

**Design and
Implementation of MOVES:
*EPA's New Generation Mobile Source Emission Model***

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Collaborators

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MOVES Documentation Available

- **Draft MOVES Design and Implementation Plan**
- **Draft MOVES GHG Emission Analysis Plan**
- **Emission Analysis Background**
 - On-Board “Shootout” Reports
 - Modal emission analysis (NCSU)
 - Proof-Of-Concept Physical Model (Ed Nam)
 - Analysis of CO₂/CH₄ Emissions (ERG)
 - Mobile Source Observation Database update (ERG)
- **www.epa.gov/otaq/ngm.htm or **newgen@epa.gov****



MOVES Implementation Plan

- **MOVES GHG (on-road)**
 - Draft release: Early 2004
 - Energy consumption, CO₂, CH₄, N₂O inventories 1999 forward
 - Would include life cycle and policy evaluation components
- **Full on-road implementation: Fall 2005**
 - Add HC, CO, NO_x, Toxics, PM, NH₃, SO₂
 - Multi-scale analysis capability
 - Will replace MOBILE6
- **Off-Road: 2006**
 - Will replace NONROAD



MOVES Software Framework

- **Language: Java[®]**
- **Database-driven structure**
 - **Open-source relational database (MySQL[®])**
 - **Enables modularity, easy updates with new data**
- **Graphical user interface or batch mode**
- **Designed for single or multiple computer processing**
- **Output reporting and visualization**



MOVES Use Cases

- **Developed from National Research Council recommendations, expert consultation**
- **Primary use cases:**
 - Inventories at national and local levels
 - Multi-scale analysis
 - Model integration (air quality, transportation)
 - Policy evaluation
 - Flexible and easy updates



Design Objectives

- **Generic framework which can be applied across scale, source, pollutant**
- **Database-driven, modular design to allow easy updates**
- **High performance**



MOVES Emission “Processes”

- **Emission process = emission pathway with unique activity and emission characteristics**
- **Combustion Products**
 - Running exhaust, Start exhaust, Extended idle, Crankcase
- **Hydrocarbon Evaporation**
 - Diurnal, Hot Soak, Running Loss, Resting Loss, Refueling
- **Other**
 - Brake Wear, Tire Wear, Well-To-Pump, Manufacture/Disposal



Characterizing the Fleet

- **Source Use Types**

- a specific class of vehicles or equipment defined by unique activity patterns
- Mapped to HPMS Vehicle Types for on-road
- Off-road equivalent is SCC

- **Source Bins**

- Subcategories of use type that differentiate emission levels
- Examples: weight class, fuel type, engine technology, standard, horsepower range, etc.

Source Use Types

HPMS Vehicle Type	MOVES Use Type
Passenger car	Passenger car
Other 4-tire / 2-axle	Passenger truck Light commercial truck
Single Unit Trucks	Refuse truck Commercial truck (< 200 miles) Delivery truck (> 200 miles) Motorhomes
Combination Trucks	Commercial truck Delivery truck
Buses	Urban buses School buses Interstate buses
Motorcycles	Motorcycles

Source Bins

(running fuel consumption)

Source Bin Field	Source Bin
Fuel Type	Gas, Diesel, CNG, LPG, Ethanol (E85/95), Methanol (E85/95), Gas H₂, Liquid H₂, Electric
Engine Technology	Conventional, Direct Injection, Hybrid, Fuel Cell
Model Year Group	Pre-1981, 1981-85, 86-90, 91+
Loaded Weight	< 2000 lbs, 2000-2500 lbs,...>130,000 lbs
Engine Size	< 2.0 liters, 2.1 – 2.5 liters, ...> 5.0 liters



Characterizing Activity

- **Total Activity**

- Population * per-source activity for a given time, location, use type, age
- Proposing a time basis – more broadly applicable than g/mi

- **Operating Mode Bins**

- Division of total activity into categories that differentiate emissions

Total Activity Basis

Emission Process	Activity Basis
Running Exhaust, Brake Wear, Tire Wear, Running Loss, Crankcase, Extended Idle	Source Hours Operating (SHO)
Start Exhaust	Number of Starts
Diurnal, Hot Soak	Source Hours Parked (SHP)
Resting Loss, Manufacture/Disposal	Source Hours (SH)
Refueling, Well-To-Pump	Energy (Fuel) Used

Operating Mode Bins

Emission Process	Operating Mode Bins
Running Exhaust, Brake Wear, Tire Wear,	Engine Specific Power (ESP)
Start Exhaust, Hot Soak	Soak Time
Diurnal	Tank Pressure
Running Loss	Time Since Start
Running Loss, Refueling, Well-To-Pump, Crankcase, Extended Idle, Manufacture/Disposal	No Operating Modes



Characterizing Emissions

- **Emission Rate**

- the most disaggregated rates the model produces internally by source and operating mode bins
- grams per activity basis
 - e.g. grams/time, grams/start



Characterizing Scale

- **Macroscale**

- Large-scale inventories (e.g. U.S. at county level)
- 1 hour resolution

- **Mesoscale**

- More refined inventories, generally at regional level
- Based on Link-level Travel Demand Model framework
- 1 hour resolution

- **Microscale**

- Emission analysis for intersection or group of links
- Based on project-level CAL3QHC framework
- 15 minute time resolution



Characterizing Scale

- **Domain: the area being modeled**
 - Fleet makeup is assumed constant over domain
 - Treated as a “closed box”
 - Default is nation
- **Zone: a subdivision of domain**
 - Default is county
 - Can be defined at sub-county level, must belong to a county
- **Link: a representation of roadways**
 - Definition depends on scale
 - Macroscale: HPMS roadway types
 - Mesoscale/Microscale: Specific links
 - Can belong to either a domain or a zone



MOVES Components

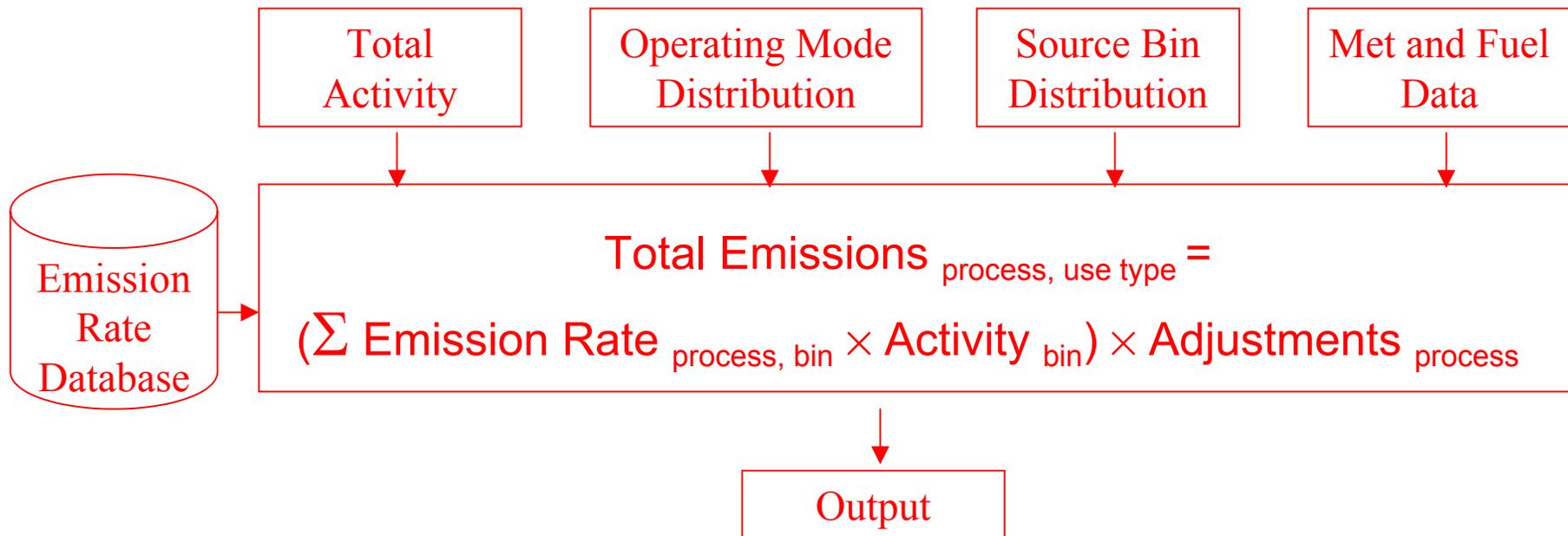
- **Core Model**
 - Generic structure applied across sources, scales, pollutants
- **Generators**
 - Produces core model inputs using available data
- **Control Strategies**
 - Modifies inputs for evaluation of policy scenarios
- **Databases**
 - Input: Fleet, Activity, Emission, Meteorology, Fuel Data
 - Output
- **User Interface**



Core Model

- **Inputs for a given time & location:**
 - Total Activity
 - Operating Mode Distribution
 - Source Bin Distribution
 - Meteorology and Fuel Data
- **Calculate activity by source & operating mode bins**
- **Retrieve emission rates**
- **Calculate total emissions**
- **Apply emission corrections**
- **Produce output**

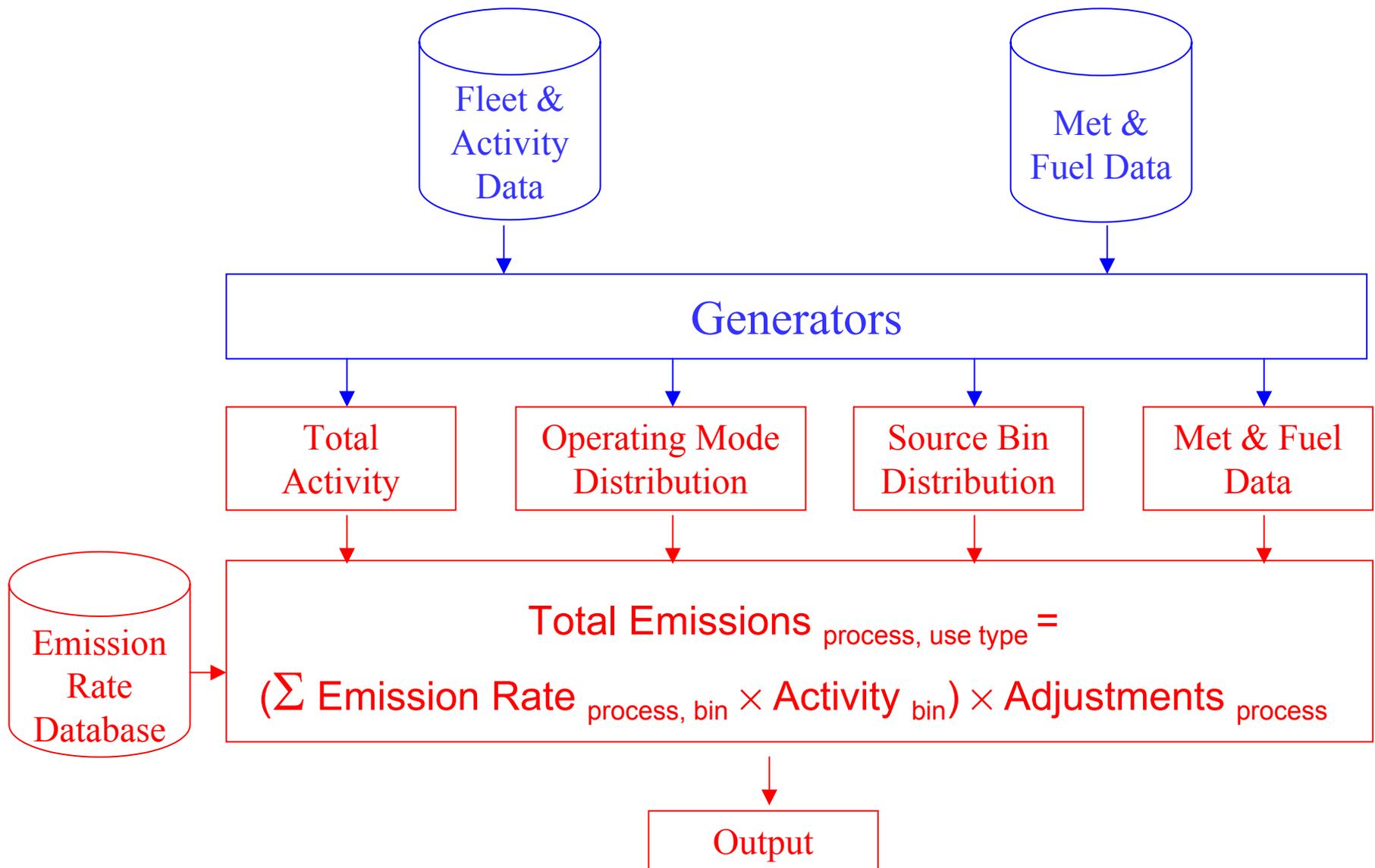
Core Model





Generators

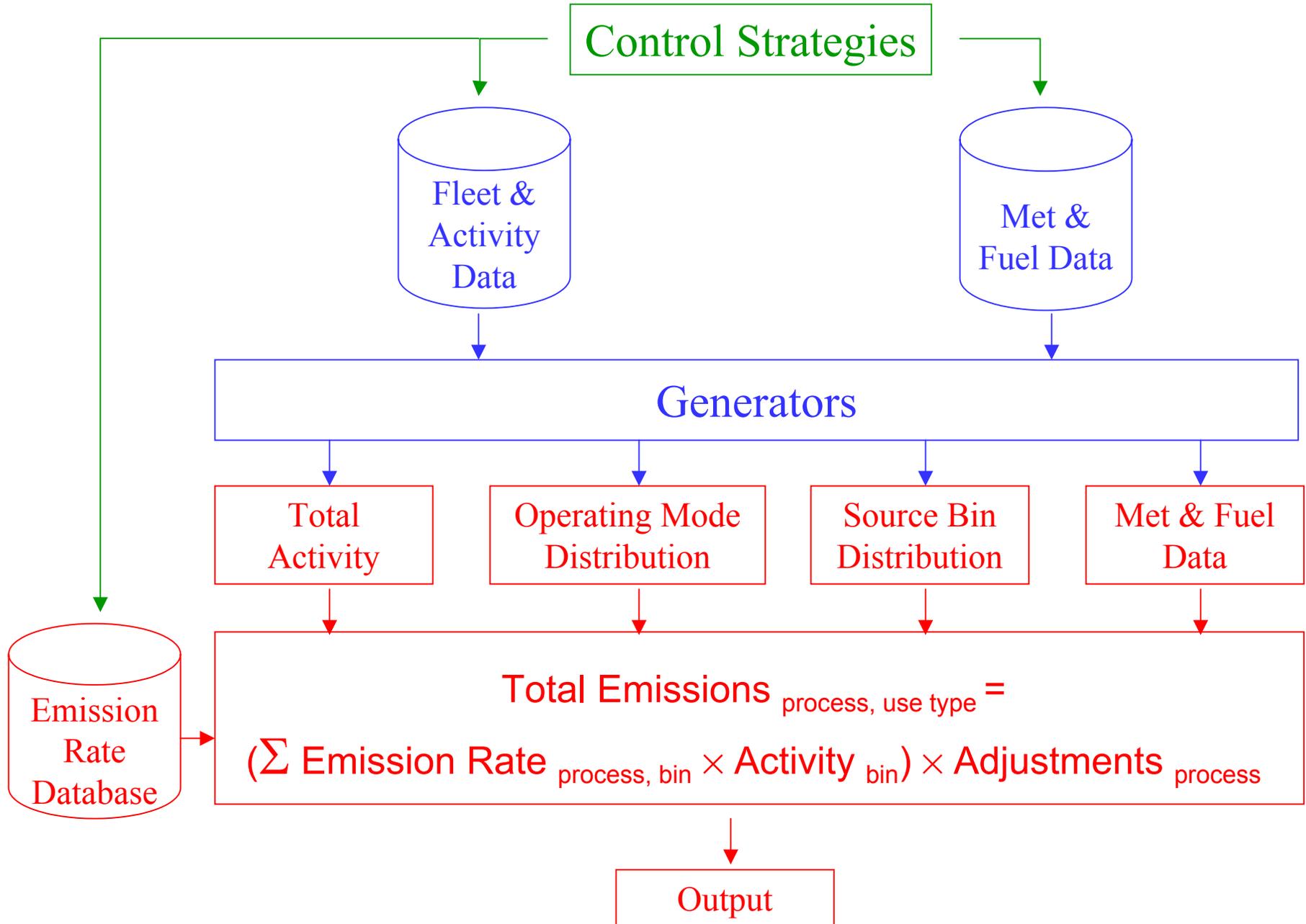
- **Produce core model inputs from available data**
 - 5 generators provide 5 input data types
- **Implementation-specific**
 - Provides link between generic core model and specific implementations
 - Total Activity and Operating Mode Distribution generators are where most of the implementation-specific math will happen





Control Strategies

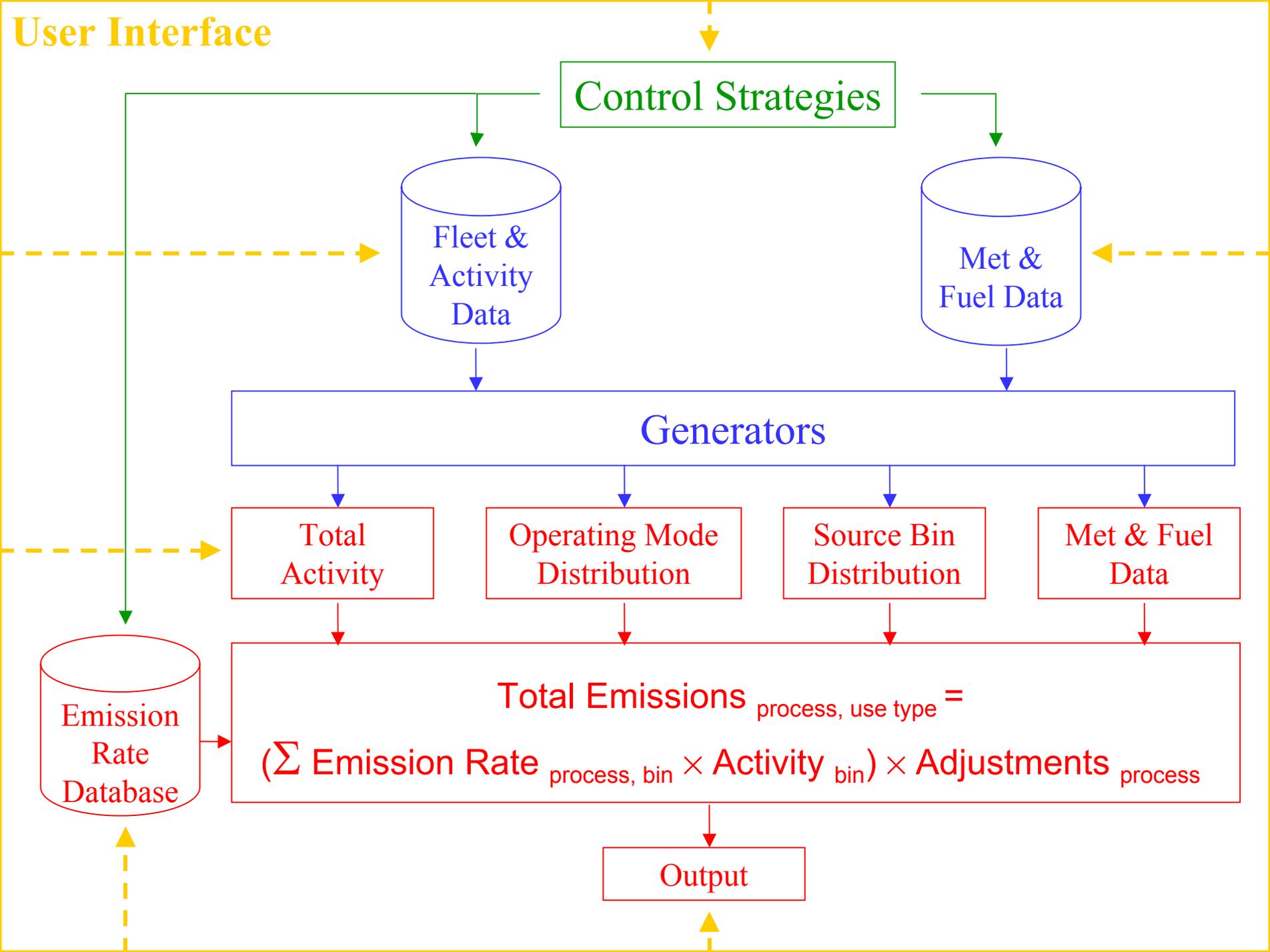
- **Fuel Control**
 - Alters fuel parameters, e.g. sulfur, oxygenate
- **Source Bin**
 - Alters distribution of source bins, e.g. new standards, fuel penetration,
- **Source Maintenance**
 - I/M, OBD
- **Source Population and Usage**
 - Alters total activity and/or operating mode distribution, e.g. reduced VMT, traffic smoothing





User Interface

- Run Specification GUI
 - Establishes analysis parameters
 - e.g. time, location, scale, pollutants, sources, etc.
 - Access control strategies
 - Supply custom data
 - Output reporting
 - Well-to-Pump inputs
 - via GREET





Implementations

- **Custom generators & control strategies can be developed to support specific use cases**
- **Default implementations to be developed:**
 - On-Road Macroscale Inventory
 - Default inventory for U.S at county-level
 - Local inventory development with user-supplied inputs
 - On-Road Mesoscale Inventory
 - Link-level based on output from travel demand model
 - On-Road Microscale Analysis
 - Intersection modeling in conjunction with CAL3QHC
 - Off-Road
 - TRANSIMS



(A few of the) Big Changes from MOBILE Framework

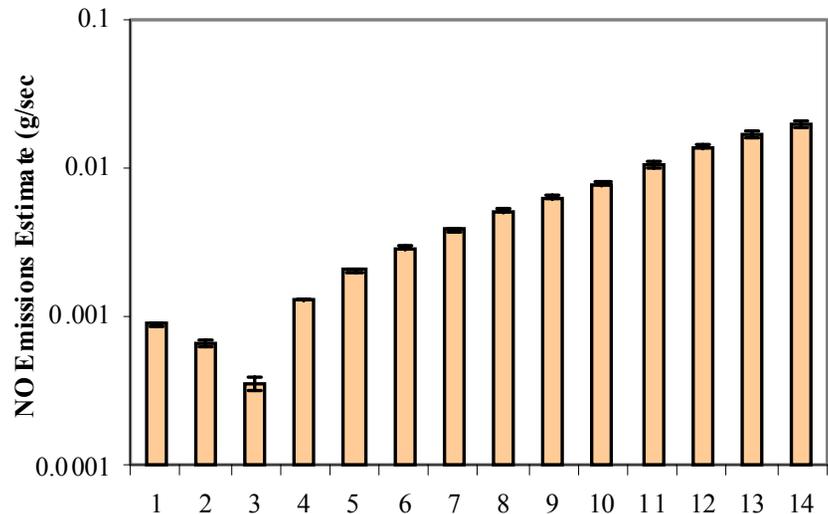
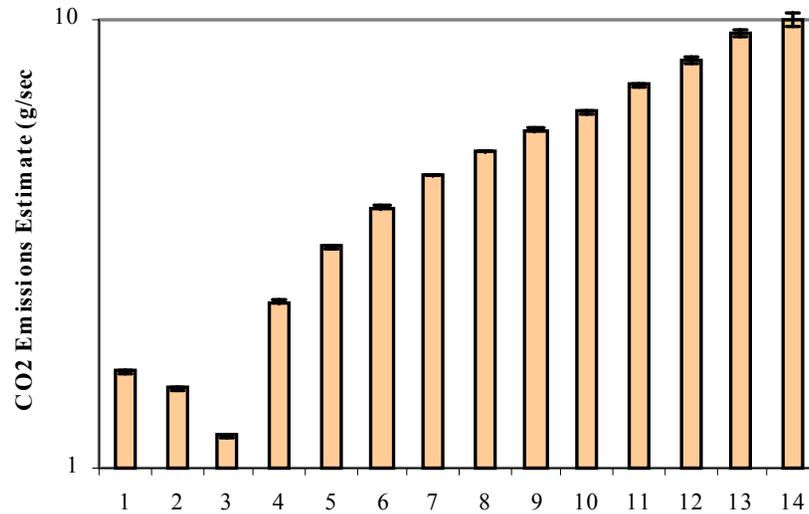
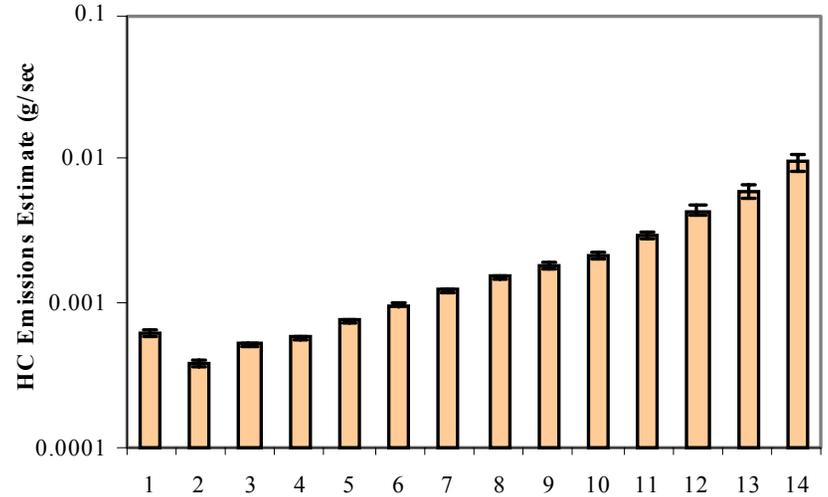
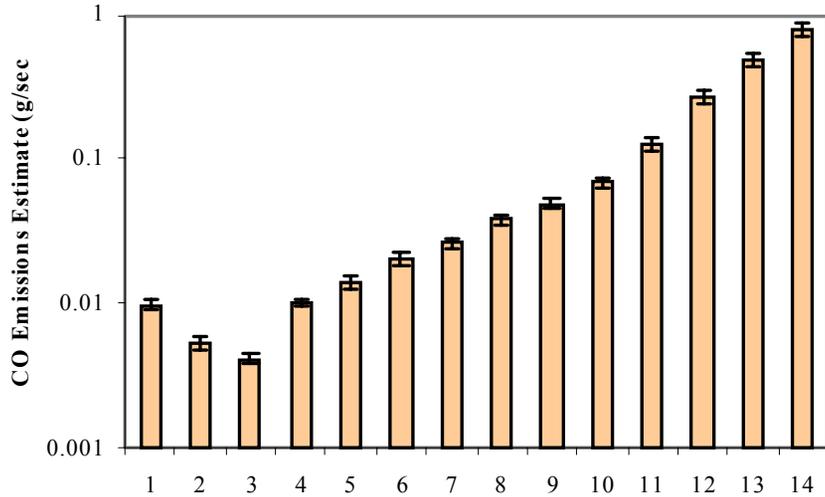
- **Estimating inventories**
 - MOBILE estimates emission factors (grams/mile)
- **Multi-scale analysis**
- **Emission rates on modal basis**
 - MOBILE rates based on aggregate driving cycles
- **Software framework**
 - Relational database structure
 - Graphical User Interface
 - Object-oriented programming approach
- **Uncertainty estimation**



Emission Rates: Modal Approach

- **Group activity and emissions into “Bins”**
 - Vehicle Specific Power (VSP)
 - Accounts for speed, acceleration, grade, road load
- **Any driving pattern can be modeled based on distribution of time spent in bins**
 - Adds major flexibility compared to MOBILE
- **Provides common emission rates for macroscale, mesoscale, microscale**

Emissions by 14 VSP Bins Recommended by NCSU





Data To Be Used in MOVES GHG

- **Fuel consumption/emissions**
 - EPA Mobile Source Observation Database
 - Adding additional programs:
 - CARB
 - CRC E-55
 - UC Riverside (CMEM, Heavy-Duty Trailer, Other Studies)
 - Environment Canada
 - WVU (Thousands of heavy-duty chassis tests)
 - Other state and university programs
 - Initial PEMS work (Shootout)
- **Fleet characterization (e.g. populations)**
 - Polk, VIUS
- **Activity characterization (e.g. VMT, driving patterns)**
 - HPMS, NPTS, VIUS, light-duty and heavy-duty driving studies



Summary

- **MOVES Design:**

- Developed from expert recommendations and user consultation
- Flexible framework for multi-scale analysis
- Inventory development and policy evaluation across pollutants and sources under one roof
- Modular approach will allow easier updates

- **MOVES Implementation:**

- Iterative development approach will produce useful products on the way to full implementation