in response to policy constraints applied by the user.

Municipal Solid Waste (MSW) and Landfills

Methane emissions from landfills are divided into two time periods, pre-2005 and post-2005 emissions. Methane emissions from the pre-2005 landfills are based on the known amount of waste in place that is still active, and mitigation technologies that capture landfill gas are applied to emissions from these landfills. After 2005, mitigation options are expanded to include diversion of MSW to other types of uses such as composting, mechanical biological treatment, etc. The diagram in Figure 1 illustrates the post-2005 MSW structure.

Landfills are modeled as large, medium and small to account for different methane generation rates and the applicability of the Landfill Rule[5] to large and medium landfills. Because MSW deposited in landfills will generate methane over a 30-year period the post-2005 landfills are modeled to accept a one-time input of MSW which continues to generate methane for their full lifetime (30-years). Characteristics for the MSW and landfill gas mitigation technologies were developed from EPA and other sources[6].

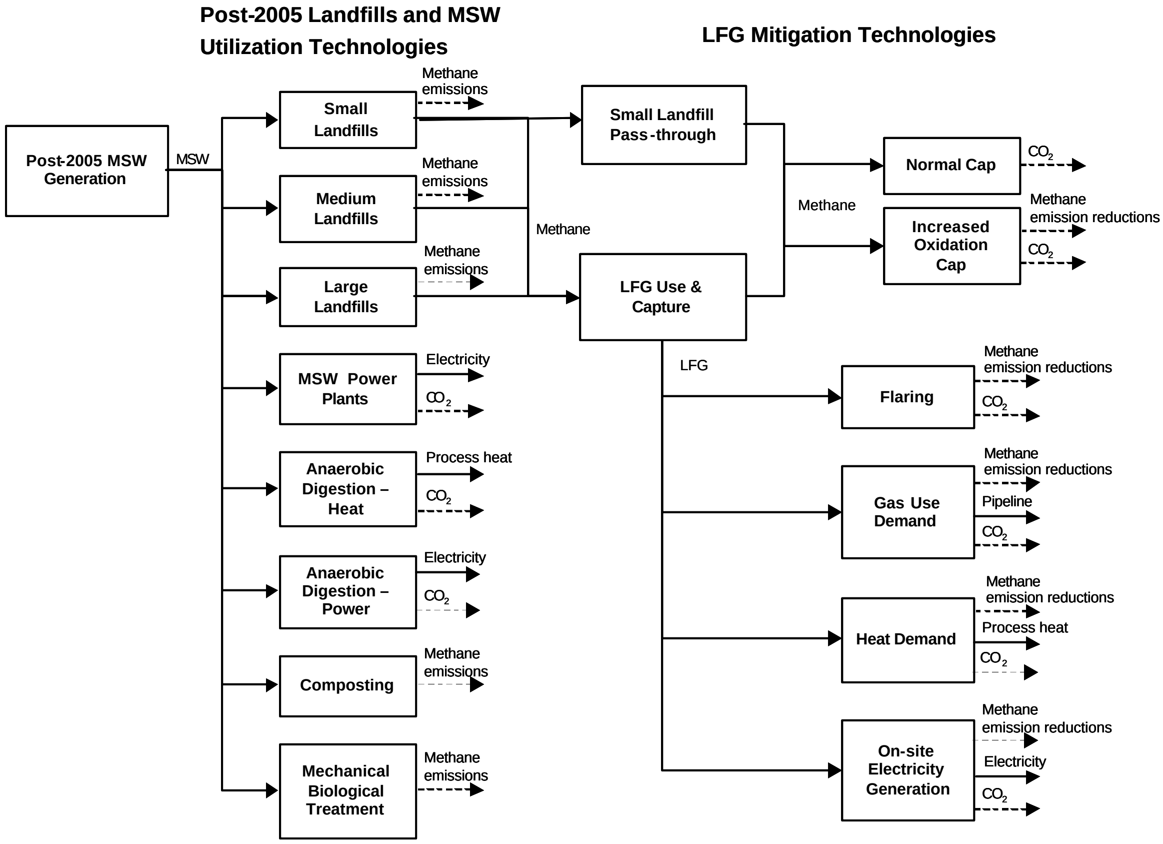

Figure 1: Flow Diagram for New MSW Utilization and LFG Mitigation

As illustrated in Figure 1, waste flows into a choice of small landfills, medium-sized landfills, large landfills or several possible utilization technologies including power plants, anaerobic digestion (heat and power), composting or mechanical biological treatment. Landfill gas (LFG) that is generated in the landfills can either be ignored (leading to emissions), or it may be captured and used by technologies including flaring, on-site heat demand or electricity generation, or off-site gas use (normally in industrial boilers). Reductions can also occur by using a more effective (increased oxidation) landfill cap.

Coal Mining

Figure 2 shows the methodology used to model coal mining emissions and the mitigation options for coal mining. Methane emissions from production and transport of surface-mined coal are accounted for, but have no mitigation options.

Underground-mined coal has several mitigation options including degasification before mining and ventilation air methane capture and use.

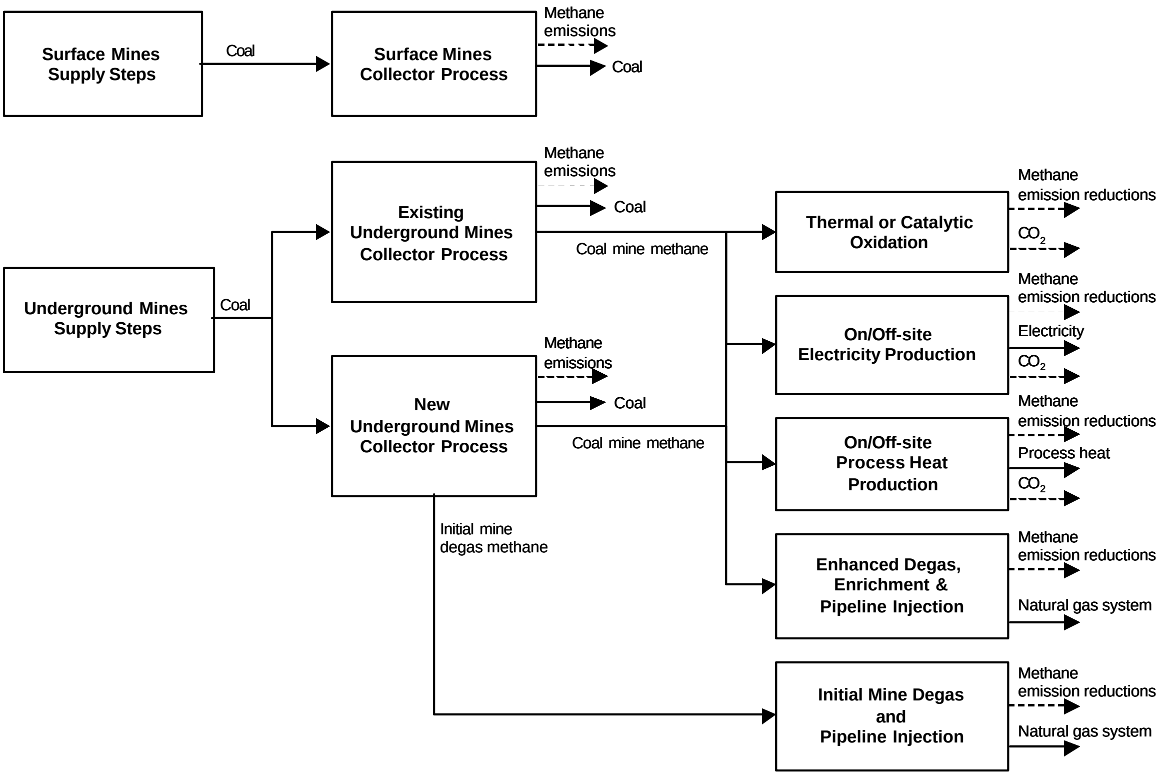

Figure 2: Flow Diagram for Coal Mine Methane Emissions and Mitigation Options Example: Appalachian Underground High Sulfur Coal

Natural Gas Production, Transmission and Distribution

All three major subsectors of natural gas use were modeled: domestic gas production, transport and storage of domestic and imported natural gas, and distribution to end-users. Each of the major subsectors (production, transmission and distribution) is modeled separately, though fully inter-connected, as is shown in Figure 3. Each subsector is elaborated in a detailed framework as illustrated in Figure 4. Within each subsector, mitigation technologies specific to that subsector are implemented in series allowing competing and complimentary options to be implemented.

Imported gas and other pipeline quality gas (e.g. from coal mining) are introduced into the natural gas sector after the production process. Methane that is captured in the natural gas system by mitigation technologies is added back to the flow in the next subsector of the natural gas system.

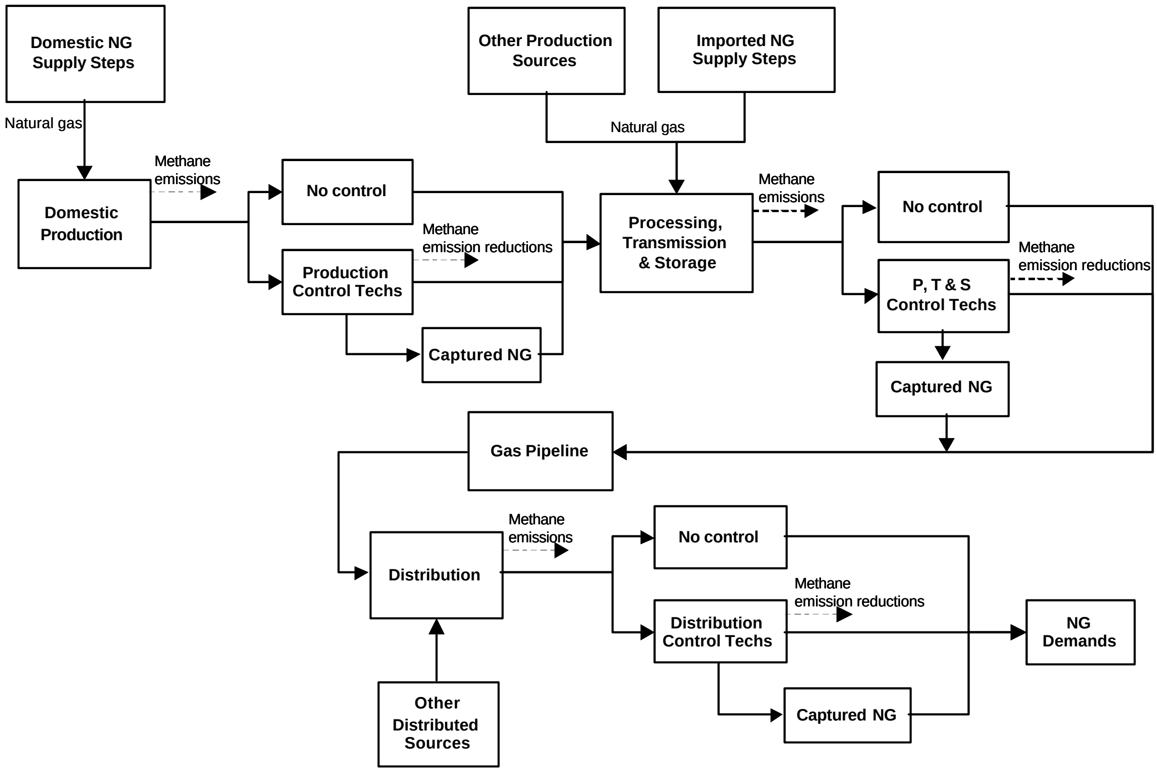

Figure 3: Detail Flow Diagram for the Overall Natural Gas Subsystem

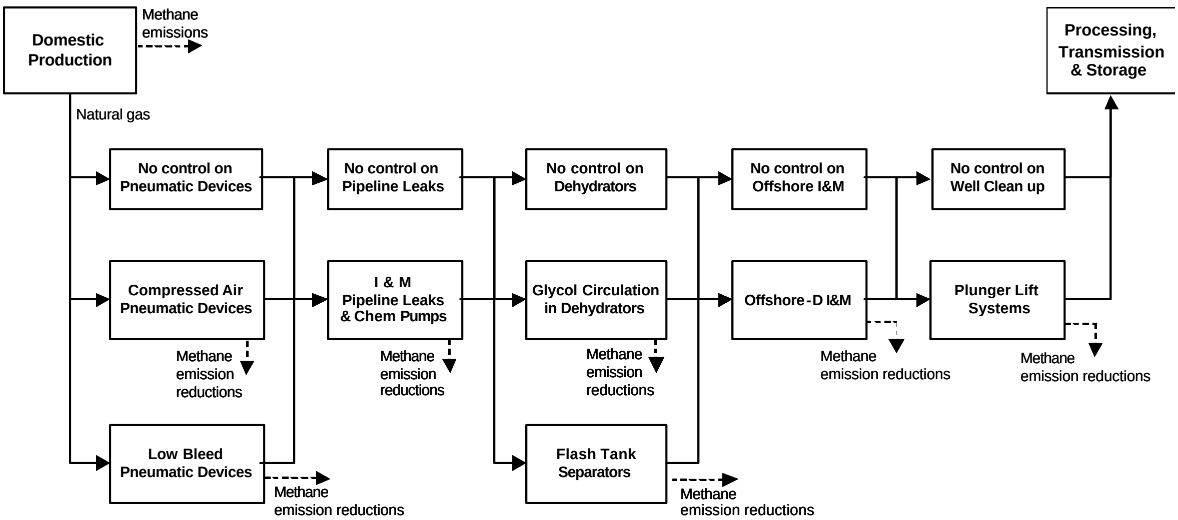

Figure 4: Flow Diagram for Mitigation Options in the Natural Gas Production Subsector

Manure Treatment

Methane emissions from livestock manure management are generated from the anaerobic decomposition of the manure and are dependent on three principal factors:

the manure source, the manure management system and the emission mitigation technology. Because liquid management systems promote anaerobic processes that generate methane, while dry management systems maintain greater exposure of the manure to air and do not promote methane generation, the manure sources were grouped according to their likelihood of using liquid or slurry management systems.

Dairy cows and swine were modeled as the dominant manure sources that could use liquid manure management systems, and all other livestock were modeled as using dry treatment systems. The methane emissions from dry treatment have no mitigation options, while the liquid management systems have several options available. As in the above sectors, once waste flow was divided between liquid or slurry management, the appropriate mitigation technologies are applied.

Oil Production

Only emissions and mitigation options from domestic oil production are modeled. Domestic oil is segregated into on-shore and off-shore production, so that different mitigation options can be applied appropriately. The structure of the oil production sector is similar to what was described previously for the natural gas sector.

Model Calibration

In the first model run the methane mitigation options were inactivated to allow calibration of 1995 and 2000 to the EPA methane inventory, and comparison of the model's projected emissions to the EPA baseline projections. As can be seen in Figure 5 the current calibration of the methane from the coal, oil and manure closely matches that of EPA, while the estimates diverge some for landfills and natural gas starting in 2005. We are currently exploring the various factors that may be contributing to this difference. For landfills this includes considering the assumed linear decay rate for emissions from existing landfills, the projected amount of MSW going to landfills, and assumptions as to the landfill gas power plants in place now..

Natural gas emissions in the model are higher compared to the EPA projections due to higher projected demand for natural gas in the MARKAL model. Oil production emissions from the model are in line with the EPA baseline projections. Further refinement in the oil sector could be achieved by adding in the transportation and refining emissions, which we currently do not model.

Emissions from coal mining are slightly higher in 1995 and 2000 because coal production calculated by MARKAL is higher than the actual production level. The coal production numbers in MARKAL will be adjusted to match actual production numbers. Emissions in this sector after 2005 vary from the EPA baseline slightly. The assumed proportion of future underground mining as a proportion of total production is being reviewed.

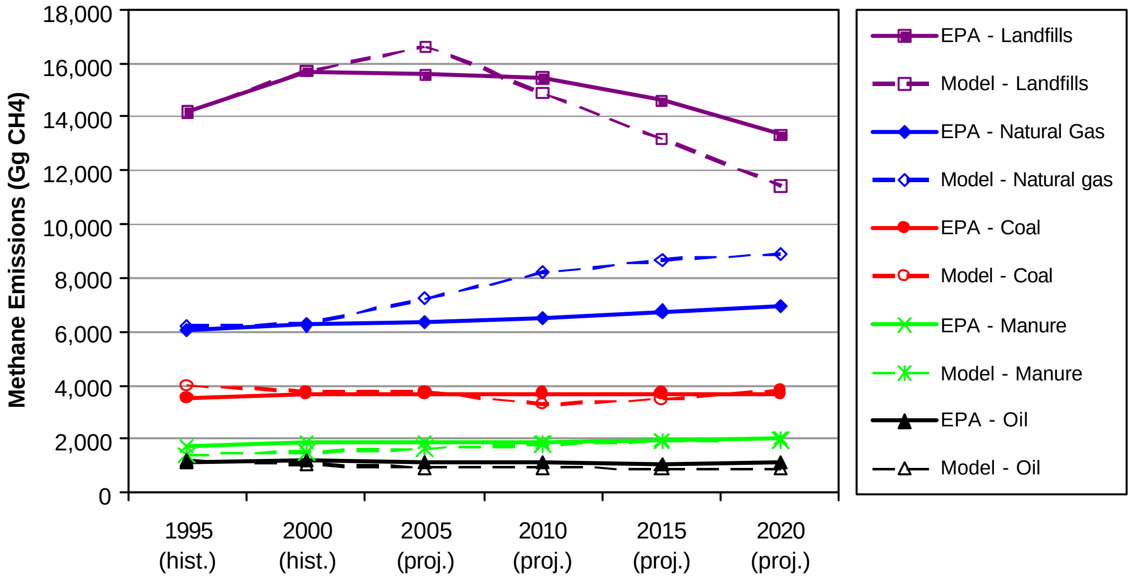

Figure 5: Methane Subsystem Calibration to EPA Baseline Projections

Manure management emissions predicted by the model are slightly lower than the EPA baseline emissions. This is likely due to the assumptions made about the number of liquid treatment systems, such as the decision to ignore the portion of poultry manure that goes to liquid treatment systems and the split between cattle/swine and solid/liquid treatment systems.

All these open assumptions will be finalized before conducting actual runs with the model, but to test the behavior of the various subsystems this partially calibrated model was exercised, as discussed in the next section.

Preliminary Results of Methane Mitigation Runs

In addition to the model calibration run, where the methane mitigation options were not active, several mitigation scenarios were run to test the model's implementation of various methane reduction options. In the reference mitigation scenario, shown in Figure 6, the model was free to select those methane mitigation options it considered cost-effective. In this reference case, the methane mitigation options selected included on-site electricity generation using MSW and LFG, dry seals on centrifugal compressors used in natural gas production, some coal mine degasification, and farm-scale electricity generation using manure digester technology.

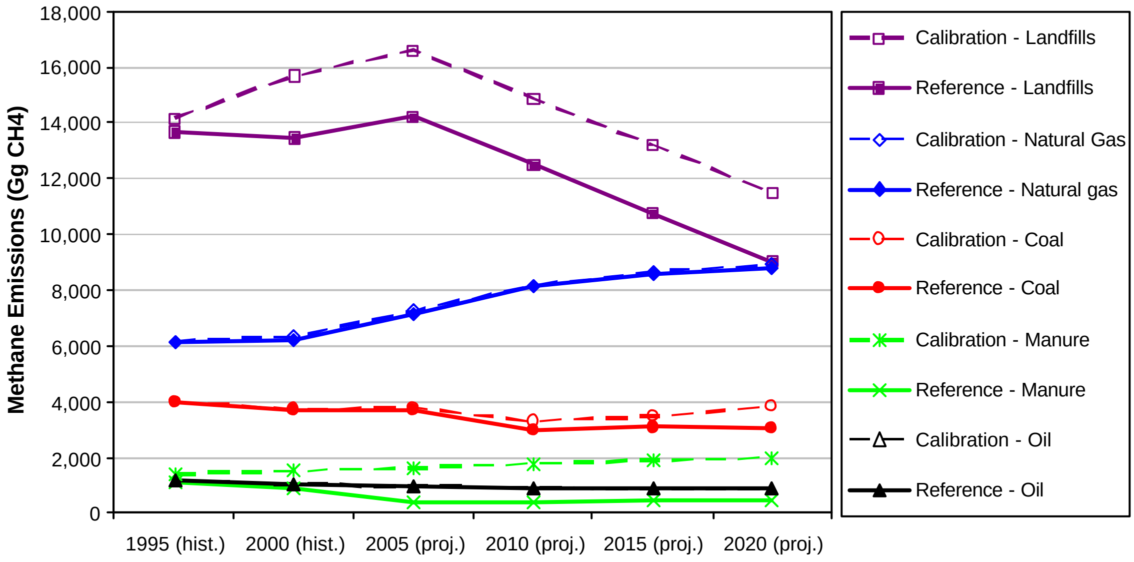

Figure 6: Preliminary Methane Scenario Reference Results (No Emission Constraints)

Three additional scenario runs were then made in which methane emissions were reduced 10%, 15% and 20% below the level in the reference case. The result of these reduction runs were used for two purposes.

First, they highlighted several issues that to be addressed in future work. For example, domestic production from some coal supply steps changes because the model shifts some coal production from existing mines to new mines so as to reduce emissions and capture gas for the energy system. Also, most of the mitigation options are being selected from the MSW/landfill and manure sectors. Very little mitigation takes place in the natural gas sector beyond the initial cost-effective options, and virtually no mitigation options are selected in the oil sector. The causes and implications of these issues will be further explored with the support of technical experts within EPA.

Second, the results of these reduction runs were used to generate a very preliminary continuous emission cost curve, which indicates that the modeling of the methane sub-model is sound and behaves, from a modeling perspective, as expected. Eventually, the model will be tailored to provide such mitigation cost information in a variety of formats.

Conclusion and Next Steps

This paper shows that this Methane sub-model to the EPA US-national MARKAL model is able to handle the complexities of the methane emission sectors and their interactions with the energy system. The model development is not complete, and more work will be performed this year to complete methane scenario calibration and to refine the mitigation technology characterizations. In addition, the accounting of

CO_2 in the EPA national model will be calibrated and broken down to the sectoral level so that analysis with the methane sub-model can be based on setting targets for CH_4 mitigation only or for mitigation of both CO_2 and CH_4 on a global warming potential basis. Finally, a mitigation analyses will be performed to determine how best to apply the model in support of EPA objectives.

References

[1] See www.etsap.org for a summary of MARKAL, its applications and its user community.

[2] U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions, USEPA Office of Air and Radiation, EPA-430-R-99-013, September 1999.

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Draft report, International Mitigation of Adipic and Nitric Acid Emissions, ICF 2002.

[3] Annual Energy Outlook 2002 with Projections to 2020, US Energy Information Administration, DOE/EIA-0383(2002), December 2001.

[4] Technical and Economic Assessment: Mitigation of Methane Emissions from Coal Mine Ventilation Air, USEPA, Office of Air and Radiation, EPA-430-R-001, February 2000.

[5] The U.S. Landfill Rule requires landfills with a certain level of waste-in-place to flare landfill gas in order to control for Volatile Organic Compounds (VOCs).

[6] Judith Bates and Ann Haworth, "Economic Evaluation of Emission Reductions of Methane in the Waste Sector in the EU: Bottom-up Analysis," Final Report (Updated version), AEA Technology Environment, March 2001.