



# Data-Driven Modeling of Spatially Explicit Air Pollutant Inventories for Agricultural and Forestry Feedstock Production

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2019 International Emissions Inventory Conference

August 2, 2019

# Background: FPEAM 2.0

- Feedstock Production Emissions to Air Model calculates criteria air pollutants generated during biomass feedstock production and transportation
- Python codebase initially developed in 2014, revised and expanded for the 2016 update to DOE's Billion Ton Report
- Refactored and expanded since 2017 to increase utility to air pollutant and air quality analysts
  - Data-driven structure ensures modeling flexibility and user control over scenarios
  - Modular code base makes future expansions, updates easy to implement for developers and for users

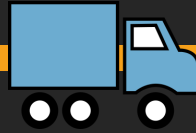
# FPEAM Scope

Agricultural Operations

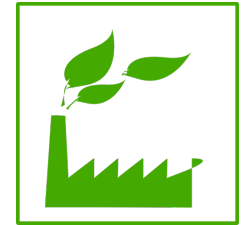


Forestry Operations

Backhauling



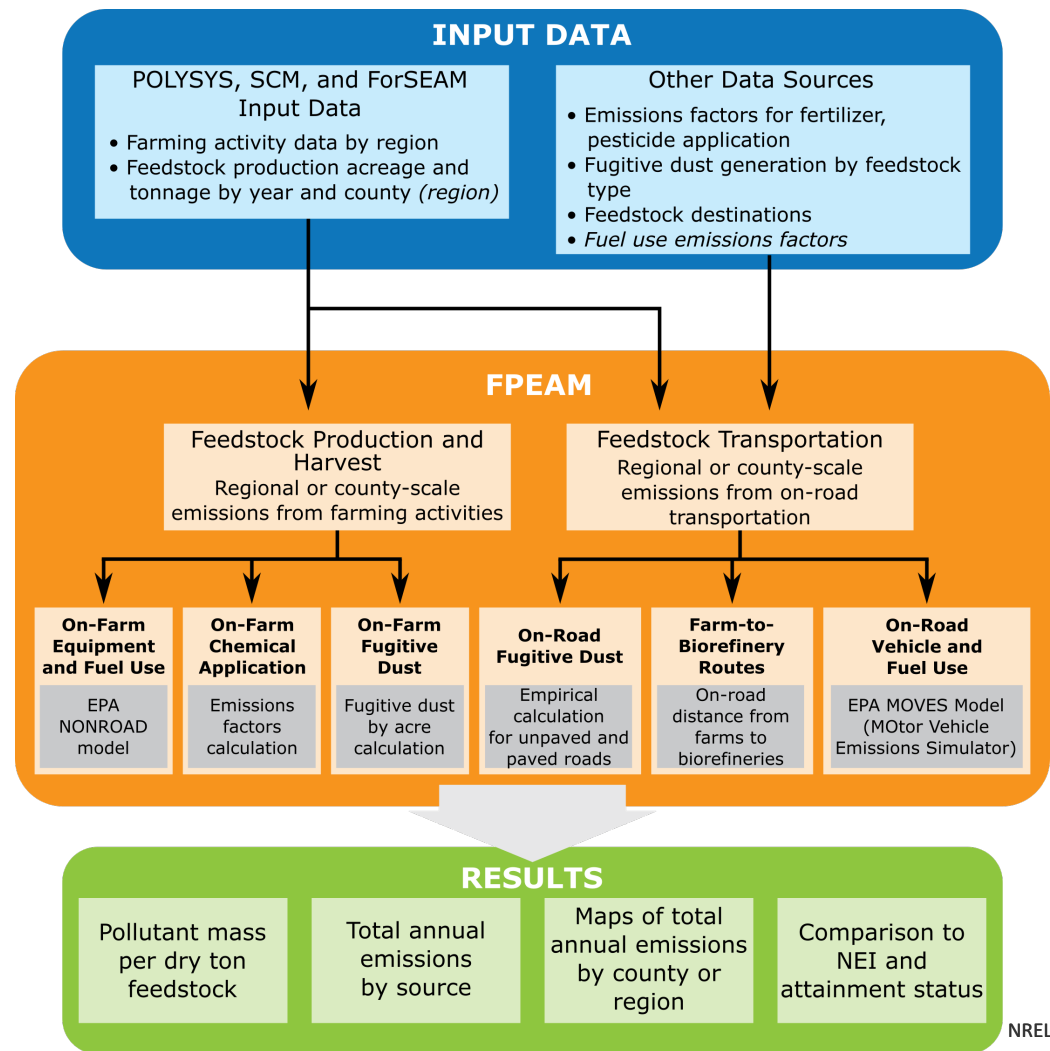
Feedstock Transportation



Biorefinery  
*(out of scope  
for FPEAM)*

# FPEAM 2.0 Model Structure

Module	Pollutant Process
MOVES	On-road feedstock transportation
NONROAD	Agricultural and forestry equipment use
Fugitive Dust	On-farm and on-road feedstock transportation
Emission Factors	On-farm chemical application



# Default Inputs and Outputs

## Feedstock Parameters

- Production: Where, what, how, how much
- Acreage planted, amount produced, amount harvested, yield per acre

## On-Farm Activities

- Agricultural and forestry equipment and resource use
- Fugitive dust generation per acre by feedstock type
- Emission factors for fertilizer and pesticide application
- Feedstock dry matter loss factors

## On-Road Activities

- Transportation vehicle parameters
- Parameters for calculating on-road fugitive dust

## Emissions Inventory

- Seven criteria air pollutants and precursors by county, feedstock, tillage type, and pollutant process

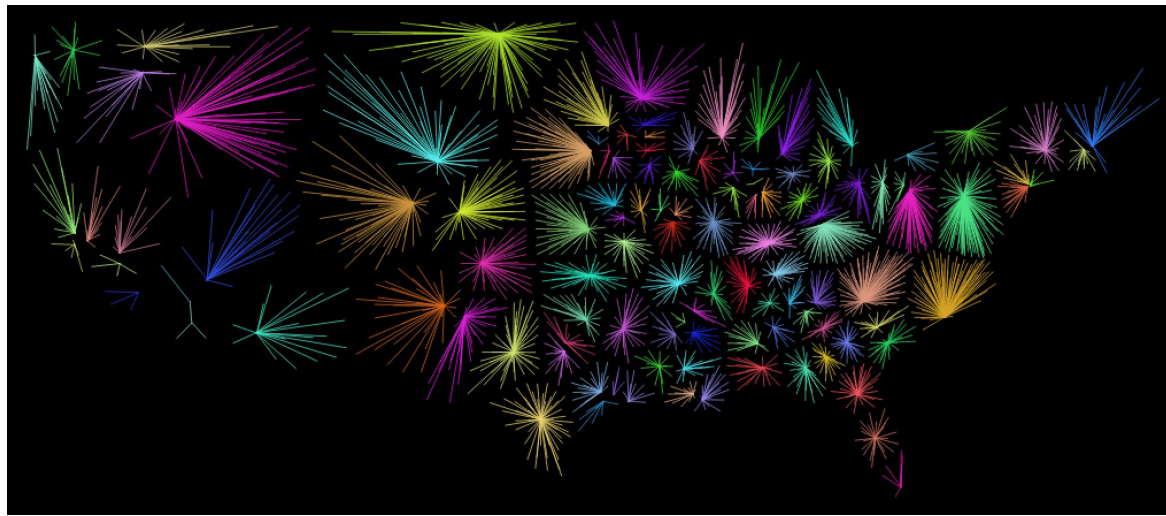
# Modules

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Router Engine, MOVES, NONROAD,  
Fugitive Dust, Emission Factors, and  
Postprocessing and Results

# Router Engine

[Global Roads Open Access  
Data Sets \(gROADS\) v1](#)

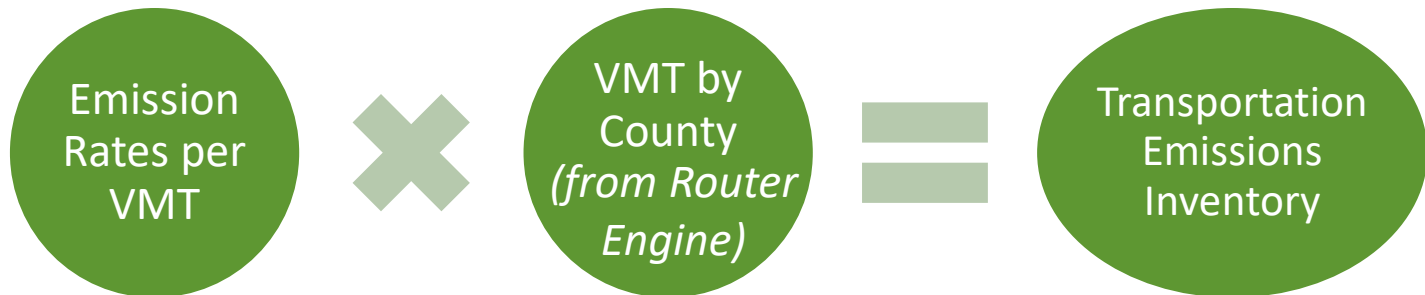


- Input data specifies feedstock production latitude/longitude pairs and biorefinery latitude/longitude pairs
- Routing module finds shortest path between origin and destination via major paved roads
- Outputs VMT by county, for every county through which feedstocks are transported including production and destination counties

# MOVES



- Motor Vehicle Emission Simulator, developed by the U.S. EPA, simulates mobile pollutant sources at various spatial scales
- MOVES module creates input files and calls MOVES in batch mode to calculate emission factors at a county level
  - Optional aggregation of feedstock production data can keep FPEAM run time down





# NONROAD



- Emissions simulator developed by the U.S. EPA for off-road mobile sources
  - Packaged with MOVES
- Used for emissions from agricultural and forestry equipment and fuel use
  - Combines, tractors, chemical applicators, irrigation pumps, loaders, wood chippers, and others
- Equipment use rates combine with emission factors to calculate pollutant inventories for on-farm and forestry equipment use

# Fugitive Dust

- PM<sub>2.5</sub> and PM<sub>10</sub> generated from on-farm agricultural equipment operation and from biomass transportation over unpaved and paved roads

Road Type	Equation	Parameters
Unpaved	$T d_{unp} k_{unp,p} \left( \frac{S_{st}}{12} \right)^{A_{unp,p}} \left( \frac{W}{3} \right)^{B_{unp,p}}$	<ul style="list-style-type: none"> <li>• <math>T</math>: trips (includes backhauling)</li> <li>• <math>d_r</math>: vehicle miles traveled on road type <math>r</math></li> <li>• <math>k_{rp}, A_{rp}, B_{rp}</math>: Empirical constants for road type <math>r</math> and pollutant <math>p</math></li> </ul>
Paved	$T d_{pav} k_{pav,p} S_L^{A_{pav,p}} W^{B_{pav,p}}$	<ul style="list-style-type: none"> <li>• <math>W</math>: Average vehicle weight</li> <li>• <math>S_{st}</math>: Surface material silt content for unpaved roads, by state</li> <li>• <math>S_L</math>: Silt loading on paved roads (constant)</li> </ul>

# Emission Factors

- $\text{NH}_3$ ,  $\text{NO}_x$  from nitrogenous fertilizers and VOCs from herbicides and pesticides applied to agricultural land
- Additional pollutants and resources may be included with the use of custom emission factors and/or resource use data



# Postprocessing and Results

- Inventories from MOVES, NONROAD, Fugitive Dust and Emission Factors are combined into one pollutant inventory for the scenario
- Completely disaggregated results are returned as CSV files and Pandas DataFrames
  - Pollutants are categorized by feedstock, tillage type, production and transportation regions, and pollutant processes
- Basic results summaries are also returned
  - Total pollutants by region, total pollutants by feedstock

# Workflow and User Interface

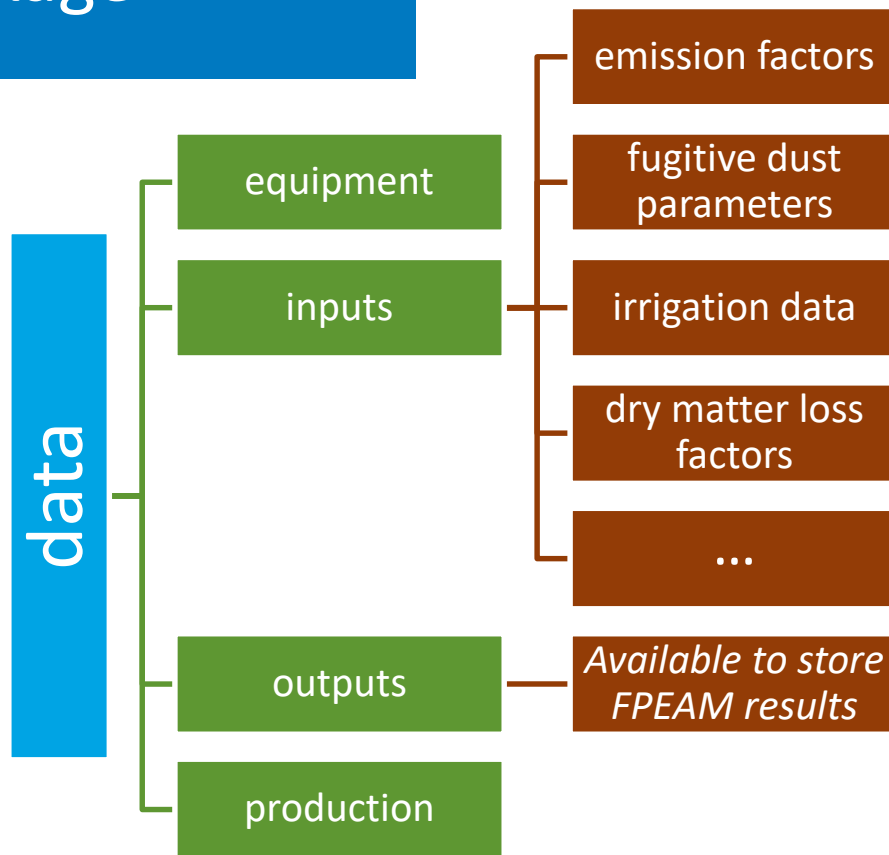
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How do I use FPEAM to calculate pollutant inventories?

# Default Data Package

All data necessary to run default FPEAM scenarios is packaged and released with the FPEAM code base.

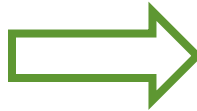
These data files can be edited or replaced by users to run custom scenarios.



# Graphical User Interface

- FPEAM requires around 20 input data files and several dozen user-specified parameters to run
- A GUI eliminates the need to use config files and command line syntax

```
1 [moves]
2
3 ### MOVES application options
4 moves_path = 'C:\MOVES2014b'
5
6 ### MOVES database connection options
7 moves_database = 'movesdb20180517'
8 moves_output_db = 'moves_output_db'
9 moves_db_pass = 'root'
10
11 moves_by_state = True
12 moves_by_state_and_feedstock = False
13
14 use_cached_results = True
```



FPEAM

FPEAM MOVES NONROAD EMISSION FACTORS FUGITIVE DUST

Aggregation Level  Moves By Each County  Moves By State  Moves By State and Feedstock

Cached Result usage Yes

Feedstock Measure Type Production

Moves Path  Default  Custom

VMT per Truck 20

No of Trucks used 1

Year 2017

Timestamp

Month 10

Date 5

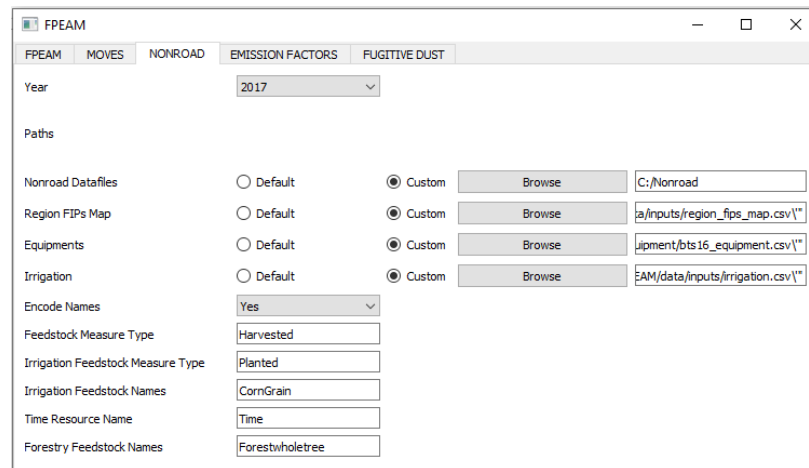
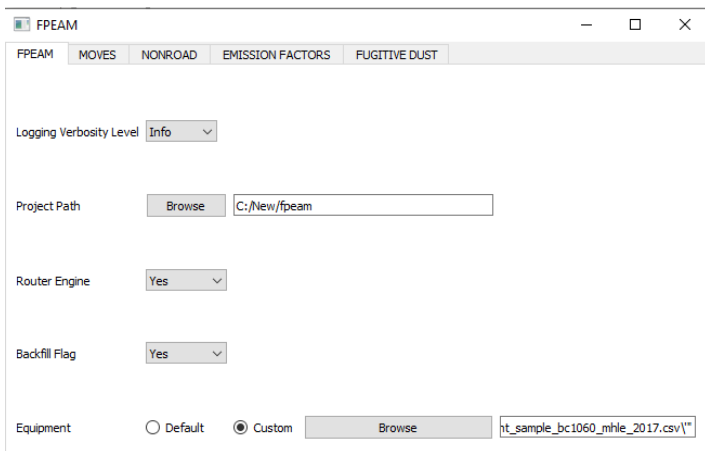
Beginning Hour 7

Ending Hour 7

Day type 5

Image credit: Snehal Talole

# Graphical User Interface



- Run default FPEAM scenarios with two or three clicks
- Easily and intuitively specify custom datasets and input parameters for each module



# Example Use Cases

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What can FPEAM do?

# Generate Inputs to Air Quality Model



- Code is being developed that will transform FPEAM results files into input data usable by InMAP, a reduced-form air quality model
- Stretch goal: Create and release this code as an additional FPEAM module that will convert the results format into information usable by InMAP and potentially other air quality models

# Compare Feedstock Supply Chains

- Tentative future analysis plan includes non-plant feedstocks including MSW and anaerobic digestate
- How do these feedstocks compare to agricultural and forestry feedstocks in terms of criteria air pollutants?
- Adds an environmental dimension to an availability and economic feasibility analysis

# Conclusion

- FPEAM is a modular, data-driven model that calculates criteria air pollutants generated during biomass feedstock production and transportation
- We plan to release FPEAM publicly by September 28, 2019
  - Release will include a complete set of default data files and a point-and-click user interface
- Next steps:
  - Address additional development needs as they arise
  - Apply FPEAM to analyses of interest at NREL and at the Bioenergy Technologies Office

For information on how to access FPEAM or with additional questions, please contact Rebecca Hanes at [rebecca.hanes@nrel.gov](mailto:rebecca.hanes@nrel.gov)

# Thank You

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[www.nrel.gov](http://www.nrel.gov)

Publication No. PR-6A20-74339

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Bioenergy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

