

Estimating Petroleum Product Consumption at Terminals using Satellite Images and Weighted Voronoi Diagram

prepared by

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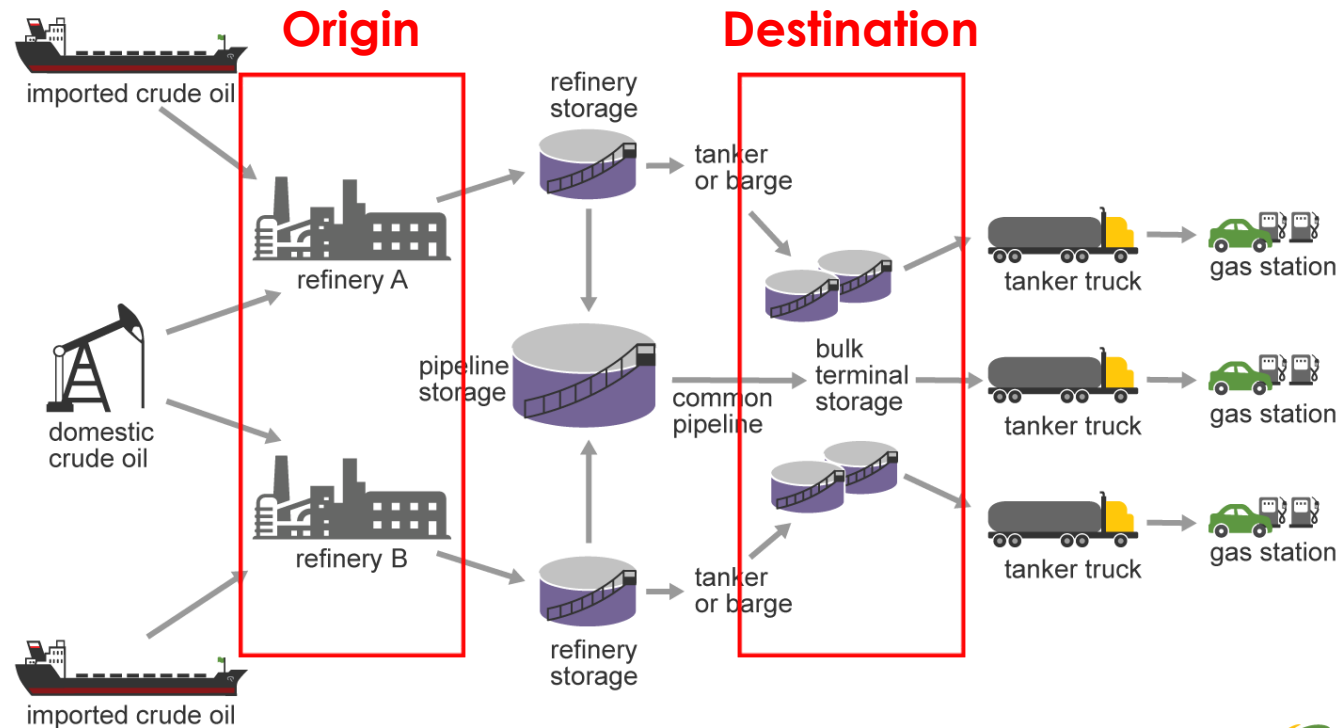


U.S. DEPARTMENT OF
ENERGY

Problem to Solve

- How can we estimate movements of petroleum products at detailed geographical level (e.g., county)?

Flow of crude oil and gasoline to your local gas station



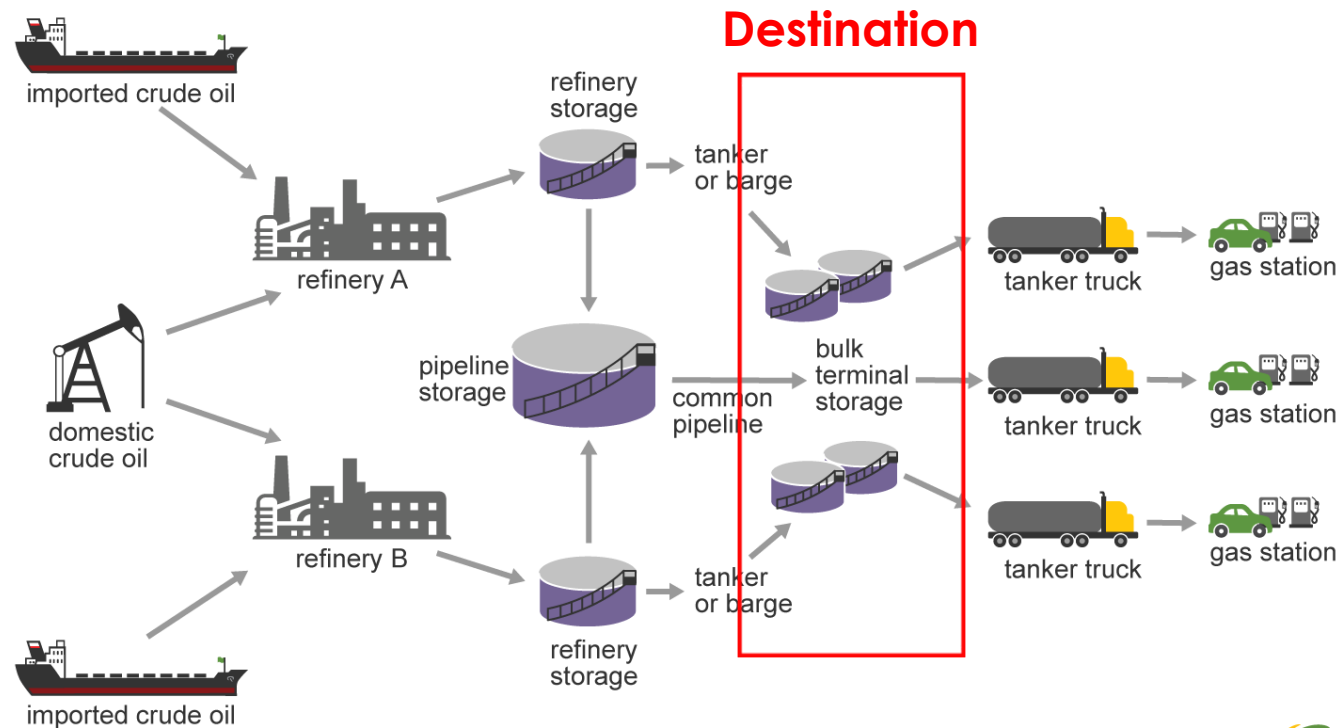
Source: U.S. Energy Information Administration



Problem to Solve

- As the part of process in estimating the petroleum product movements, how can we better estimate the petroleum product consumptions?

Flow of crude oil and gasoline to your local gas station



Source: U.S. Energy Information Administration



Challenges

- US Energy Information Administration (EIA) provides productions and consumptions at highly aggregated level (e.g., PADD and state).

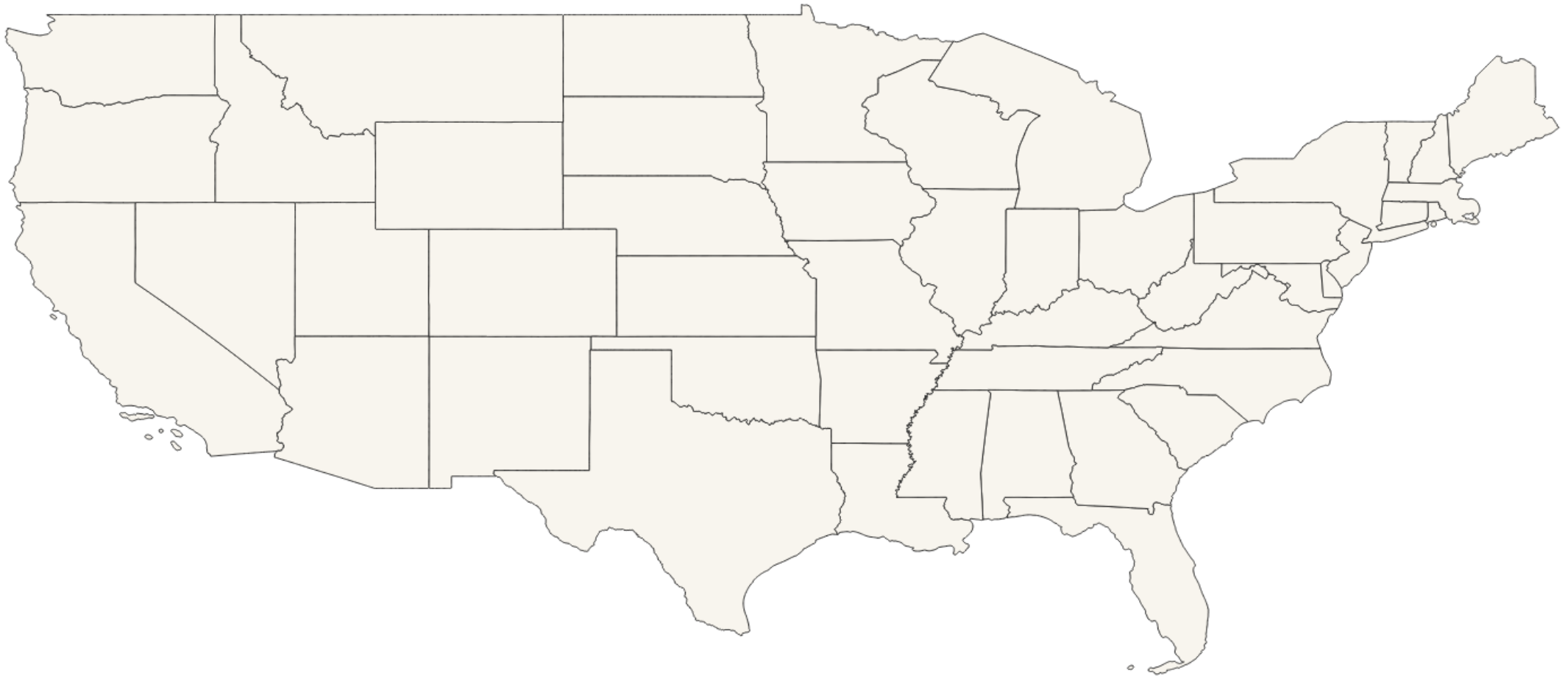
- Input variables at different levels

$$\hat{y} = f([x_1, x_2|state], [x_3|county], [x_4, x_5|link], [x_6|point], \dots)$$

- No y ? No readily available data to validate the estimation results at the county level.
- There are location information of petroleum product terminals, but no consumption/termination information.
- Potentially, we can integrate other data sources, such as HPMS or FAF. But, how?

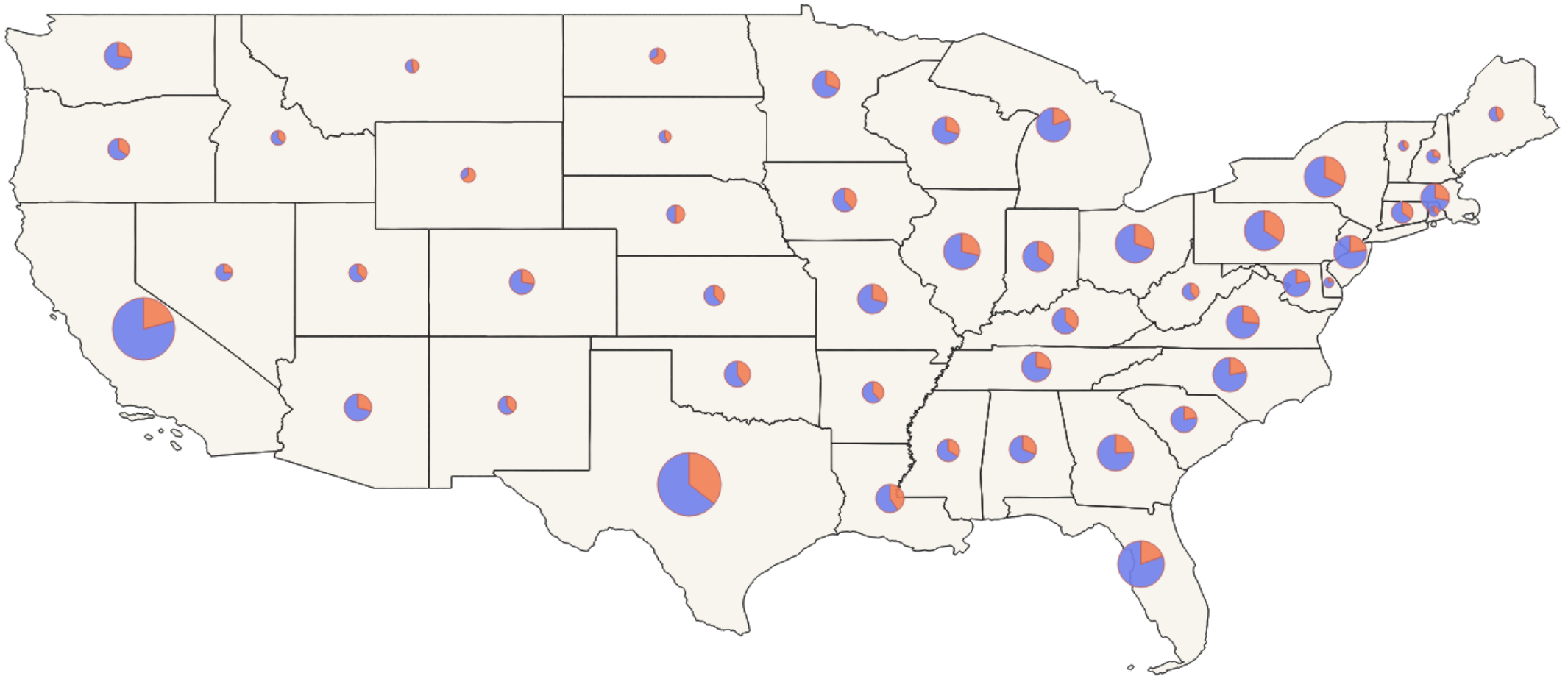
Data Sources

- What are the available data sources?



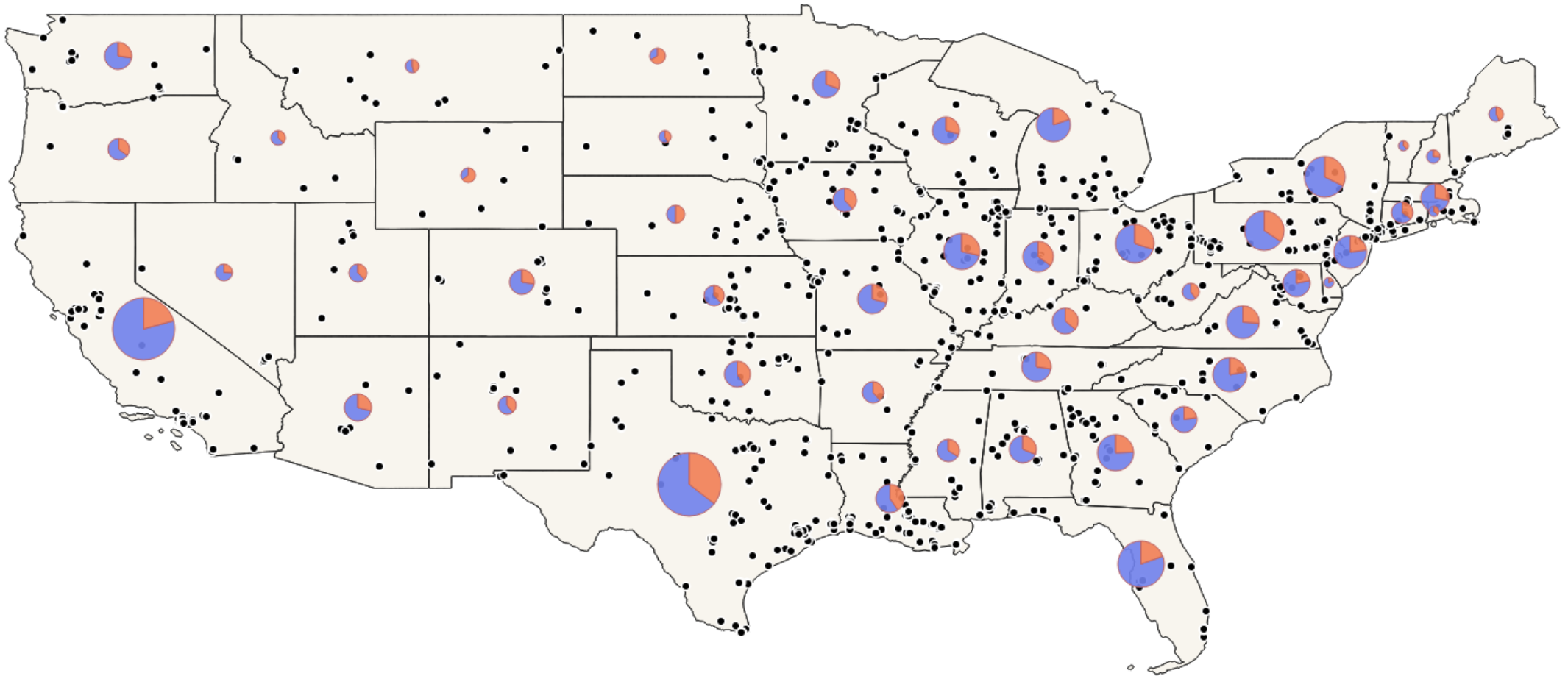
Data Sources

- State level petroleum product consumptions (EIA)



Data Sources

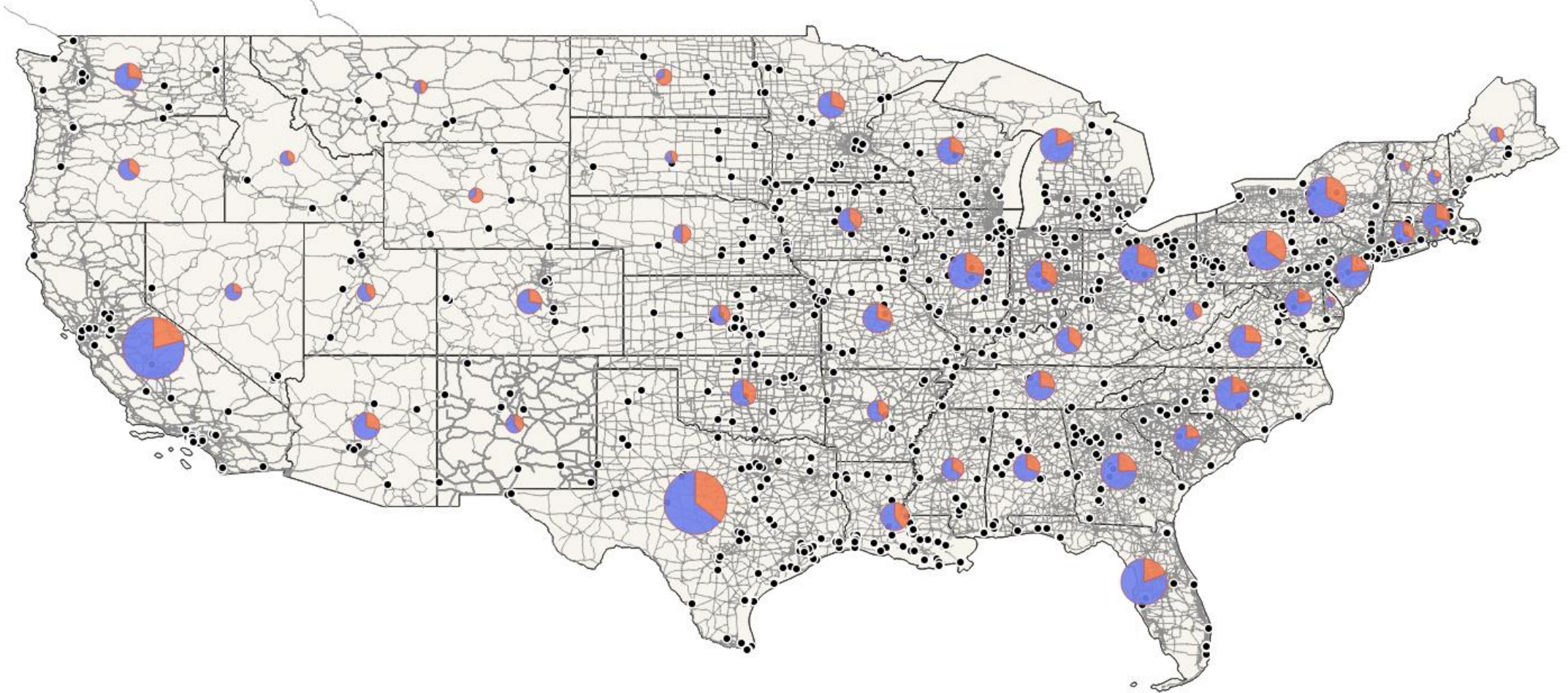
- Locations of petroleum product terminals, but no consumption/capacity information.



Data Sources

- Vehicle Miles Traveled of Light Duty Vehicles and Medium/Heavy Duty Trucks (FAF/HPMS)

$$\hat{y} = f([x_1, x_2 | state], [x_3 | county], [x_4, x_5 | link], [x_6 | point], \dots)$$

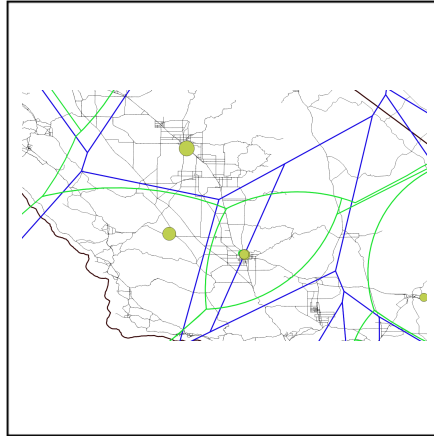


Estimation Process

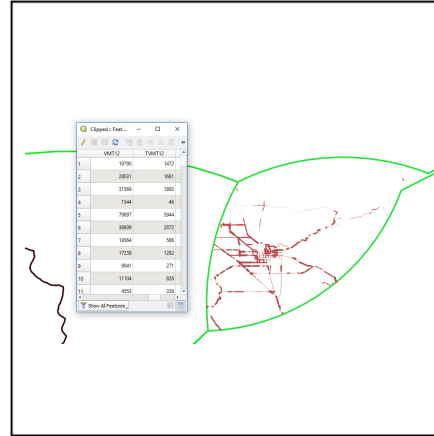
Process 1 Terminal Capacity



Process 2 Terminal Coverage



Process 3 VMT



Process 4 Consumption Estimate1 Validation/Calibration

$$[LFC12]_i = [LVMT12]_i \times [LAFC]$$

$$[TFC12]_i = [TVMT12]_i \times [TAFC]$$

Process 5 \hat{Y} vs Y State-level Estimates vs EIA

Calibrate weight parameters for Voronoi diagram

Process 6 (Final) – Adjustment by EIA's state level petroleum product consumptions

Process 1 – Petroleum Product Terminal Capacity

← → ↻ ⌂ ⚠ Not secure | energysupplylogistics.com/map/

Energy Supply Logistics

495 River 1/1 ^ v x

Search Results Detail Map Links

CITGO Petroleum Corporation - Glenmont

[Terminal Website](#)

▼ Address

CITGO Petroleum Corporation - Glenmont
495 River Road
Glenmont, NY 12077

▼ Products

Refined Products,

▼ Additional Terminal Details

Number of Storage Tanks: 13
Storage Capacity (barrels): 1,200,000

▼ Access

	In	Out
Rail	No	No
Truck	No	Yes
Marine	Yes	No

Pipeline Access
In: No
Out: No

▼ Access Details

Number of Truck Bays: 4
Number of Ship Docks: Yes
Dock Draft (ft): 22
Dock Length (ft): 500

Map Satellite

Smultz Rd

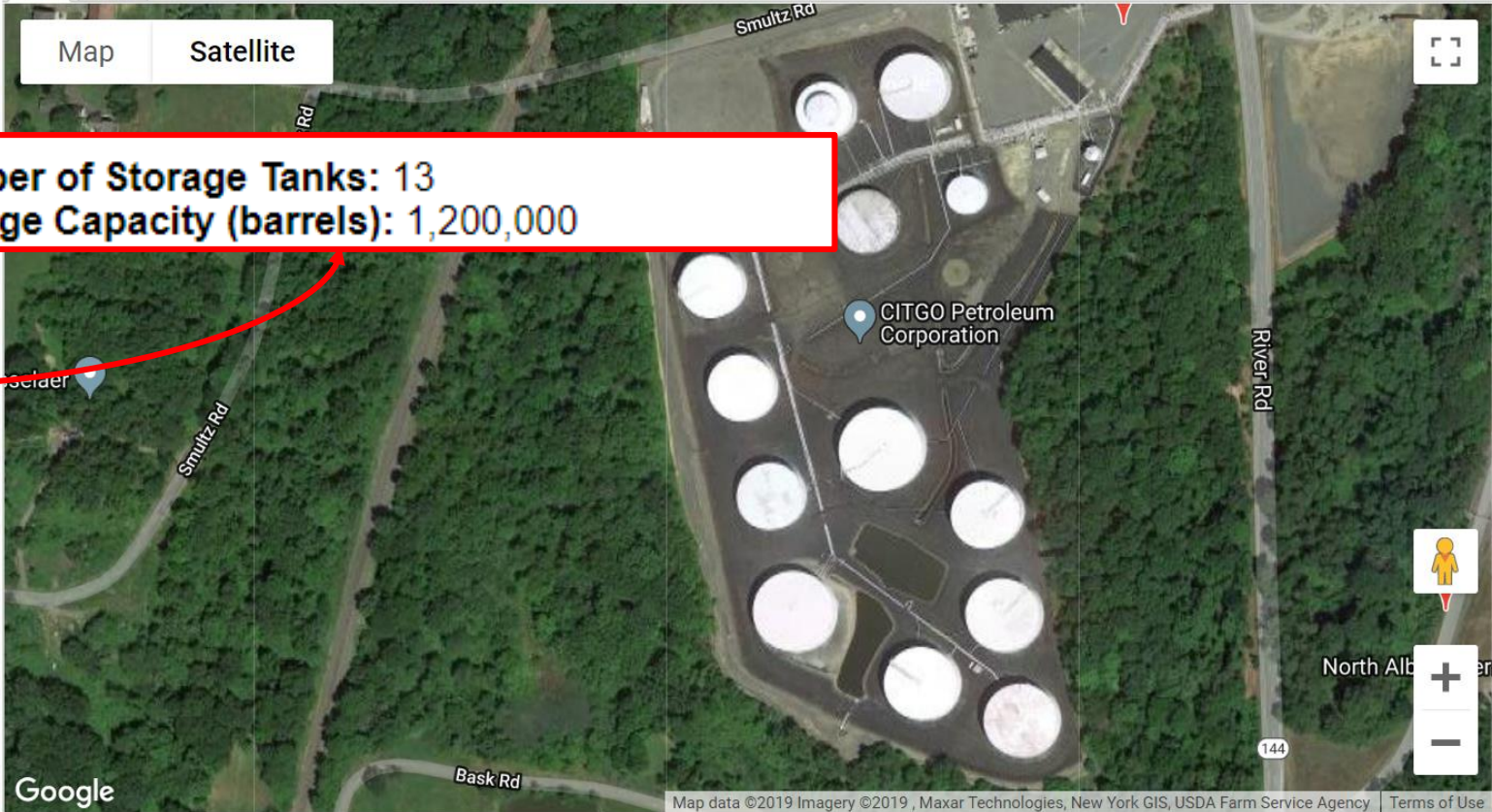
CITGO Petroleum Corporation

Smultz Rd

Bask Rd

Google

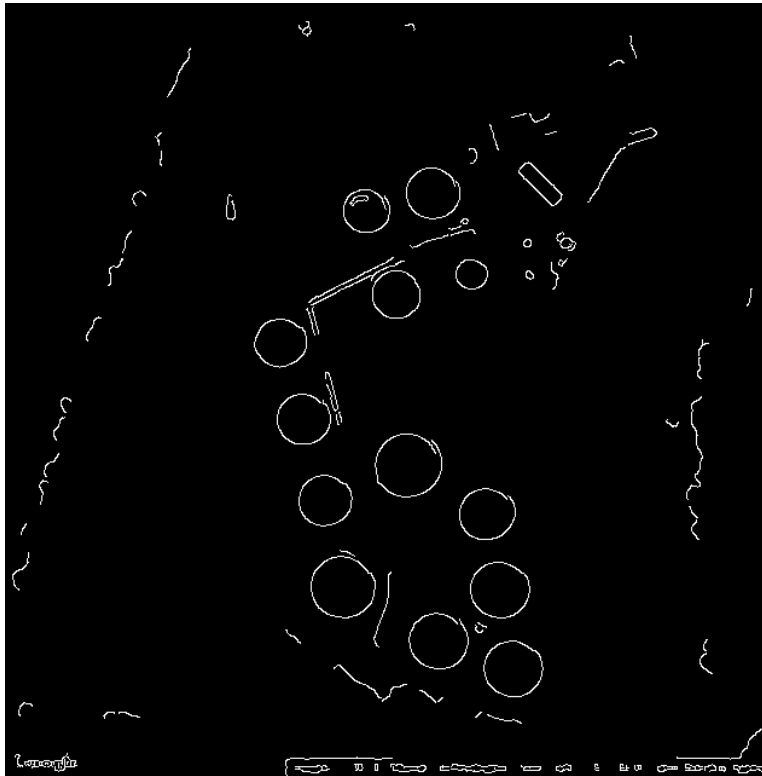
Map data ©2019 Imagery ©2019, Maxar Technologies, New York GIS, USDA Farm Service Agency | Terms of Use

A satellite map view of the CITGO Petroleum Corporation terminal in Glenmont, NY. The map shows a large industrial facility with 13 large, white, cylindrical storage tanks arranged in a grid-like pattern. The facility is surrounded by green trees and vegetation. A red box highlights the text "Number of Storage Tanks: 13" and "Storage Capacity (barrels): 1,200,000" on the left side of the map. A red arrow points from this box to the tanks on the map. The map includes labels for "Smultz Rd", "Bask Rd", and "River Rd". A "Google" logo is visible in the bottom left corner of the map area. The map data is attributed to ©2019 Imagery ©2019, Maxar Technologies, New York GIS, USDA Farm Service Agency.

Process 1 – Petroleum Product Terminal Capacity

Circle Hough Transform (CHT)

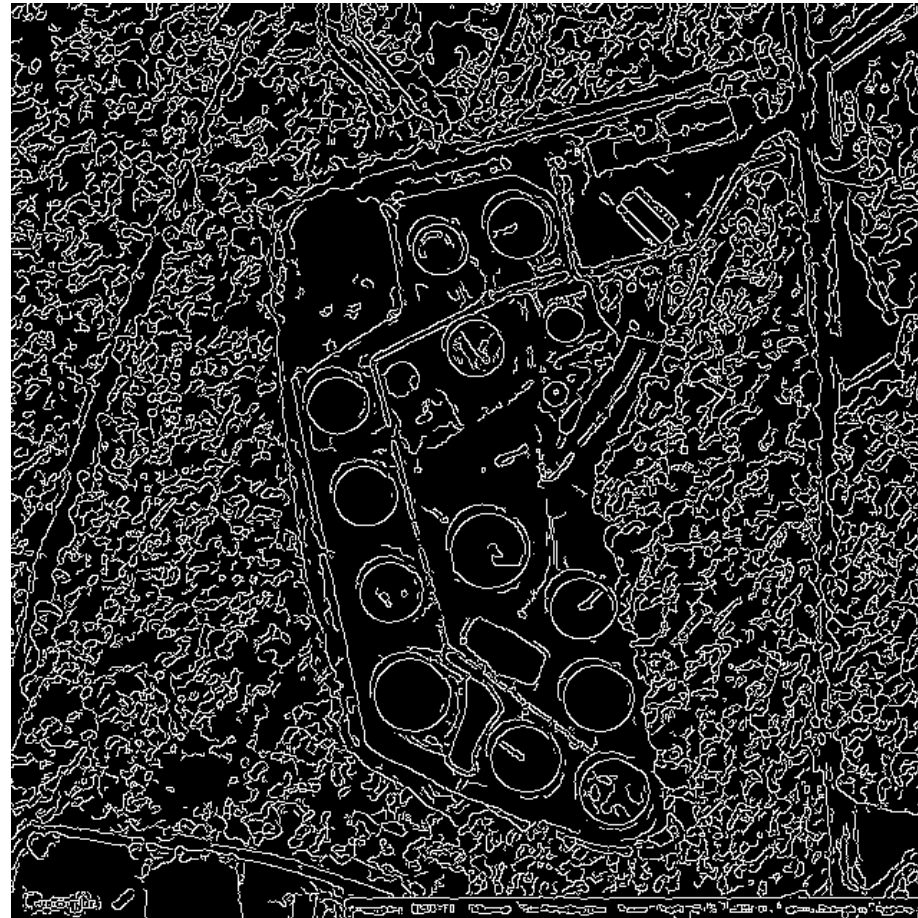
- The circle candidates are produced by “voting” in the Hough parameter space and then select the local maxima in a so-called accumulator matrix.



Process 1 – Petroleum Product Terminal Capacity

Two Main Parameters in Hough Transform

- Parameter 1: the higher threshold of the two passed to the Canny edge detector



Process 1 – Petroleum Product Terminal Capacity

Two Main Parameters in Hough Transform

- Parameter 2: the accumulator threshold for the circle centers at the detection stage. The smaller it is, the more false circles may be detected.



Process 1 – Petroleum Product Terminal Capacity

Estimating Capacity from Radius

- $V = \pi r^2 h$



$[r_1 = \text{XX},$
 $r_2 = \text{XX},$
 $r_3 = \text{XX},$
 $\dots]$

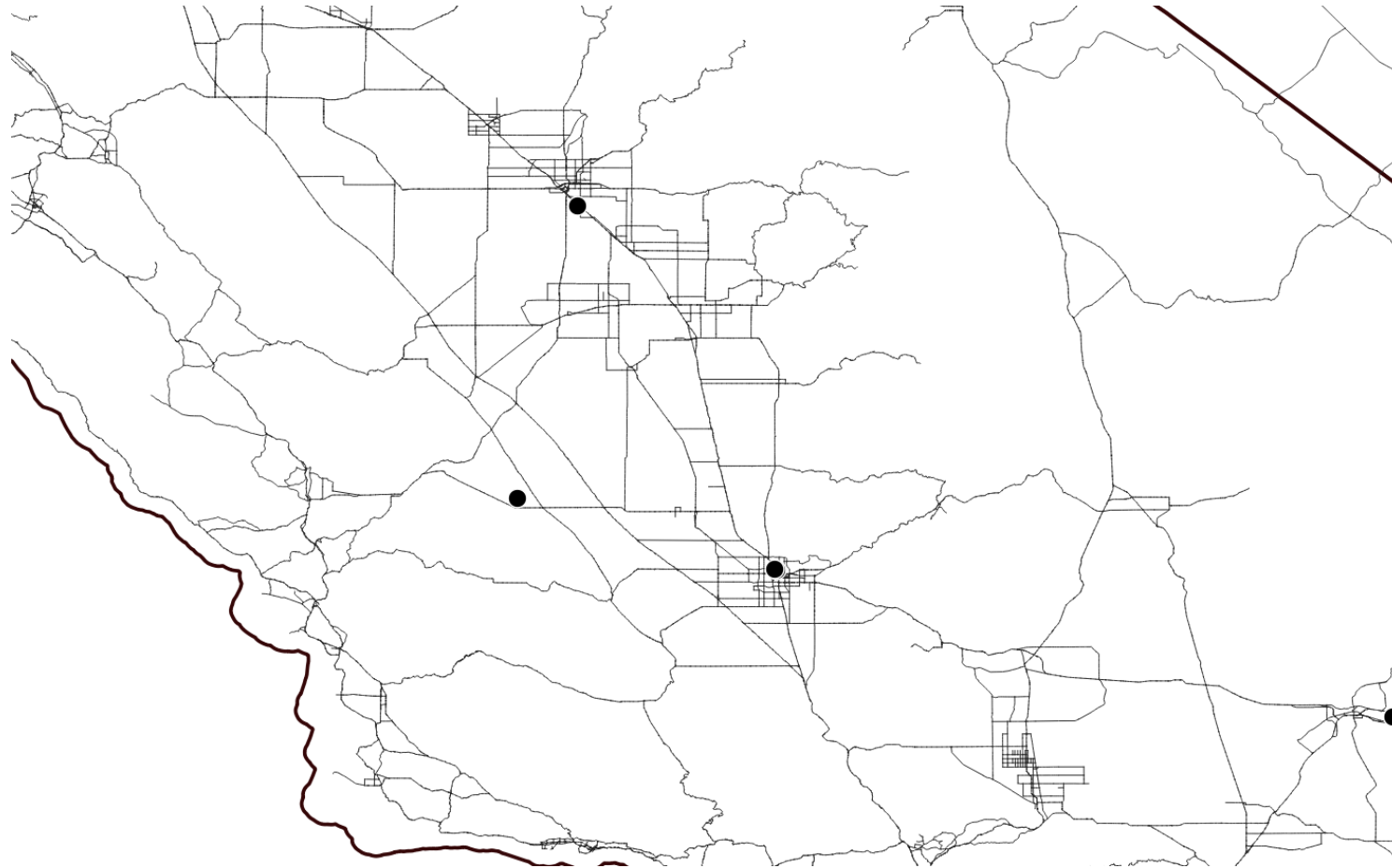
$$\text{Estimated Capacity} \propto \sum r^{\alpha}$$

- Determine α based on r-squared of estimated capacity in the validation set
- α is expected to be between 2 and 3



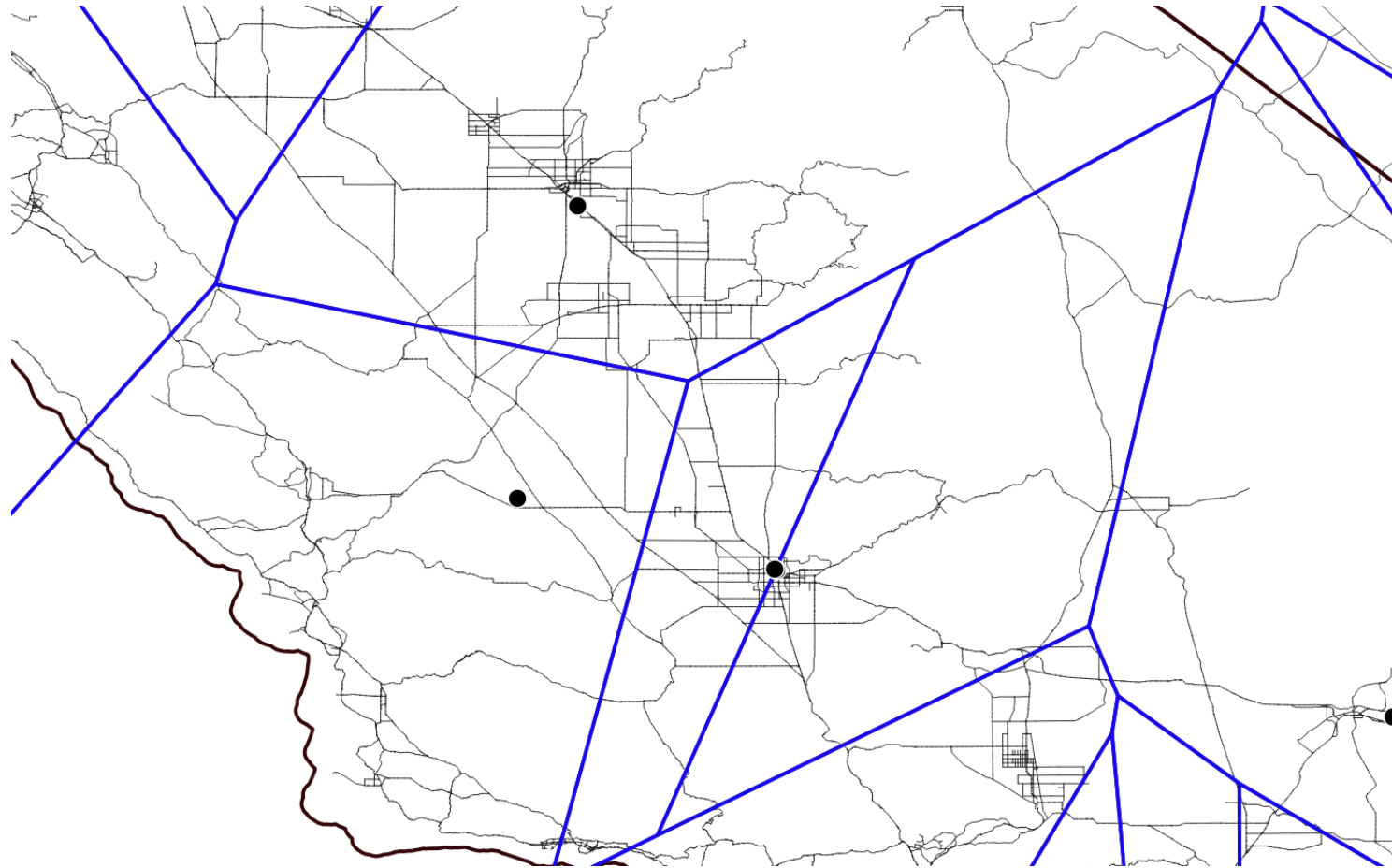
Process 2 – Coverage by Weighted Voronoi Diagram

- If the petroleum product terminal capacity was not considered...



Process 2 – Coverage by Weighted Voronoi Diagram

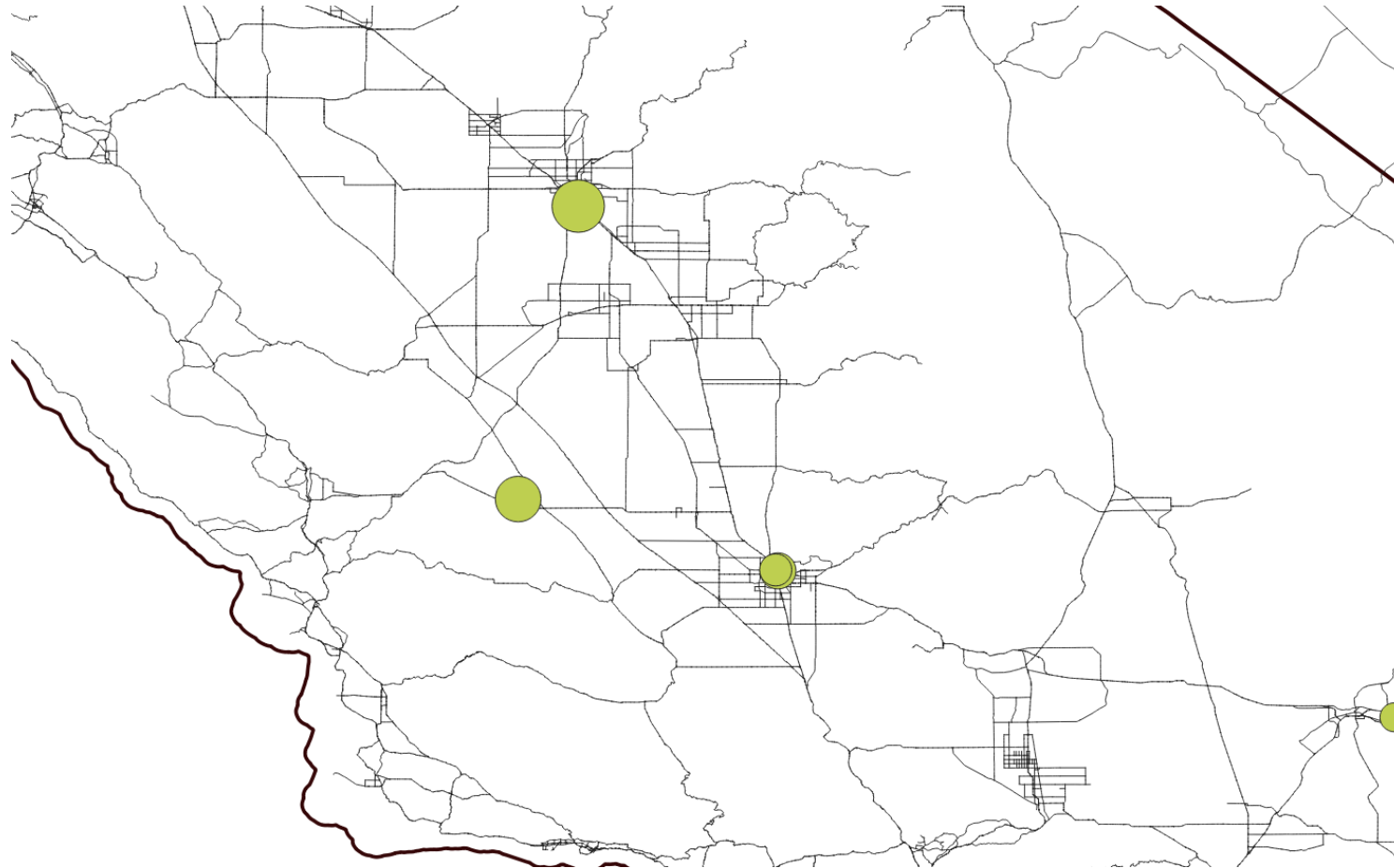
- Unweighted Voronoi Diagram (based on Euclidean Distance)



Process 2 – Coverage by Weighted Voronoi Diagram

- Weighted Voronoi Diagram (based on Euclidean Distance + Estimated Capacity)

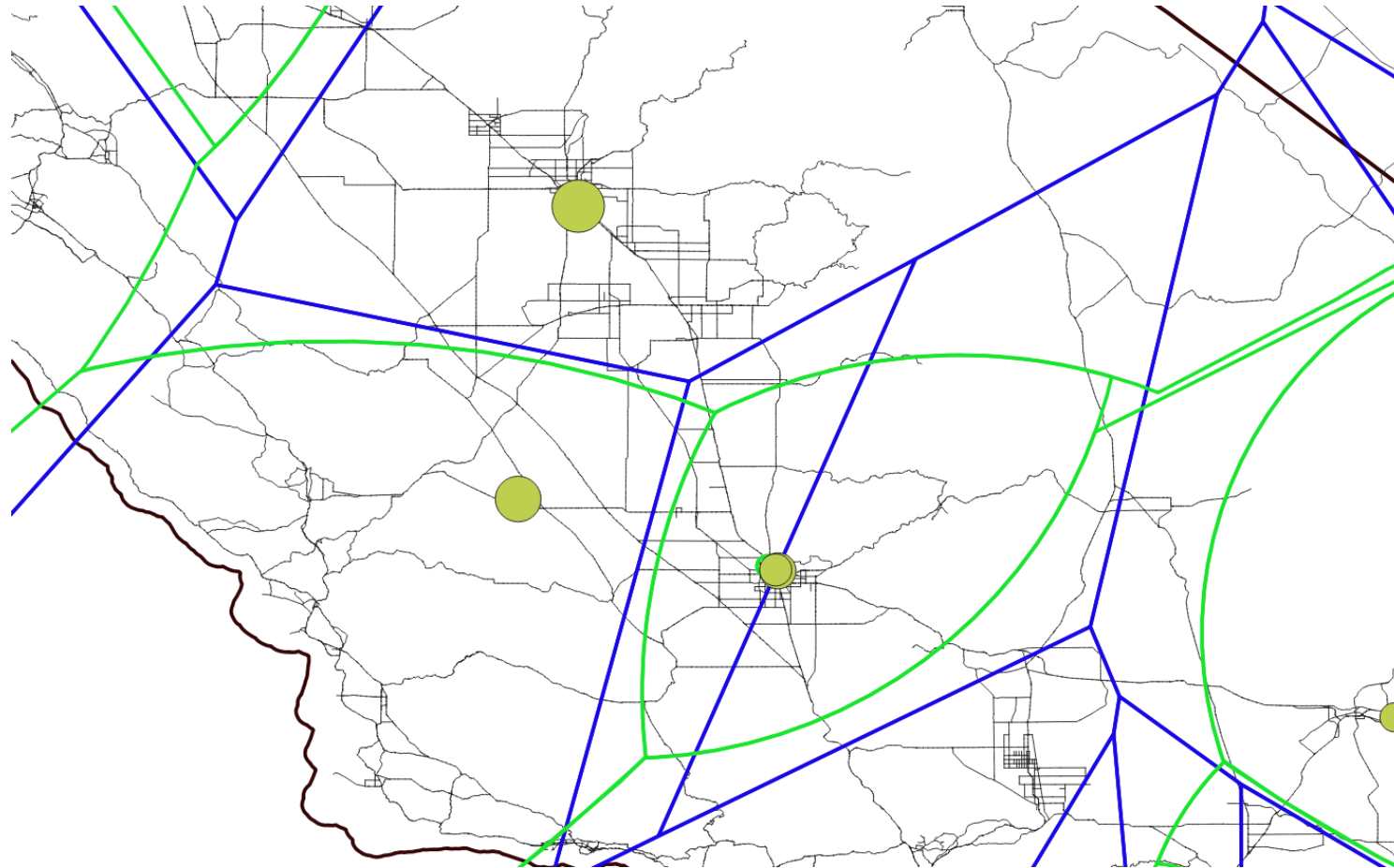
$$\text{Weight for Voronoi Diagram} = [\text{Estimated Capacity}]^{\beta}$$



Process 2 – Coverage by Weighted Voronoi Diagram

- Weighted Voronoi Diagram (based on Euclidean Distance + Estimated Capacity)

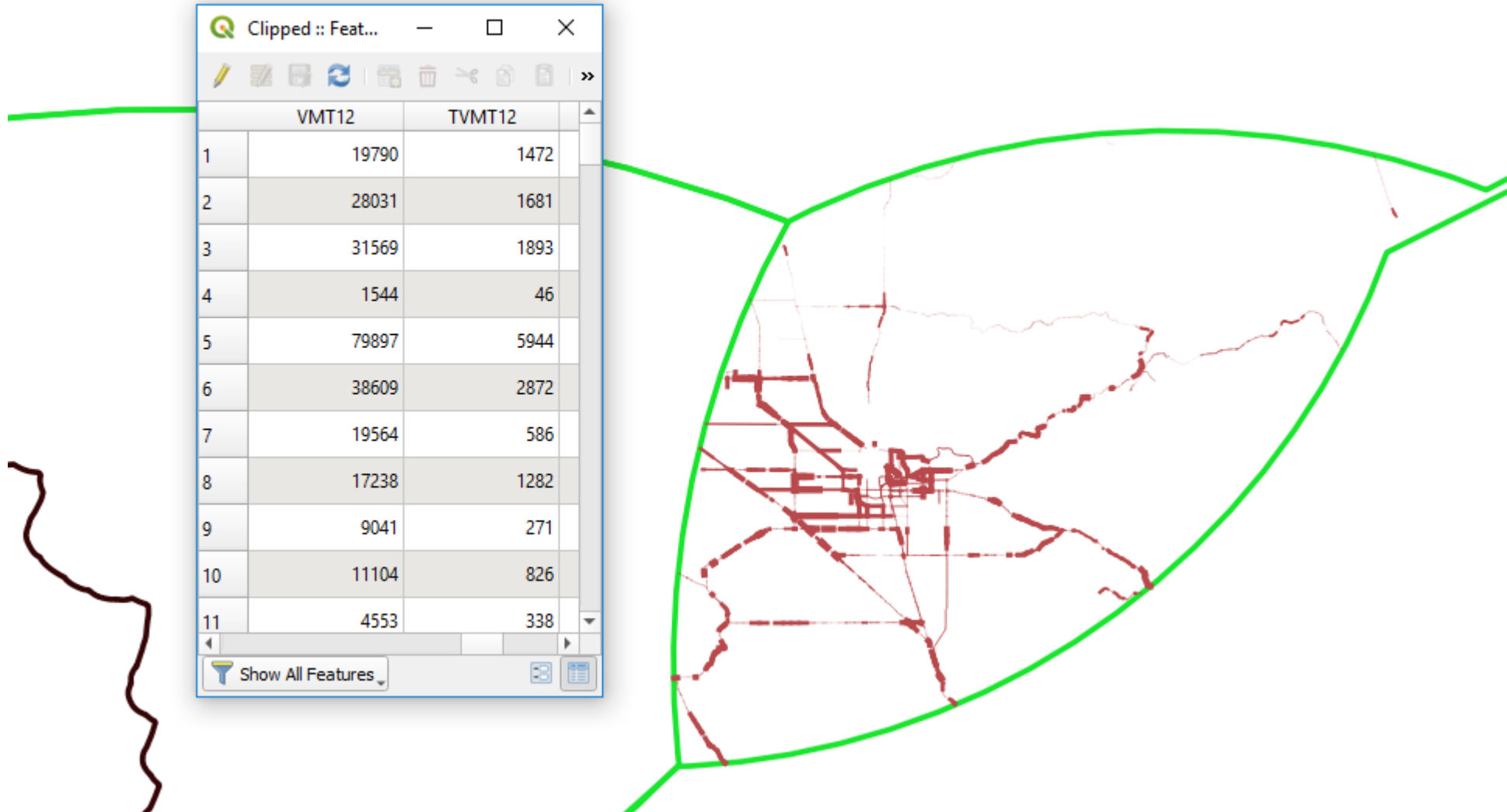
$$\text{Weight for Voronoi Diagram} = [\text{Estimated Capacity}]^{\beta}$$



Process 3 – Total VMT within the Coverage

VMT within the Coverage

- $LVMT12 = VMT12 \text{ (HPMS)} - TVMT12 \text{ (FAF4)}$



Process 4 – Estimating Petroleum Product Consumptions

Fuel Consumption Estimates from the VMT at Process 3

- $[LFC12]_i = [LVMT12]_i \times [LAFC]$, $[TFC12]_i = [TVMT12]_i \times [TAFC]$
- LAFC/TAFC is the average fuel consumption per VMT

FID	Company	State	PADD	Sum_LFC12	Sum_TFC12
0	BUCKEYE CARRIBEAN TERMINALS LLC	PR	6	0	0
1	PETRO 49 INC	AK	5	32773194.462	8485580.098
2	CPD ALASKA LLC	AK	5	998789.558	167389.544
3	CHEVRON USA INC	CA	5	546308615.214	256061637.798
4	HOLLY ENERGY PARTNERS OPER LP	NE	2	90431862.75	59542537.438
5	CENTER POINT TERMINAL LLC	WV	1	276696926.584	107566817.861
6	TRISTAR TERMINALS GUAM INC	GU	7	0	0
7	PAR HAWAII INC	HI	5	81041024.386	8494075.432
8	TRANSMONTAIGNE PRODT SVCS INC	FL	1	677645397.178001	237807367.526
9	ARGUINDEGUI OIL CO II LTD	TX	3	2935484.55	793527.124
10	PAR HAWAII REFINING LLC	HI	5	20142217.118	2331811.862
11	PLAINS LPG SERVICES LP	CA	5	107797071.736	32242624.308
12	HOLLY ENERGY PARTNERS OPER LP	AZ	5	30594646.406	64316443.183
13	WESTERN REFINING SOUTHWEST INC	NM	3	815970619.755999	160629303.309
14	JP ENERGY CADD0 LLC	TX	3	176977663.014	97016084.996
15	TRANSMONTAIGNE PRODT SVCS INC	MS	3	237004265.458	62715702.008
16	PHILLIPS 66	GA	1	79122332.764	30250625.806

Process 5 – State Level Validation and Calibration

Compare State-level Estimates vs EIA

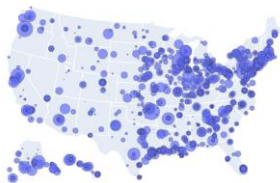
- To calibrate model parameters (weighting factor for Voronoi diagram)

Weight for Voronoi Diagram = [Estimated Capacity] ^{β}

Terminal ID	<i>terminal estimate</i> \hat{y}	State	<i>state estimate</i> \hat{Y}	<i>EIA</i> <i>state consumption</i> Y
0001	359	AK	6,091	6,661
⋮	⋮			
0047	122			
0048	704	AL	49,326	60,653
⋮	⋮			
0082	1,331			
0083	4,014	AR	53,806	33,732
⋮	⋮			

Final Results

Final Petroleum Consumption at Terminal



$$\hat{y}^* = Y \times \frac{\hat{y}}{\sum \hat{y}} \quad , \quad \sum \hat{y}^* = Y$$

Terminal ID	Adjusted \hat{y}^*	State	Adjusted \hat{Y}^*	EIA state consumption Y
0001	359 -> 392	AK	6,091 -> 6,661	6,661
⋮	⋮			
0047	122 -> 134	AL	49,326 -> 60,653	60,653
0048	704 -> 866			
⋮	⋮			
0082	1,331 -> 1,637	AR	53,806 -> 33,732	33,732
0083	4,014 -> 2,516			
⋮	⋮	⋮	⋮	⋮

Conclusions

Common research questions to be answered...

- Is there a better method to estimate fuel consumptions?
- How can we validate the results?
- Other data sources?

Other things that we can do with AI/ML...

- Verifying inactive/invalid petroleum product terminal locations
- Access of transportation mode at a certain location