Integrating Data Sources, Geo-Spatial Analyses, and Engineering-Based Calculations to Model Life-Cycle Emissions in Crude Oil Transport for Mobile-Source Fuels

Aman Verma[1], Christy Parsons[2], Rich Cook[2], Molly Zawacki[2], Kyle Borgert[2], Jarrod Brown[2], Alison Eyth[3], Jeff Vukovich[3], Alexis Zubrow[4]

[1] Former ORISE Participant hosted by the US EPA, Ann Arbor MI
[2] US EPA, Office of Transportation and Air Quality, Ann Arbor MI
[3] US EPA, Office of Air Quality Planning and Standards, RTP NC
[4] US DOT, Volpe Center, Boston MA

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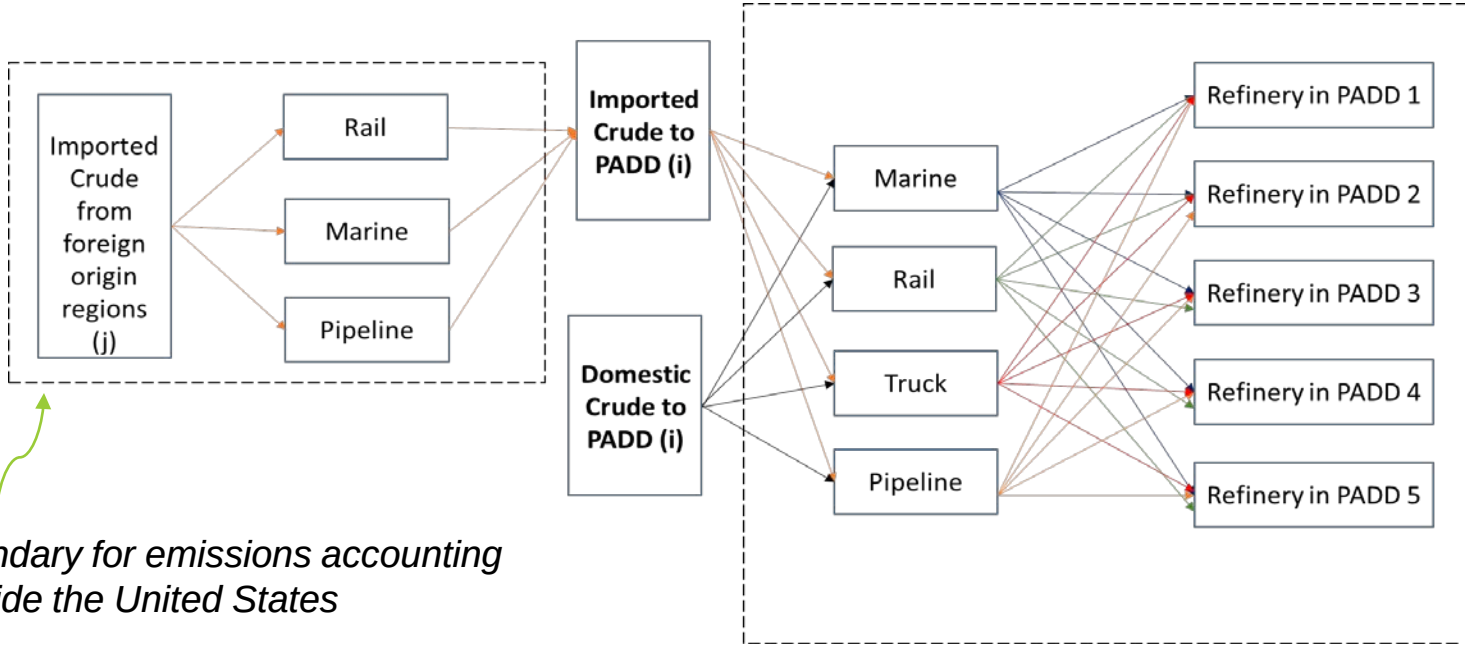
Overview of Presentation

- Background
  - Literature Review and Data Gaps
- Objective
- Method and Preliminary Results
  - *Crude transport by rail, truck, pipeline, and marine*
- Conclusions and Next Steps

Crude Oil Supply Chain



PADD = petroleum administration defense district

Boundary for emissions accounting outside the United States

Boundary for emissions accounting in the United States

Crude oil transport from the well to the refinery is complex and includes various transport modes. Emissions impact can be significant over life-cycle of mobile-source fuels.

Key questions for modeling life cycle inventories: where is the source of crude, where is the destination, what mode moves it, how much is moved, and what emissions are associated with the movement?

Existing Literature and Data Gaps – Crude Oil Transport Emissions

Existing Literature:

- includes nationally aggregated emissions factors
- focuses on emissions of greenhouse gases
- does not evaluate local scale impacts

Data Gaps:

- activity data, i.e., the amount of crude to be transported some distance, does not exist in the literature

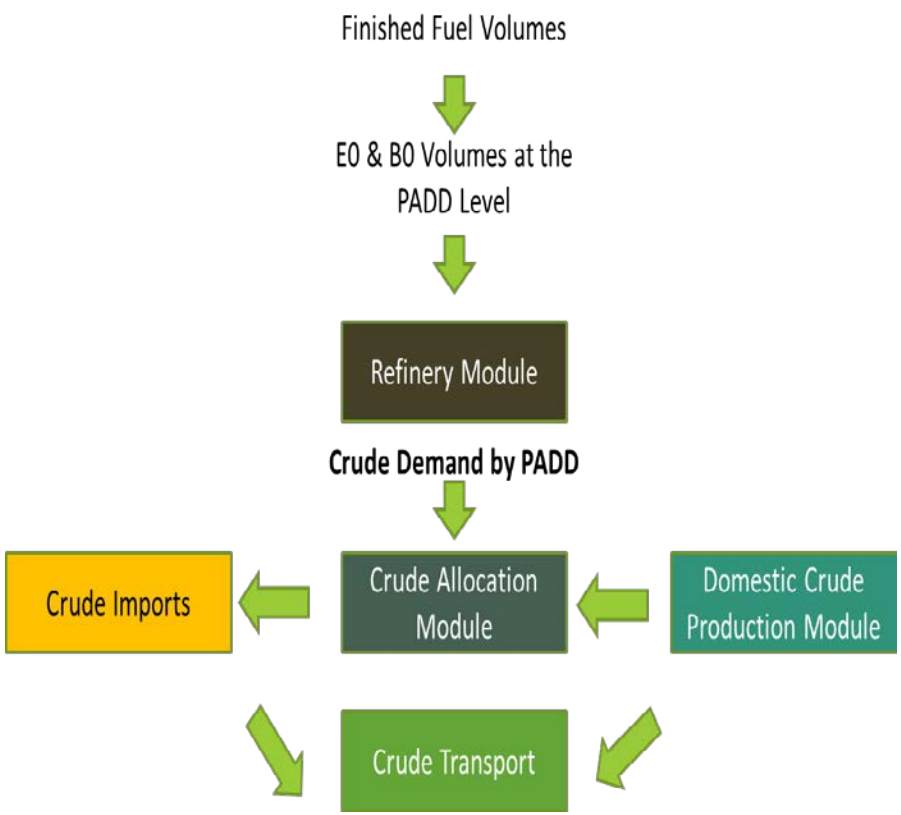
Objectives

- For a given amount of crude demand for petroleum refineries in a PADD, account for emissions of multiple pollutants that occur during the transport of crude oil for mobile sources by different modes (i.e., **truck, pipeline, marine and rail**).
  - Criteria Air Pollutants (CAPs), Hazardous Air Pollutants (HAPs) and Greenhouse Gases (GHGs) emissions inside the US
  - Greenhouse Gases (GHGs) emissions outside the US

- Quantify and spatially resolve emissions impacts of activities in a given transport mode.

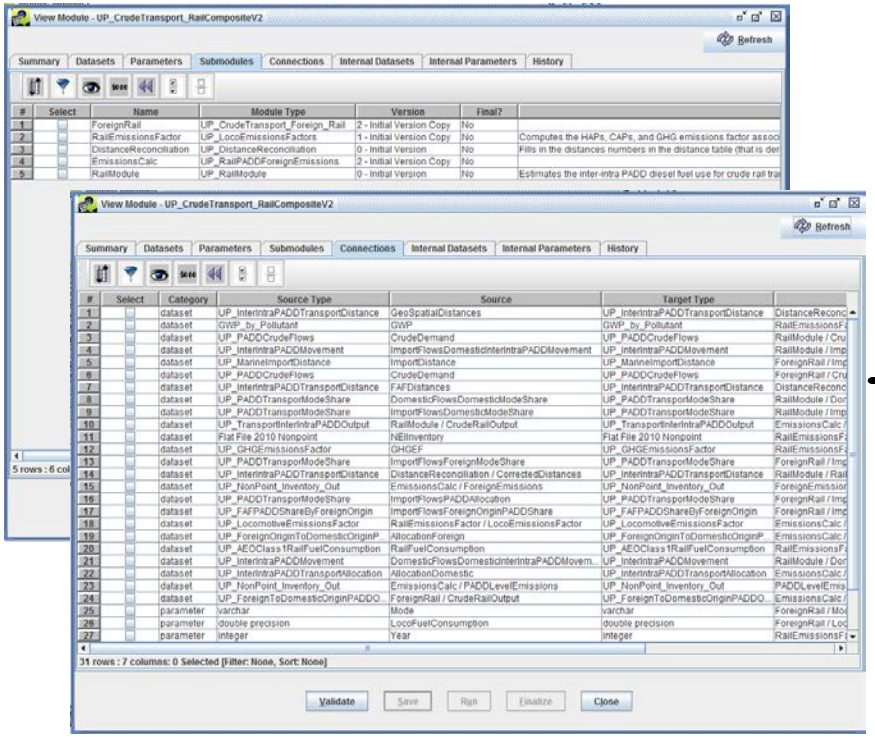
We present an approach that incorporates geo-spatial analysis and engineering-based calculations to model the activity (mass and distance during transport), and account for the emissions impact of a given type of transport mode (i.e., rail, pipeline, marine, or truck).

Overview: Crude Transport Methodology

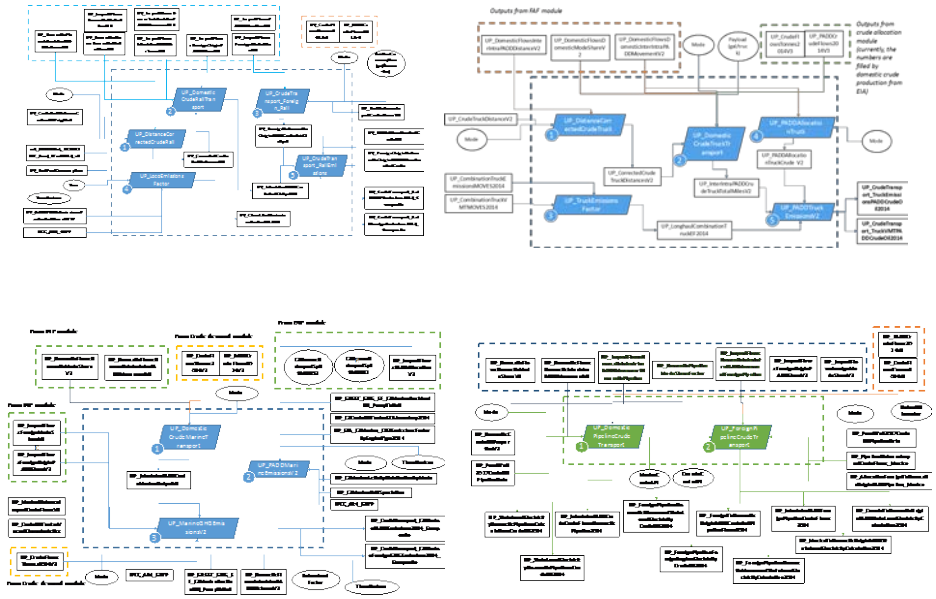


- Methodology is driven by finished fuel volumes (gas, diesel, etc.)
- Emissions for a given mode of crude transport to a refinery – rail, pipeline, truck and marine – at a Petroleum Administration Defense District (PADD) level
- Explicit characterization of impact of scale and transportation distance on emissions

Overview: Crude Transport Methodology

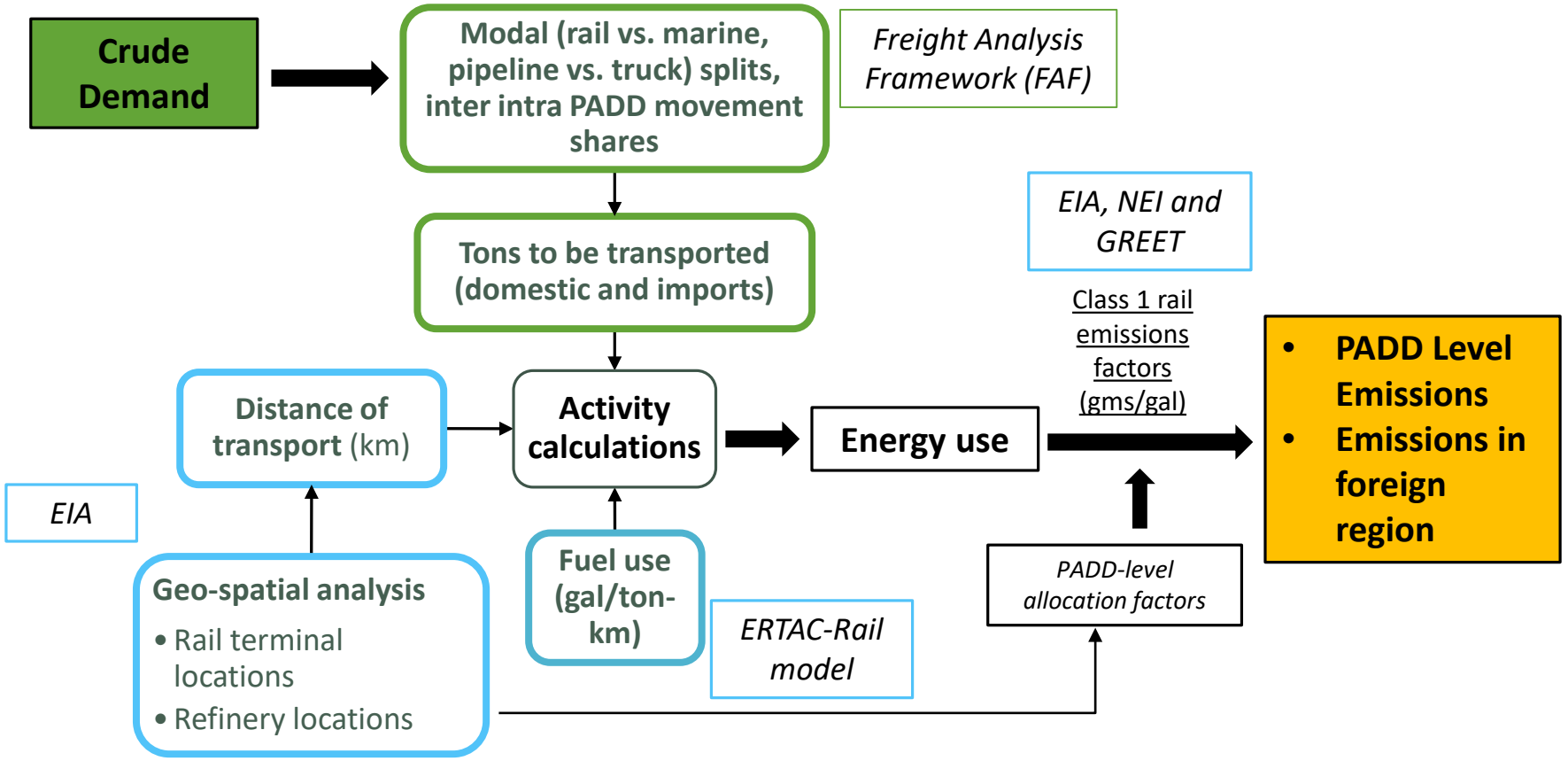


Data flows in different transport models



Draft analysis combines numerous data sources to estimate crude transport emissions specific to transportation modes (rail, pipeline, marine, truck).

Crude Transport by Rail



Crude Transport by Rail: Example Results*

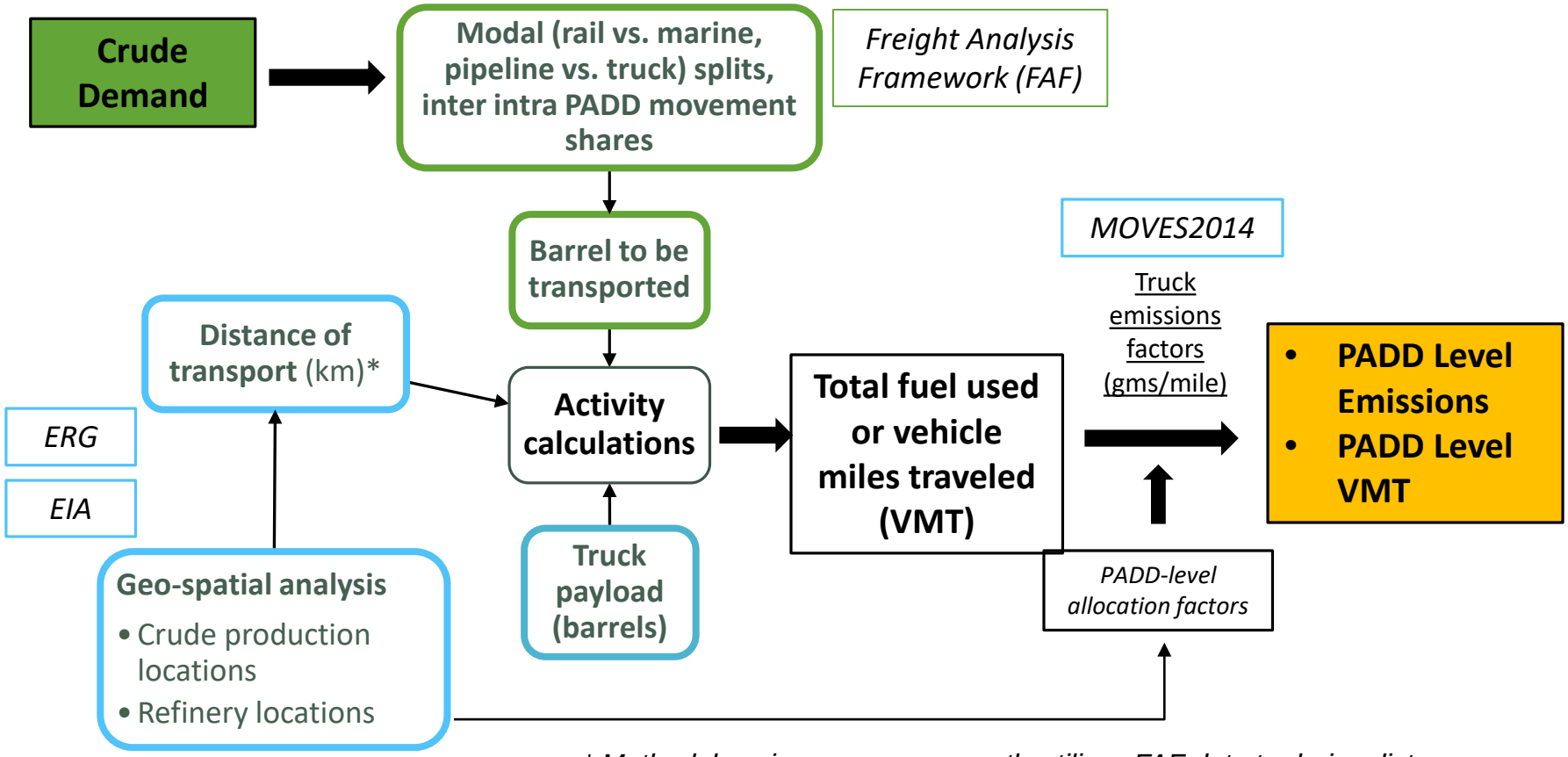
- Given PADD-level crude demand from refineries as an input, outputs generated for:
  - PADD-level emissions inventories (CAPs, HAPs, and GHGs) for domestic crude flows and domestic movement of imported crude flows
  - GHG inventories associated with transport of imported crude outside the US

country_cd	region_cd	region_cd_source	subcategory	pollutant	emissions	units
0	1	PADD	Rail	SO4	0.0	tons
0	1	PADD	Rail	OC	1.0	tons
0	1	PADD	Rail	EC	4.5	tons
0	1	PADD	Rail	PM25-PRI	5.9	tons
0	1	PADD	Rail	VOC	10.0	tons
0	1	PADD	Rail	CO2e	9665.2	tons
0	1	PADD	Rail	DIESEL-PM25	5.9	tons
0	1	PADD	Rail	PM10-PRI	6.3	tons
0	1	PADD	Rail	SO2	1.7	tons
0	1	PADD	Rail	CO	30.3	tons
0	1	PADD	Rail	DIESEL-PM10	6.3	tons
0	1	PADD	Rail	PMFINE	0.3	tons
0	1	PADD	Rail	NO3	0.0	tons
0	1	PADD	Rail	NH3	0.1	tons
0	1	PADD	Rail	NOX	194.3	tons

Sample emissions inventories in PADD 1 (CAPs and GHGs only) for domestic crude flows and domestic movement of import crude flows via rail

*Preliminary, do not cite or reproduce

Crude Transport by Truck



** Methodology in-progress, currently utilizes FAF data to derive distances*

Crude Transport by Truck: Example Results*

- Given PADD-level crude demand from refineries as an input, outputs generated for:
  - PADD-level emissions inventories (CAPs, HAPs, and GHGs) for domestic crude flows and domestic movement of imported crude flows
  - PADD-level total VMT for domestic crude flows and domestic movement of imported crude flows

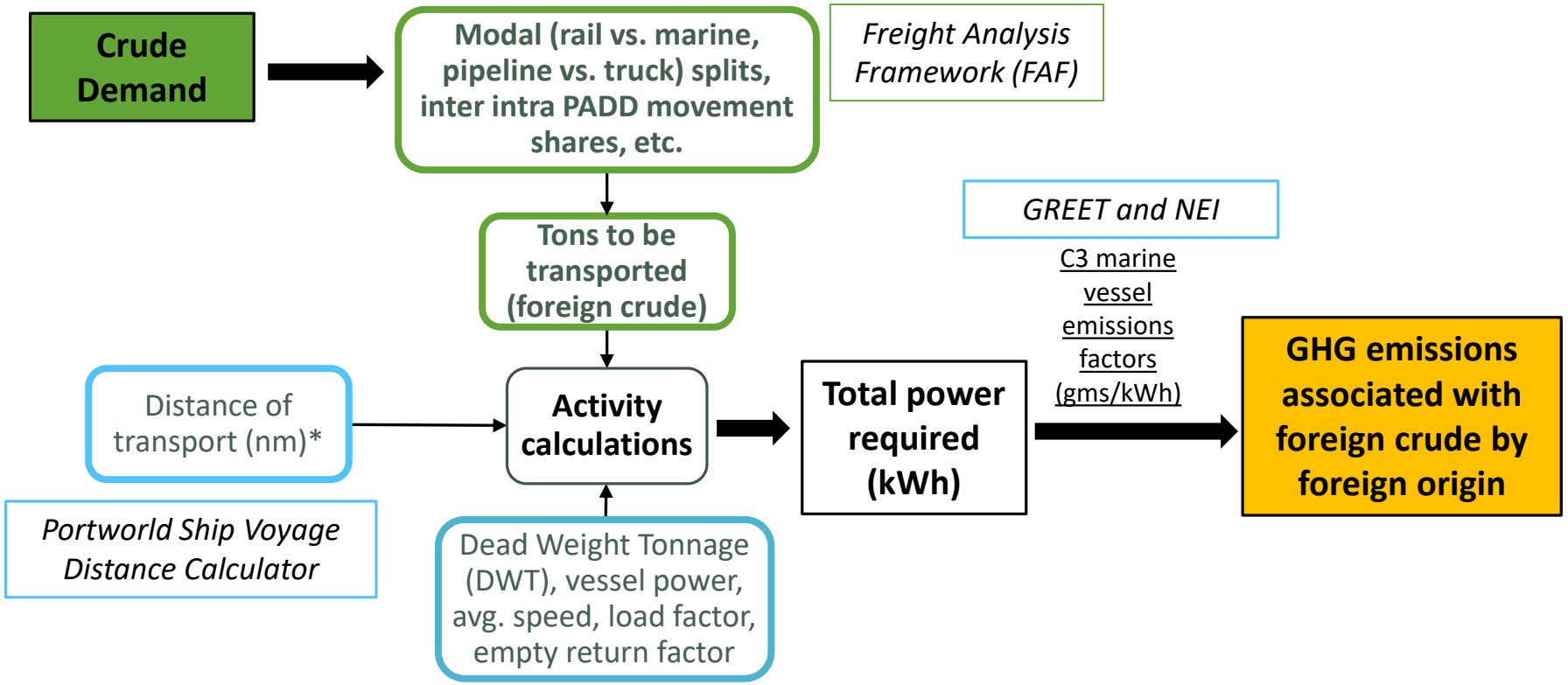
country_cd	region_cd	region_cd_source	subcategory	pollutant	value	units
0	1	PADD	Truck	VMT	5,966,729	Miles
0	2	PADD	Truck	VMT	34,264,591	Miles
0	3	PADD	Truck	VMT	224,302,816	Miles
0	4	PADD	Truck	VMT	177,193,244	Miles
0	51	PADD	Truck	VMT	4,902,243	Miles
0	52	PADD	Truck	VMT	39,153,893	Miles

Sample total VMT in all PADDs for domestic crude flows and domestic movement of import crude flows via truck

Note: PADD51 represents all states in PADD 5 except Hawaii and Alaska, and PADD52 represents Hawaii and Alaska

*Preliminary, do not cite or reproduce

Crude Transport by Marine (GHG emissions outside the US)



*distance outside the air quality boundary

Crude Transport by Marine: Example Results*

- Given PADD-level crude demand from refineries as an input, outputs generated for
  - PADD-level emissions inventories (CAPs, HAPs, and GHGs) for domestic crude flows and domestic movement of imported crude flows
  - GHG inventories associated with transport of foreign crude outside the US

country_cd	region_cd	region_cd_source	sector	category	subcategory	pollutant	emissions	units
0	0	0	Crude Transport	Crude oil	Water	CO2e	236,206	tons
2	0	0	Crude Transport	Crude oil	Water	CO2e	4,574	tons
1	0	0	Crude Transport	Crude oil	Water	CO2e	13,963	tons
7	0	0	Crude Transport	Crude oil	Water	CO2e	15,315,406	tons

*Preliminary, do not cite or reproduce

Crude Transport by Pipeline

Crude Demand

Modal (rail vs. marine, pipeline vs. truck) splits, inter intra PADD movement shares

Freight Analysis Framework (FAF)

Tonnes to be transported by (domestic and foreign pipelines)

Distance of transport (km) and distance weighted diameter on a state-segment basis

Through-put through each pipe system and energy calculations

Pipeline system allocation factors

PennWell

Geo-spatial analysis

- Crude oil main line pipeline network

- **US state-level electricity energy use due to foreign and domestic pipelines**
- **Electricity use in foreign regions (Canada and Mexico)**

Crude Transport by Pipeline: Example Results*

Given PADD-level crude demand from refineries as an input, outputs generated for:

- US state-level electricity energy to transport crude oil via domestic pipelines for the movement of:
  - Domestic crude
  - Imported crude that has pipeline as the secondary mode but primary mode is not pipeline.
- US state-level and foreign region (Canada and Mexico) electricity energy to transport crude oil via foreign pipelines for the movement of:
  - Foreign crude that has pipeline as primary and secondary mode.

country_cd	state	padd	subcategory	electricity	units
0	alabama	3	Pipeline	1003.98	MWh
0	arkansas	3	Pipeline	1420.61	MWh
0	louisiana	3	Pipeline	13599.25	MWh
0	mississippi	3	Pipeline	8129.00	MWh
0	new mexico	3	Pipeline	1258.43	MWh
0	texas	3	Pipeline	74099.33	MWh

Sample US state-level electricity energy use in PADD 3 for domestic crude flows via domestic pipelines and domestic movement of import crude flows via domestic pipelines.

*Preliminary, do not cite or reproduce

Conclusions and Next Steps

- Draft analyses generate PADD level inventories associated with transporting crude oil
  - allow explicit accounting of the CAPs, HAPs, GHGs impacts from transporting crude oil
- Methodology uses same building blocks (module type) for multiple calculations (e.g., marine transport, rail transport)
  - minimize errors
  - allows integration of different data sources for each mode
  - applicable for various scenarios (e.g., future year or control scenario)
- Next Steps: documentation, synthesizing with other sectors

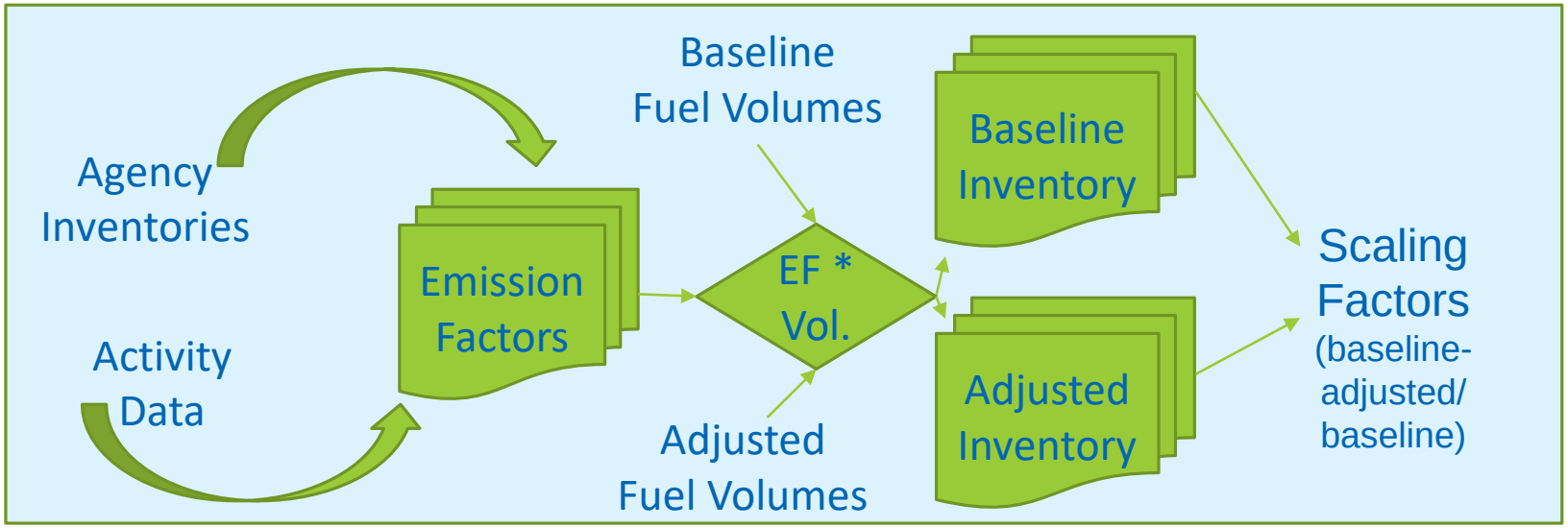
Questions and feedback?

Appendix

Data Sources: Crude Transport

- Annual Energy Outlook
- EPA's National Emissions Inventory (NEI)
- The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model by Argonne National Laboratory
- EPA's MOtor Vehicle Emission Simulator (MOVES)
- Eastern Regional Technical Advisory Committee (ERTAC) Rail Model
- PennWell
- U.S. Energy Information Administration (EIA)
- Portworld Ship Voyage Distance Calculator
- Freight Analysis Framework (FAF)
  - Produces through a partnership between Bureau of Transportation Statistics (BTS) and Federal Highway Administration (FHWA)

Context: General Upstream Approach



Methodology uses existing agency emissions inventories to maintain high fidelity between inventories generated for mobile source fuel transport and AQ modeling.

Crude Transport by Marine (Inside U.S.)

- Activity data of ships carrying crude (C3 crude tanker vessels) inside the air quality boundary, are unavailable
- Data unavailable for C3 tanker vessels carrying domestic crude vs. imported crude
- Domestic vs. import flows inventories (C3)
  - Treat flows from Alaska to California same as import flows.
  - **Disaggregate the total inventory for C3 crude tanker vessels from NEI for crude oil tanker based on the flows' split between Alaska to California (i.e. PADD 5), and Rest of the World flows as derived from the FAF.**
  - **Allocation of emissions due to import crude flows are then allocated to PADDs using FAF data.**
- GHGs for flows outside the air quality boundary are estimated using method described on the following slide

Marine shapes file (US exclusive economic zones) Federal Waterways; ~200 nm