NARA Supply Chain Emissions: Impacts on Air Quality in the Pacific Northwest
Current Status and Future Work

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Introduction

As a forest management practice, and to reduce potential catastrophic forest fires, the residue from harvesting activities is conventionally burned for removal. Under the NARA program, this residue will be harvested for use as a feedstock which will reduce the need for biomass burning and the resulting air pollutant emissions. At the same time, emissions from the supply chain and, specifically, the biorefinery, will result in new air pollutant sources. Progress on the assessment of the air quality impacts of the NARA supply chain are presented. First, the impacts of the prescribed fires on $PM_{2.5}$, and ozone are presented. We also show the improvements in model performance when prescribed fire emissions are included. The regional air quality modeling system, called AIRPACT-4 (based on WRF, SMOKE, CMAQ) , is used for this analysis. Second, initial compilation of the emissions from a biorefinery are described and an approach for future analyses is presented.

Objectives

- To assess the environmental benefits associated with biomass harvesting (i.e. prevention of biomass burning) for biofuel feedstock
- Assessing model performance improvement when prescribed fire emissions are included
- Quantifying and estimating emissions from the NARA biorefinery

Methods

- Prescribed fire emissions for the model domain were extracted from the National Fire Emission Inventory (NFEI) 2011 available from the US EPA.
- An analysis of the fire emission data shows that emissions peak during the months of October and November (Figure1).
- Model simulations were completed for the period 10 October – 15 November, 2011 for three different emission scenarios:
  - **100% Fire (with fire) Case:** includes all the fire emissions as per NFEI 2011
  - **30% Fire Case:** includes all the fire sources as per NFEI 2011, but all fire emissions (& heat flux) uniformly reduced by 70%
  - **No Fire Case:** none of the fires from NFEI 2011 were included
- Performance metrics including the Mean Fractional Bias (MFB) and Mean Fractional Error (MFE) along with Mean Bias (MB) and Mean Error (ME) are used for evaluation of the model performance.

$$\mathrm{MFE}=\frac{1}{\mathrm{N}}\sum_{i=1}^{N}\frac{(C_m-C_o)}{\frac{(C_o+C_m)}{2}},\ \mathrm{MFE}=\frac{1}{\mathrm{N}}\sum_{i=1}^{N}\frac{|C_m-C_o|}{\frac{(C_o+C_m)}{2}},\ \mathrm{MB}=\frac{1}{\mathrm{N}}\sum_{i=1}^{N}(C_m-C_o),\ \mathrm{ME}=\frac{1}{\mathrm{N}}\sum_{i=1}^{N}|C_m-C_o|$$

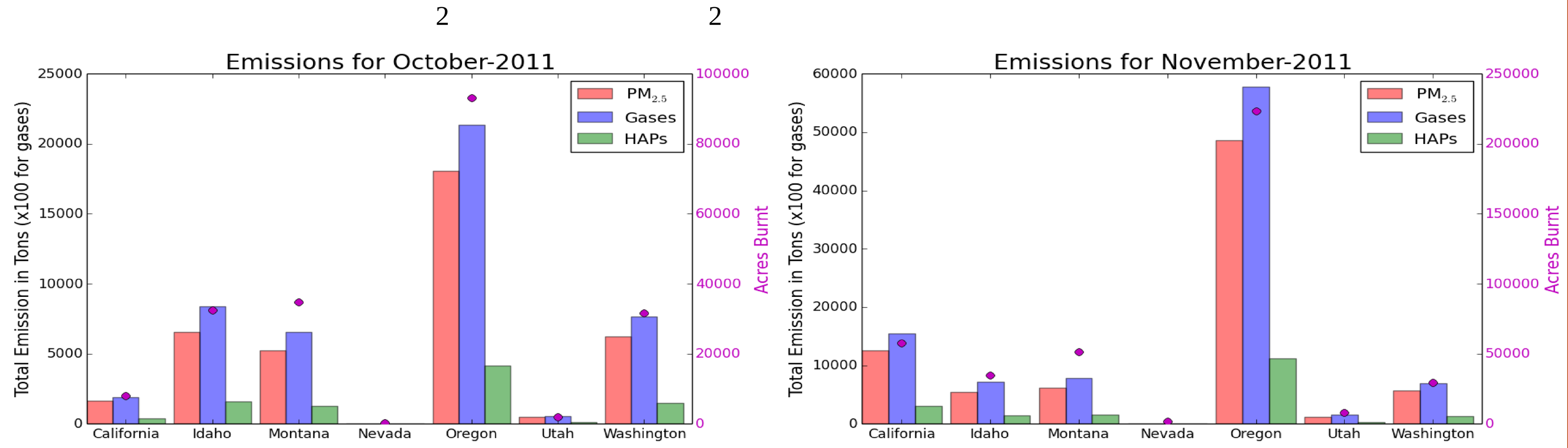

Figure 1: Prescribed fire emissions (bars) and acres burend (dots) for the AIRPACT-4 domain as per NFEI 2011.

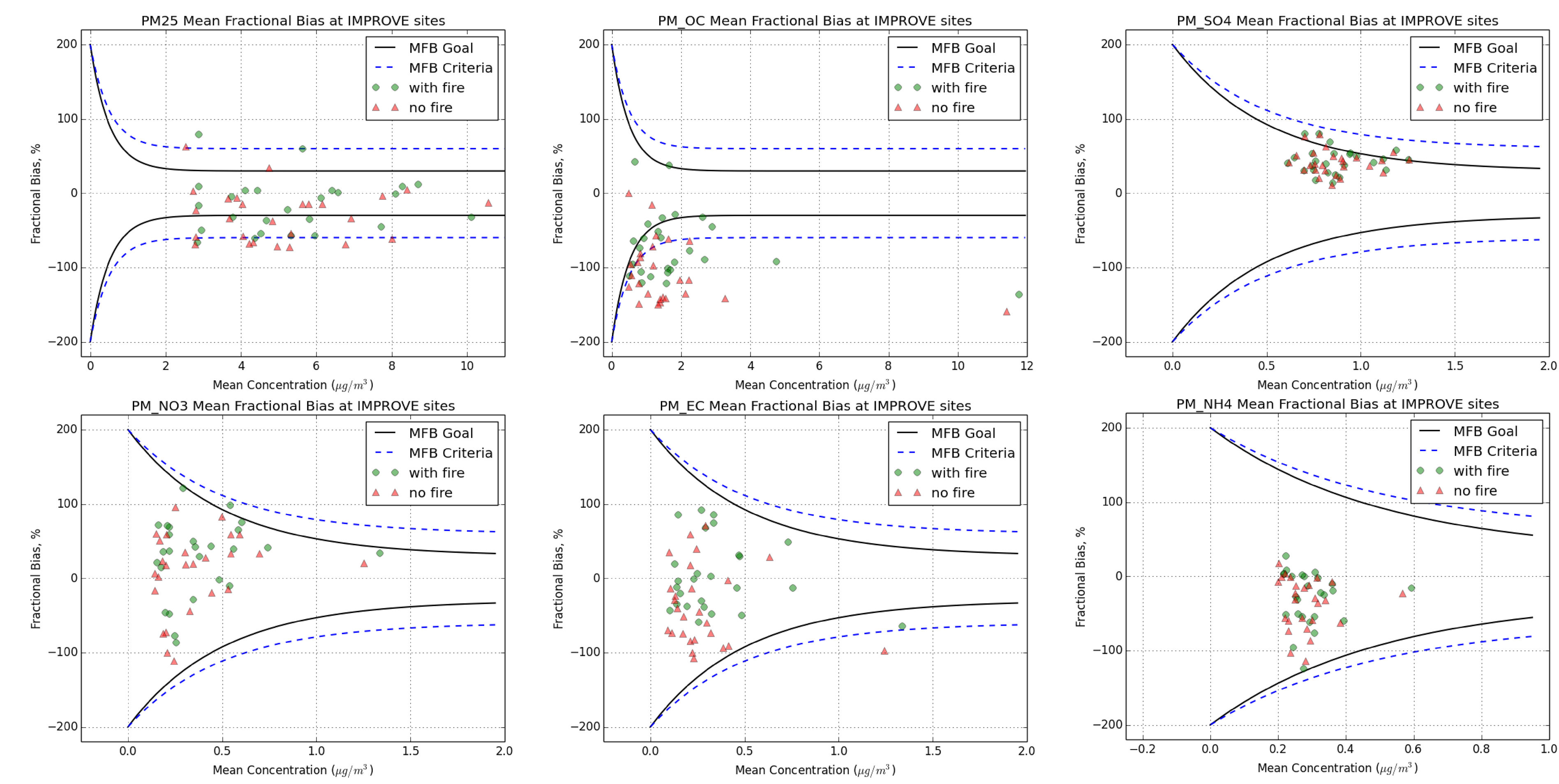

Figure 2: (clockwise from top left) Model performance evaluation for total $PM_{2.5}$ mass, Organic Carbon (OC), Sulfate ion, Ammonium ion, Elemental Carbon (EC) and Nitrate ion. Speciated observations are from 26 IMPROVE network sites in WA, OR, ID, MT, & CA. MFB for each species is compared against "goals" (best accuracy a model can achieve) and "criteria" (acceptable level of accuracy). Inclusion of prescribed fire emissions results in significant improvement of model performance for organic carbon and total $PM_{2.5}$. For OC, only 6 sites are within criteria in "no fire case, whereas 14 sites satisfy criteria in "with fire" case. This also translates to all except 2 sites satisfying criteria for $PM_{2.5}$ in "with fire" case compared to "no fire" case where 8 sites are outside criteria. For NO^-_3 and EC, an increasing trend in MFB is observed for almost all sites. MFB for EC, NO^-_3, NH^+_4, and SO_4^{2-} are within criteria for almost all the sites.

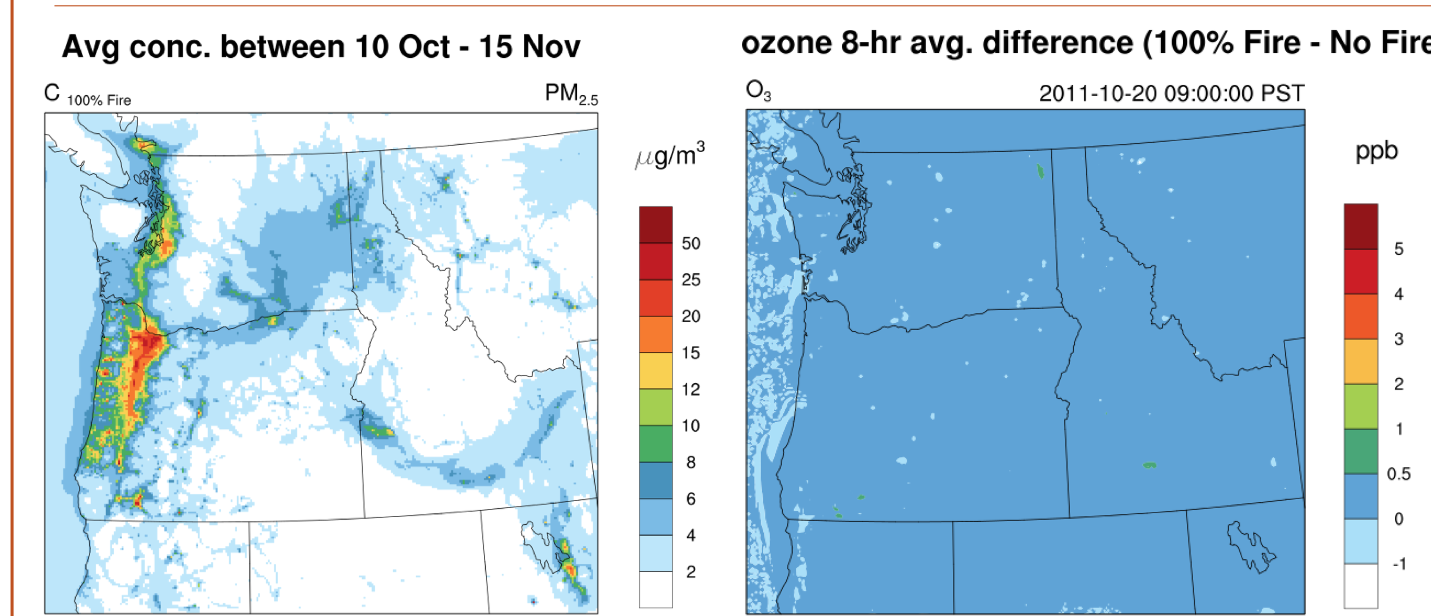

Figure 3
Key air quality issues in the Pacific Northwest are $PM_{2.5}$ and Ozone. Average $PM_{2.5}$ (averaged over the study period) can be much higher than 12 μg/m³ (Annual National Ambient Air Quality Standard, NAAQS). Also shown is the 8-hour average difference in ozone between 100% Fire and No-Fire case for a single day. Prescribed fire emissions do not cause a significant changes in O_3 concentration in this study.

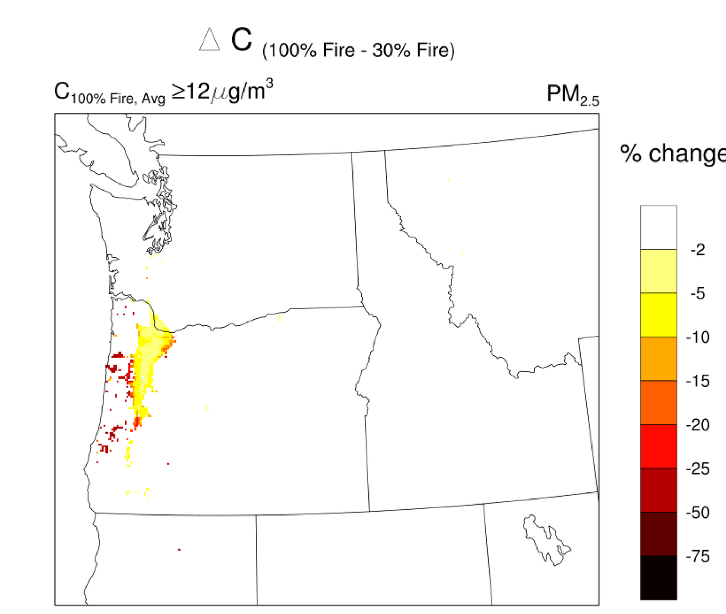

Figure 4 shows the % change in $PM_{2.5}$ concentration when all the fire emissions are uniformly reduced by 70%. Results for only those model grid cells where $PM_{2.5}$ concentration for 100% fire case is greater than 12 μg/m³ are shown.

For supply chain modeling, we will consider two scenarios:

- **Scenario I-** AIRPACT emissions for area, point and mobile sources + all prescribed fire emissions
- **Scenario II-** AIRPACT emissions + reduced prescribed fires + emissions from biorefinery

The final modeling exercise will not include emissions from various transportation components.

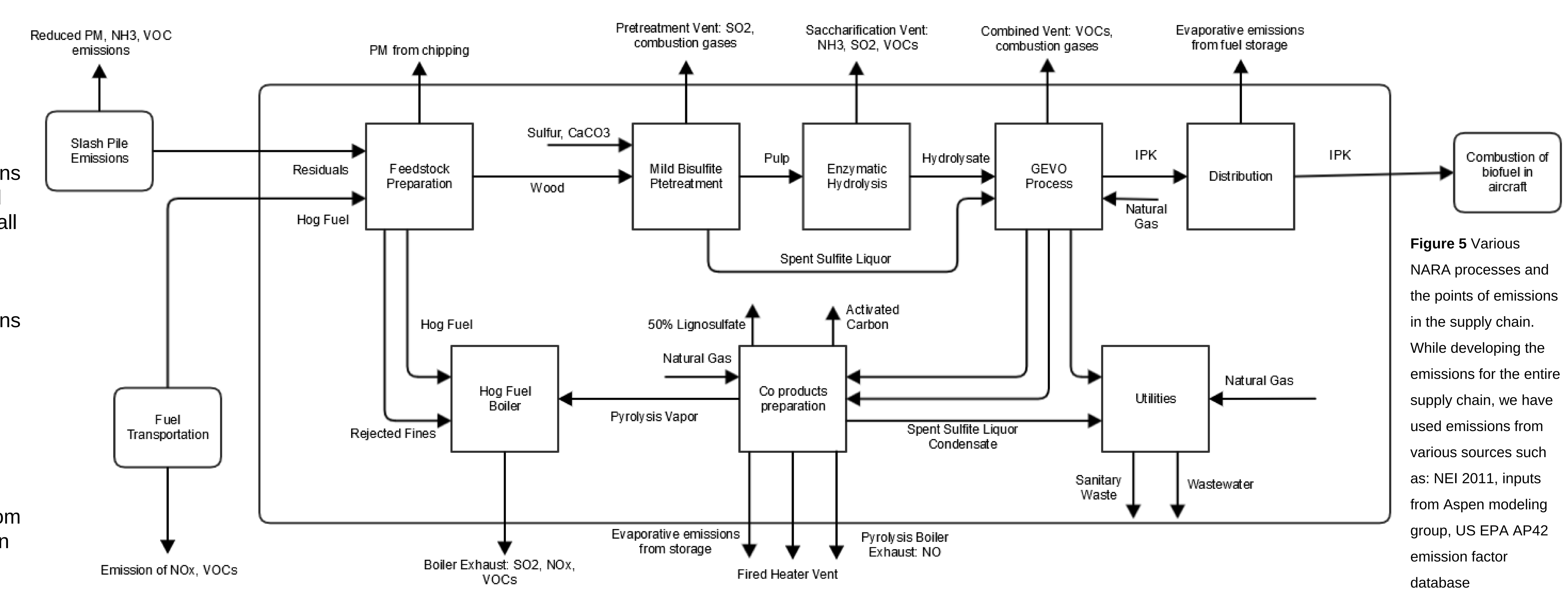

Figure 5 Various NARA processes and the points of emissions in the supply chain. While developing the emissions for the entire supply chain, we have used emissions from various sources such as: NEI 2011, inputs from Aspen modeling group, US EPA AP42 emission factor database

Conclusions

- Most prescribed fire emissions occur during October and November, with Oregon emitting the most among all the PNW states (within the AIRPACT-4 domain).
- Model performance is within EPA criteria for elemental carbon, nitrate, sulfate, and ammonium aerosols for all sites. Significant improvement in model performance is seen for total $PM_{2.5}$ and organic carbon when compared against observation data from IMPROVE sites.
- AIRPACT-4 simulations show that the impact on O_3 is negligible for the period of simulation, with some large prescribed fires contributing 0.5ppb - 1ppb.
- Under a scenario of 70% decrease in fire emissions (for biomass harvesting for biofuels), we could see significant decrease in 37-day averaged $PM_{2.5}$ concentration. This decrease is mostly for areas in Oregon, where most fire emissions take place. This is an indication of potential benefits of biomass harvesting for a biofuel industry.

Planned work – Emissions from various NARA processes have been developed and as a next step we will undertake the simulation of the entire supply chain under two different scenarios as described above for an extended period of time and analyzing different scenarios to assess the impact of NARA supply chain on the air quality

References

- Achtemeier, G. L., Goodrick, S. A., Liu, Y., Garcia-Menendez, F., Hu, Y., & Odman, M. T. (2011). Modeling smoke plume-rise and dispersion from southern United States prescribed burns with Daysmoke. *Atmosphere*, *2*(3), 358-388.
- Boylan, J. W., & Russell, A. G. (2006). PM and light extinction model performance metrics, goals, and criteria for three-dimensional air quality models. *Atmospheric Environment*, *40*(26), 4946-4959.
- Emmons, L. K., et al., Description and evaluation of the Model for Ozone and Related chemical Tracers, version 4 (MOZART-4), (2010) Geosci. Model Dev., 3, 43-67.
- Byun D. W. and Ching J.K.S. (editors). "Science Algorithms of the EPA Models-3 Community Multiscale Air Quality Modelling (CMAQ) System". Accessed from USEPA website: http://www.epa.gov/amad/CMAQ/CMAQdocumentation.html

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NARA
Northwest Advanced Renewables Alliance

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