

Analyzing the Scope and Scale of Solar Energy Adoption at Wastewater Treatment Plants in the US

Capstone Symposium
March 2024

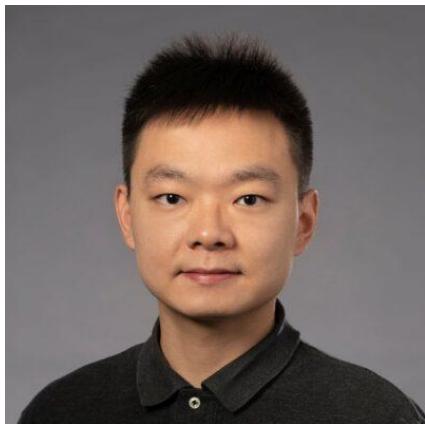
Our Team



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Our Capstone Partners



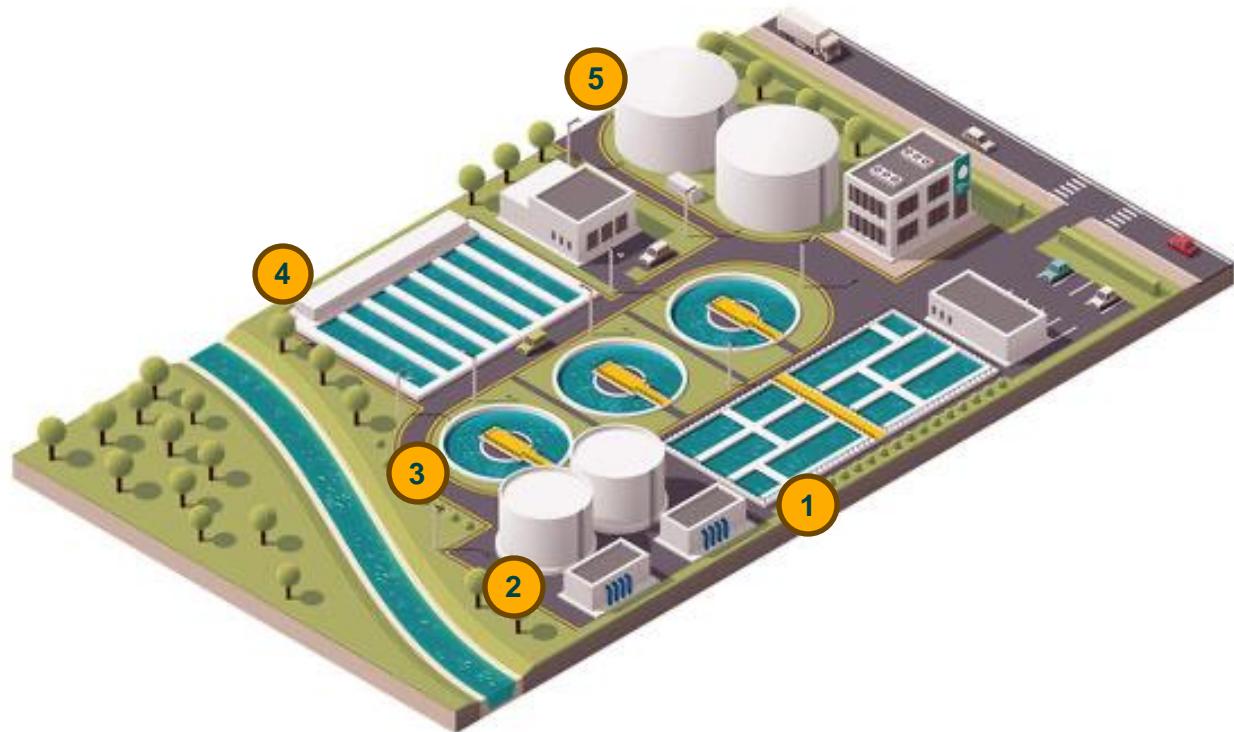
Across the United States, wastewater treatment plants require 30-40% of the total energy, estimated to consume more than 30 terawatt-hours per year of electricity, equating to about \$2 billion in annual electric costs.



Our project goal is to help our client understand the scope and scale of solar energy adoption at wastewater treatment plants (WWTPs) across the United States, in particular within California and Texas



What is a Wastewater Treatment Plant (WWTP)?



Wastewater treatment plants are facilities designated to remove contaminants from sewage from their respective surrounding communities and environments

Key Parts of a Wastewater Treatment Plant:

- 1 Aeration Basins
- 2 Granular Reactors
- 3 Clarifiers
- 4 Filter lagoons
- 5 Digesters

Identifying Wastewater Treatment Plants with Solar





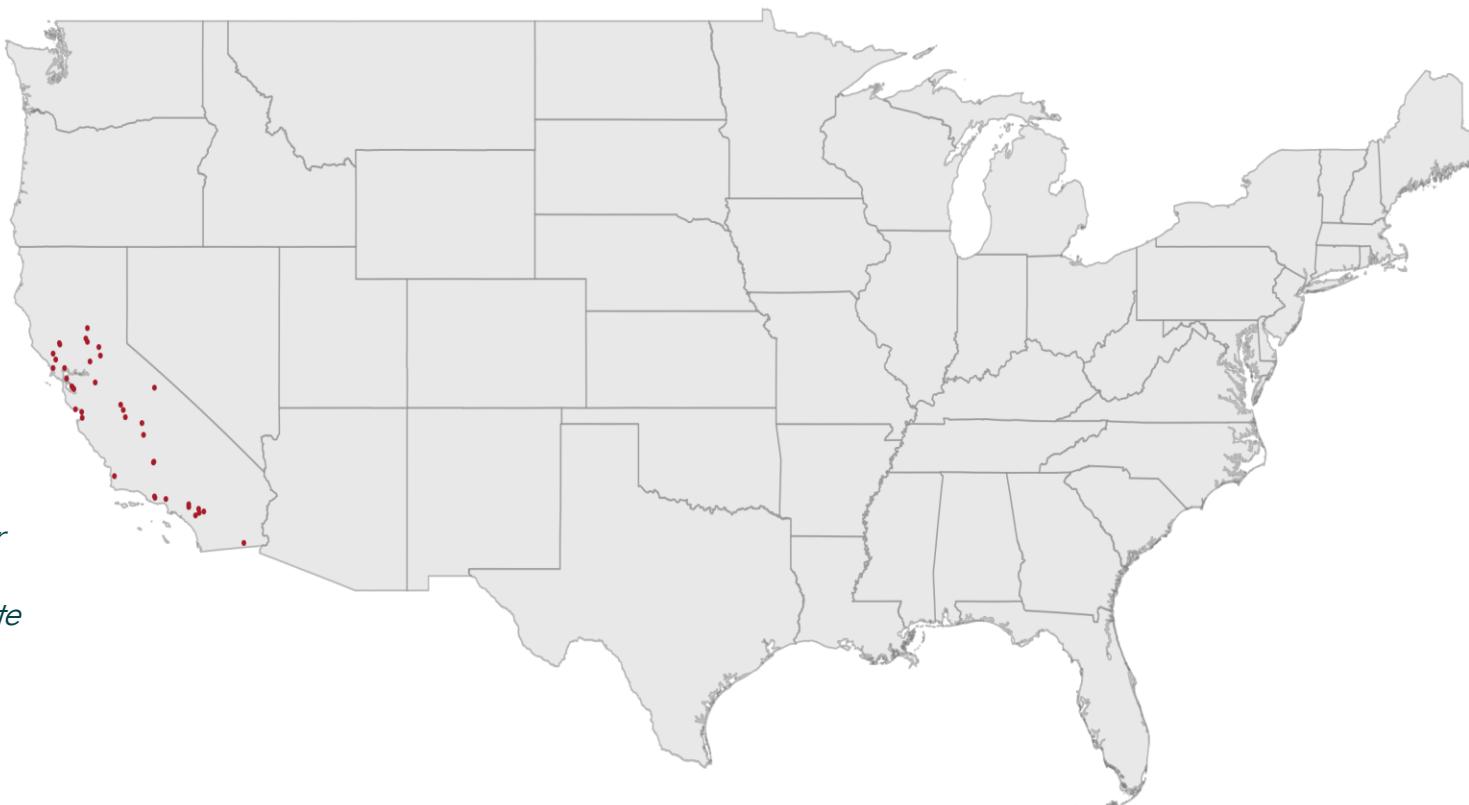
Data Source and Analysis

Data Sources



Approved List of 40 Solar Verified WWTP

An initial verified list of 40 wastewater treatment plants that utilized solar energy provided by Penn State Institute of Energy and the Environment

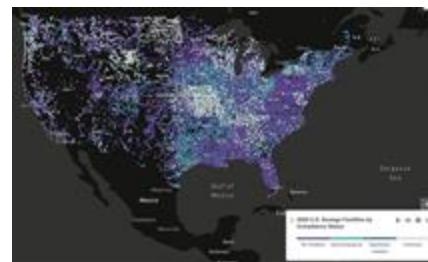


Data Sources



OpenStreet Map

A free, open, and crowdsourced geographic database updated and maintained by a community of volunteers via open collaboration.



Environmental Protection Agency (EPA)

An government published data set containing information relating to location and facility identification from the EPA's Facility Registry Service (FRS) from 2020

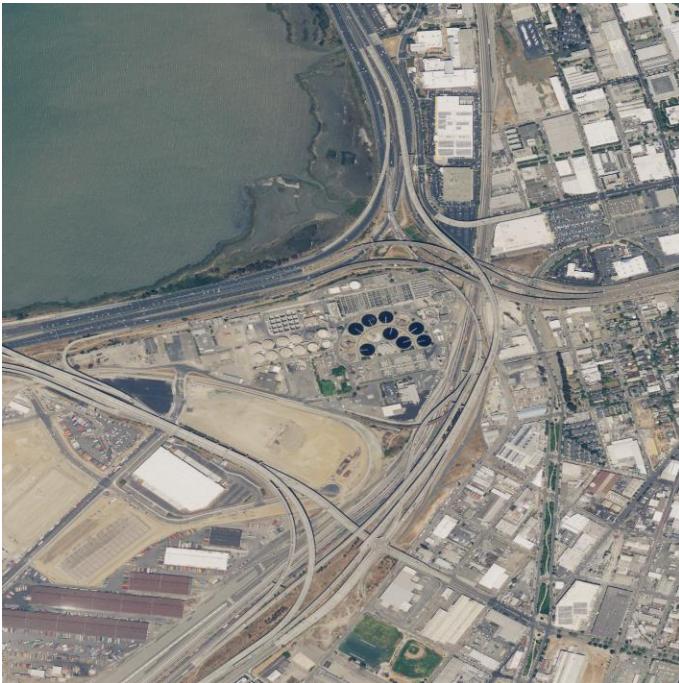
HydroSHEDS

HydroSheds HydroWaste

An open-source spatially explicit global database of 58,502 wastewater treatment plants (WWTPs)

List of Aggregated WWTPs Include Sites That Aren't Actual WWTPs

OpenStreet Map



EBMUD Wastewater Treatment Plant, CA



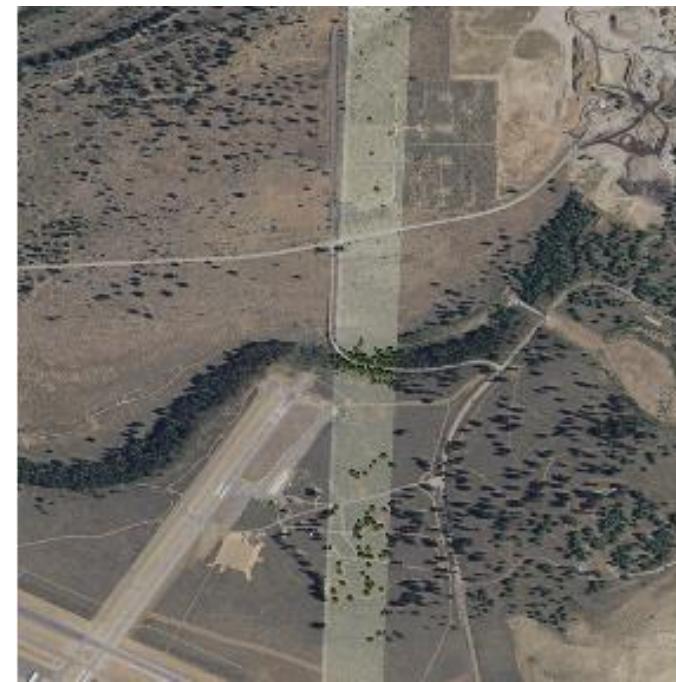
City of Mt. Enterprise Wastewater Treatment Plant, TX

List of Aggregated WWTPs Include Sites That Aren't Actual WWTPs

Environmental Protection Agency (EPA)



Haskell St WWTP, TX



Tahoe Truckee WWTP, CA

List of Aggregated WWTPs Include Sites That Aren't Actual WWTPs

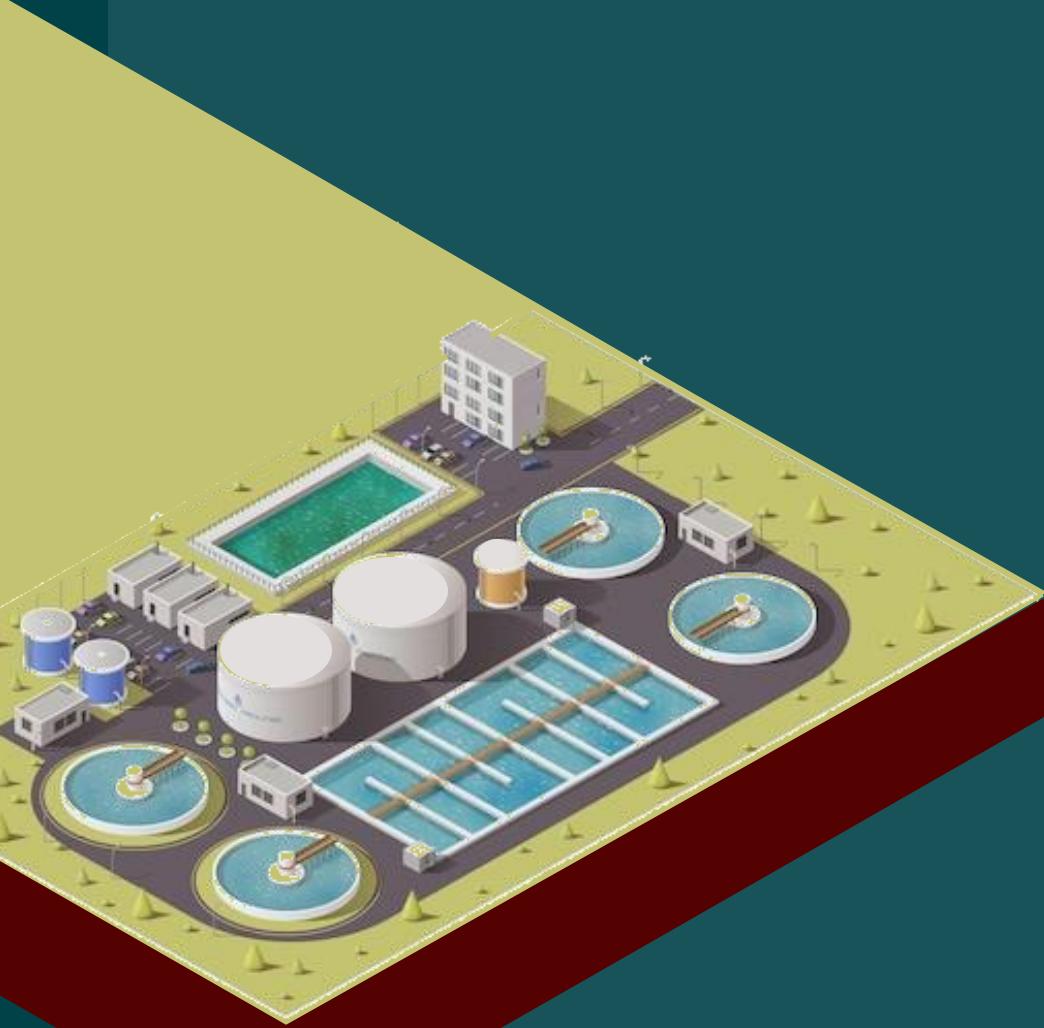
HydroSheds HydroWaste



Woodland WWTF, CA

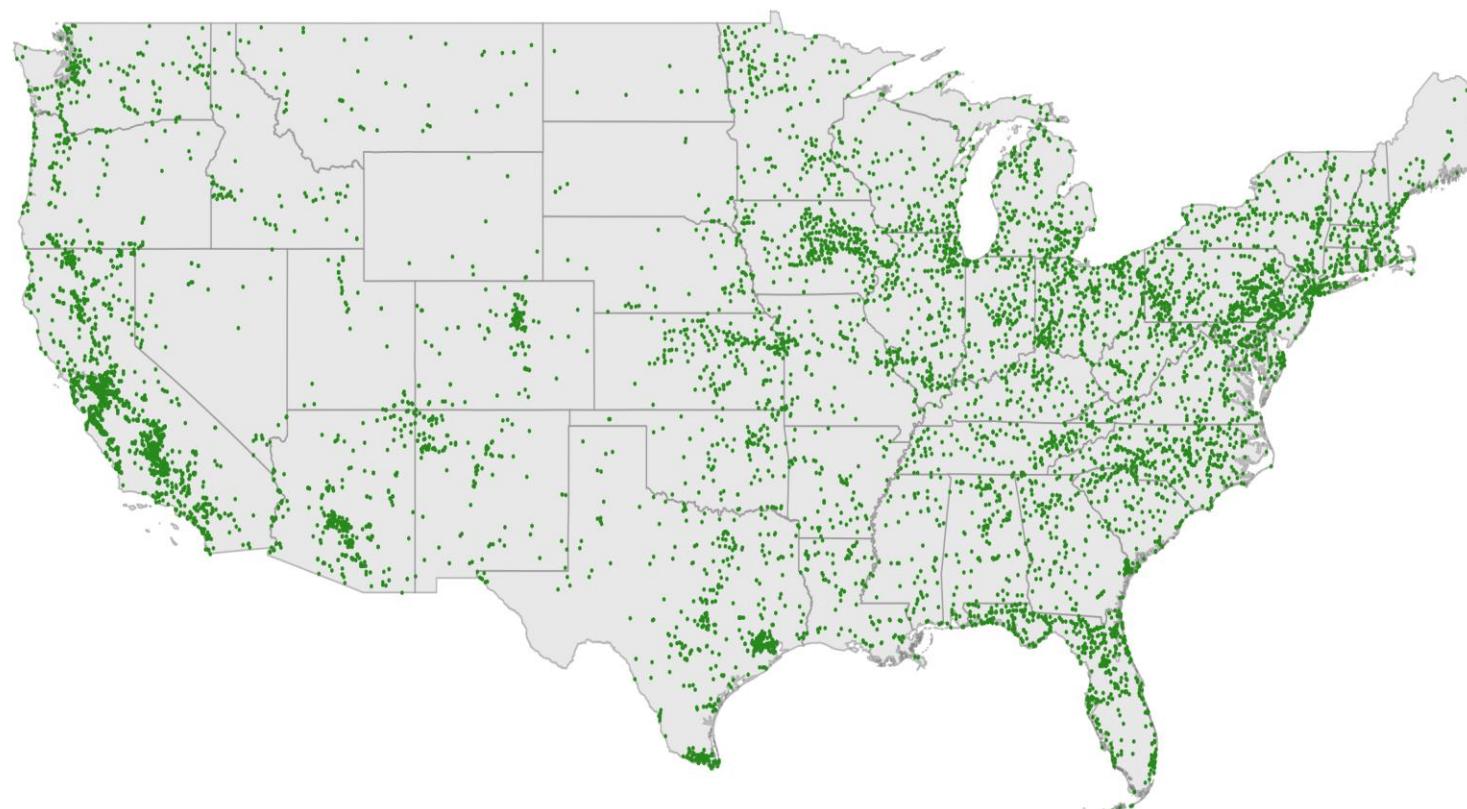


Hart WWTP, TX



**How large is this
problem?**

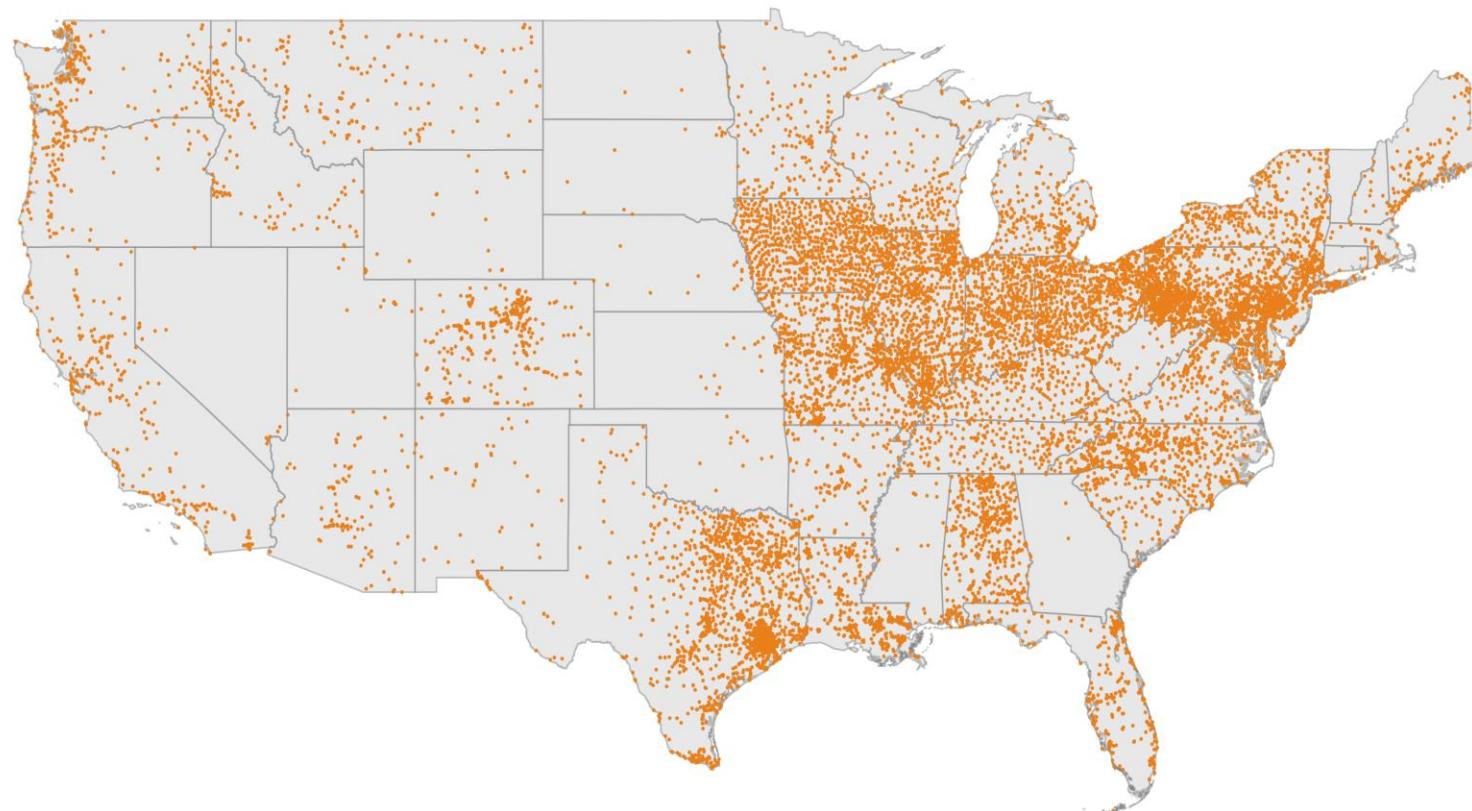
Data Source Analysis



OpenStreet Map

14,282 WWTPs

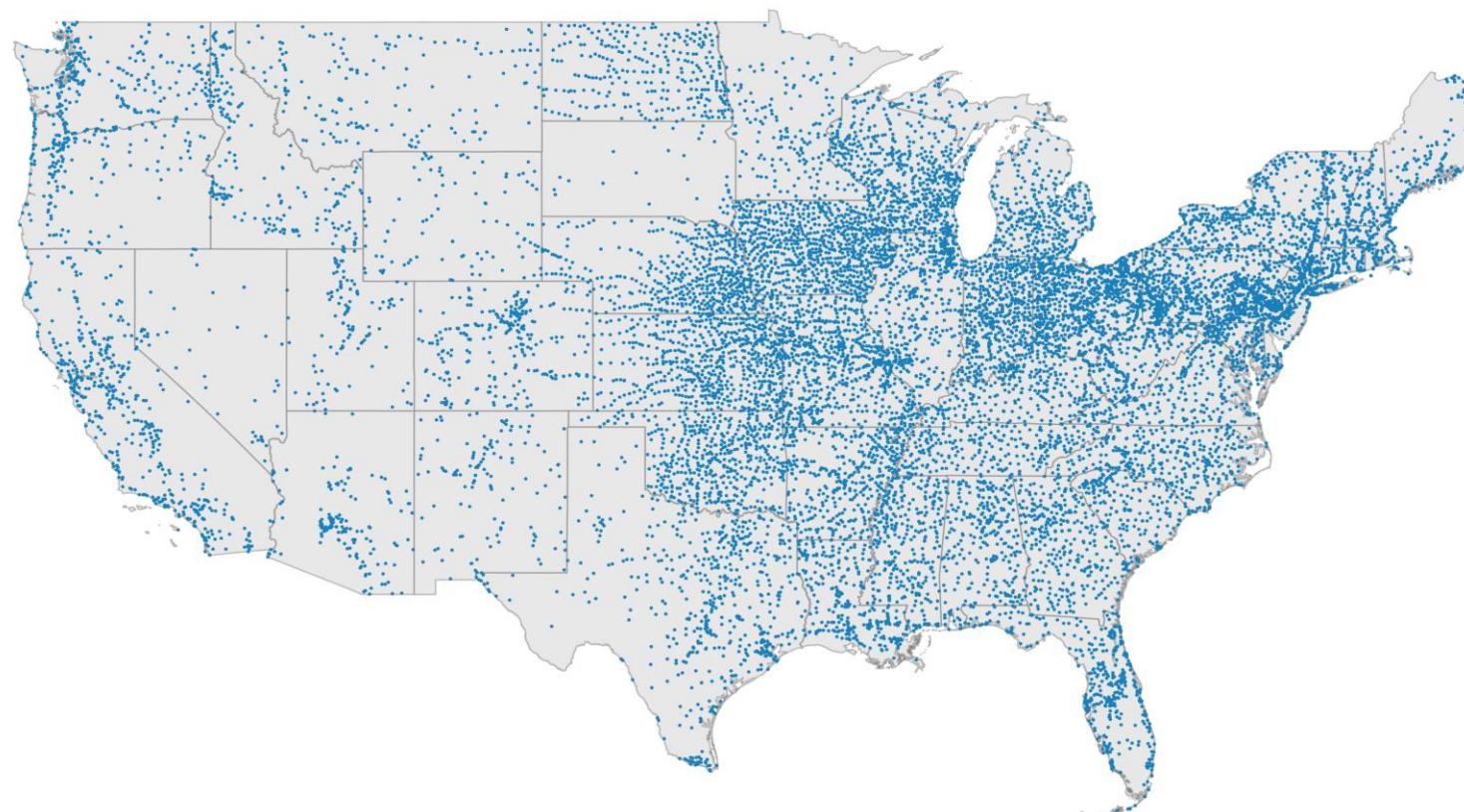
Data Source Analysis



Environmental Protection
Agency (EPA)

14,327 WWTPs

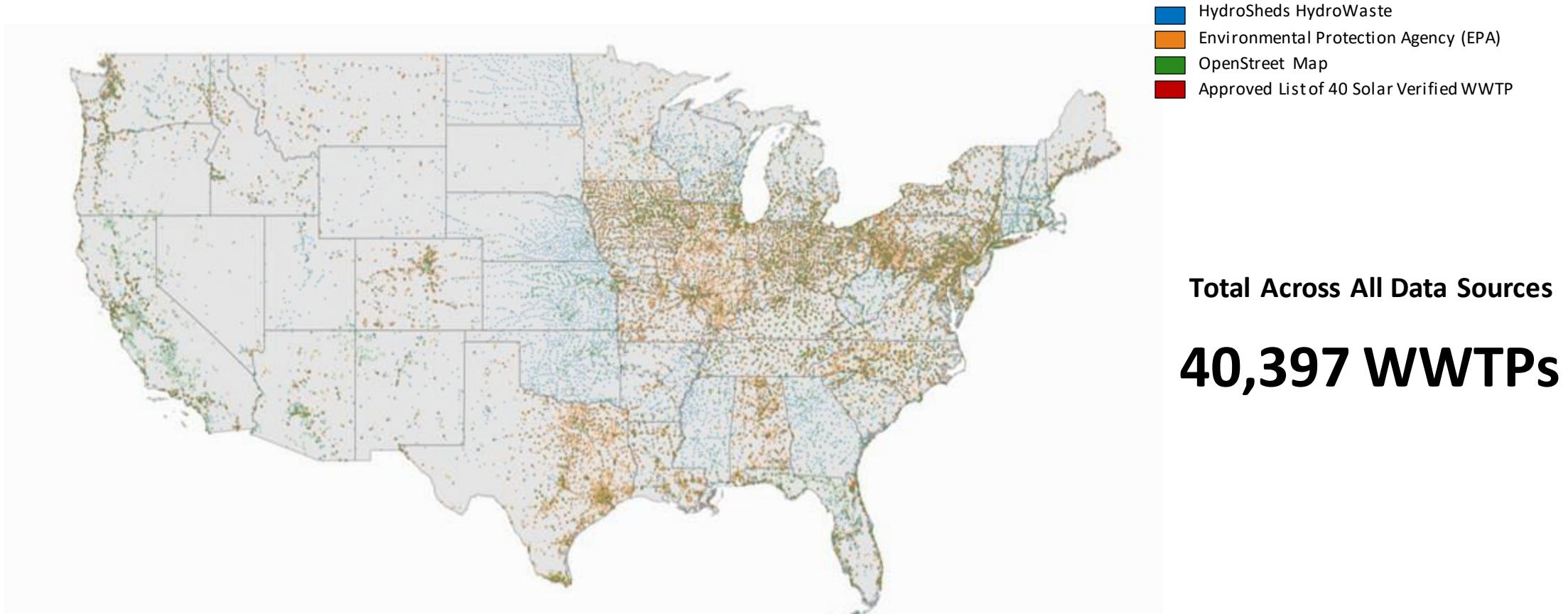
Data Source Analysis



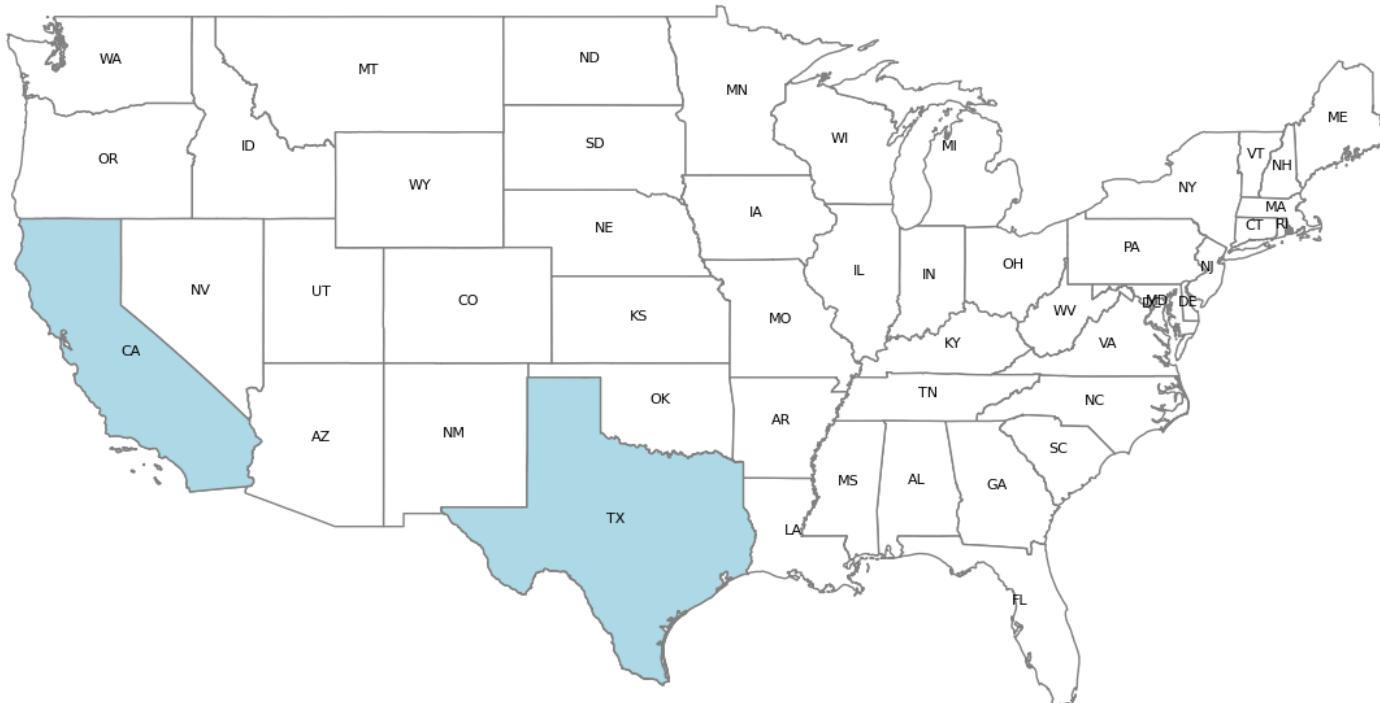
HydroSheds HydroWaste

14,748 WWTPs

Data Source Analysis



To Tackle the Challenges



Using California and Texas as our initial pilot states:

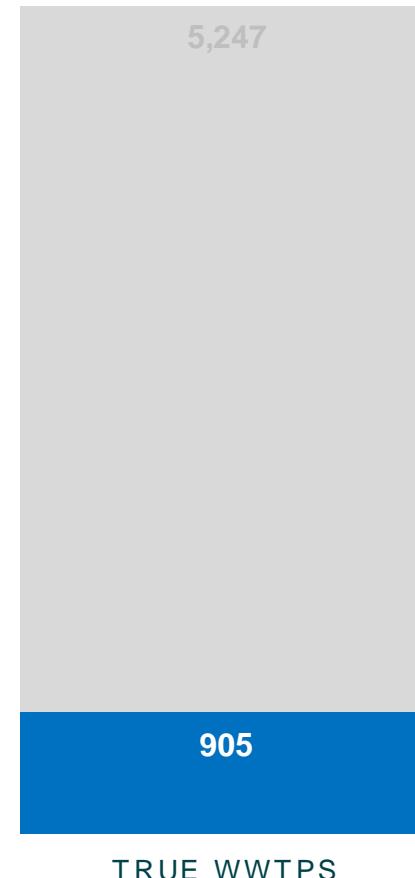
- 1 Client is interested in those respective states
- 2 Large population states would contain more WWTPs
- 3 Demographic and economic diversity

**For California and Texas, 5247 image candidates to verify
across all data sources**

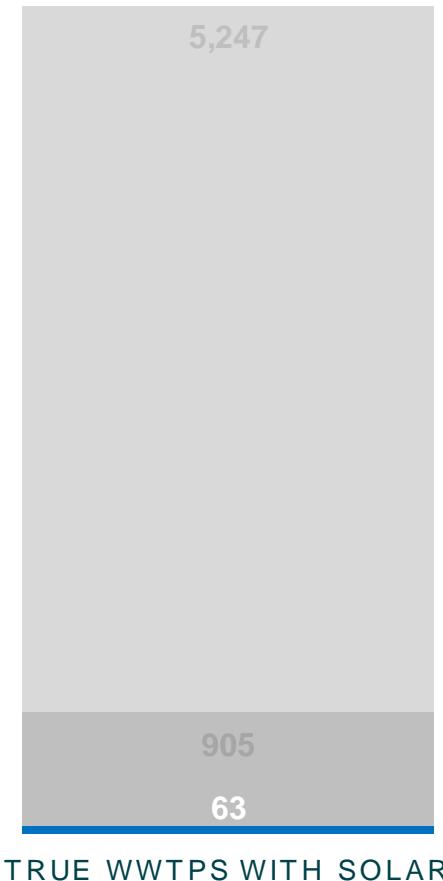


WWTP CANDIDATES

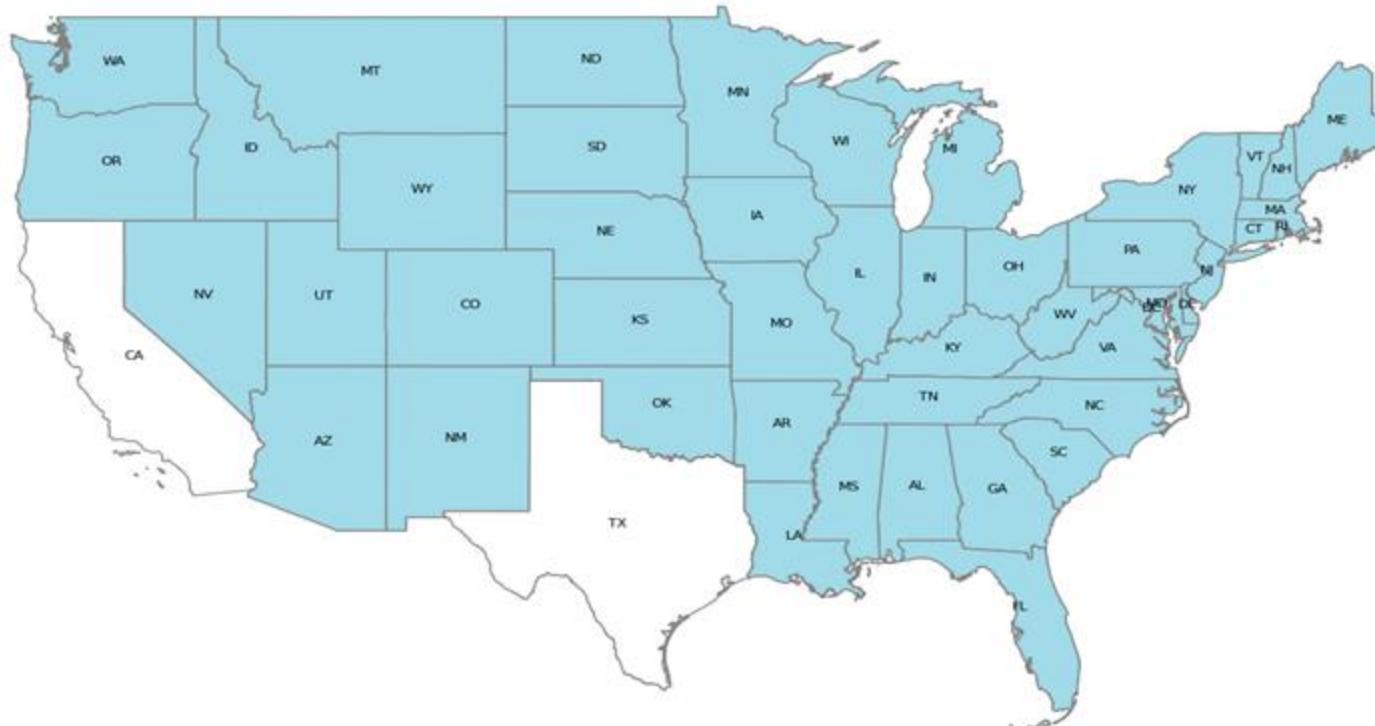
17.25% of image candidates have Wastewater Treatment Plant in them for California and Texas



6.96% of Wastewater Treatment Plants have solar adoption in California and Texas



Scale Up Nationally



Total Remaining Across All Data Sources

35,150 WWTPs

Scale our understanding on California and Texas to all remaining states

Spot the difference



Spot the difference

WWTP



NO
WWTP

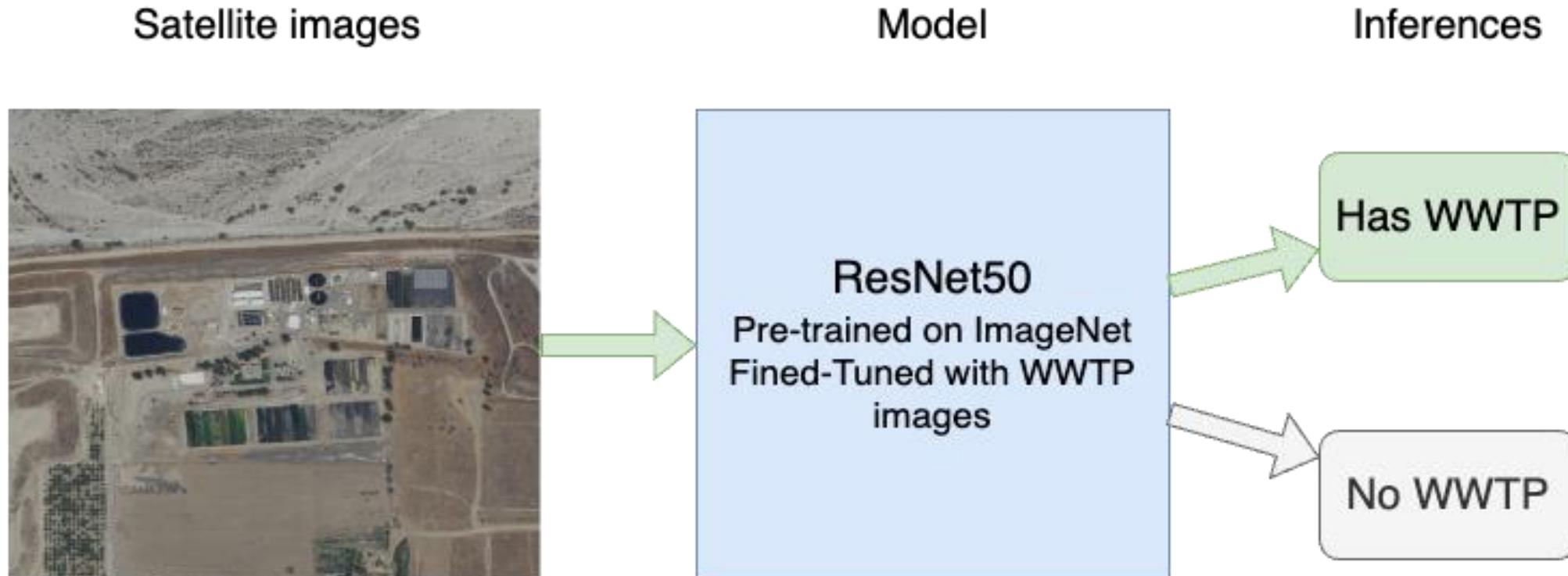


Binary Classification:

Has WWTP or Not



Scene Classification Model Pipeline



**How do we know if the model would perform well
with our data and whether it would be the same when
scaling up?**

Experiment Methodology

Stage 1: How good the model is?

Compare model performance using different crop sizes

Stage 2: Are you sure it would have decent performance when scaling up?

Within domain vs Cross domain performance check

Experiment Stage 1 – Change Crop Size

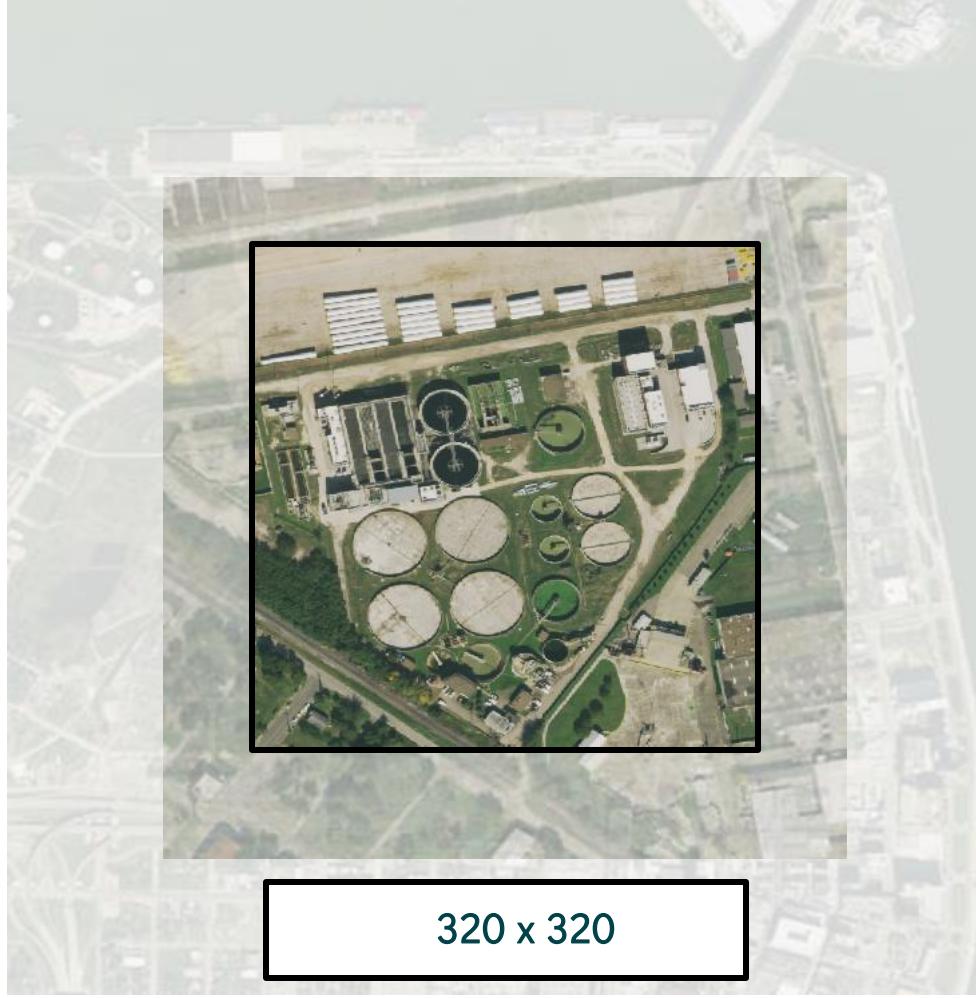


Experiment Stage 1 – Change Crop Size

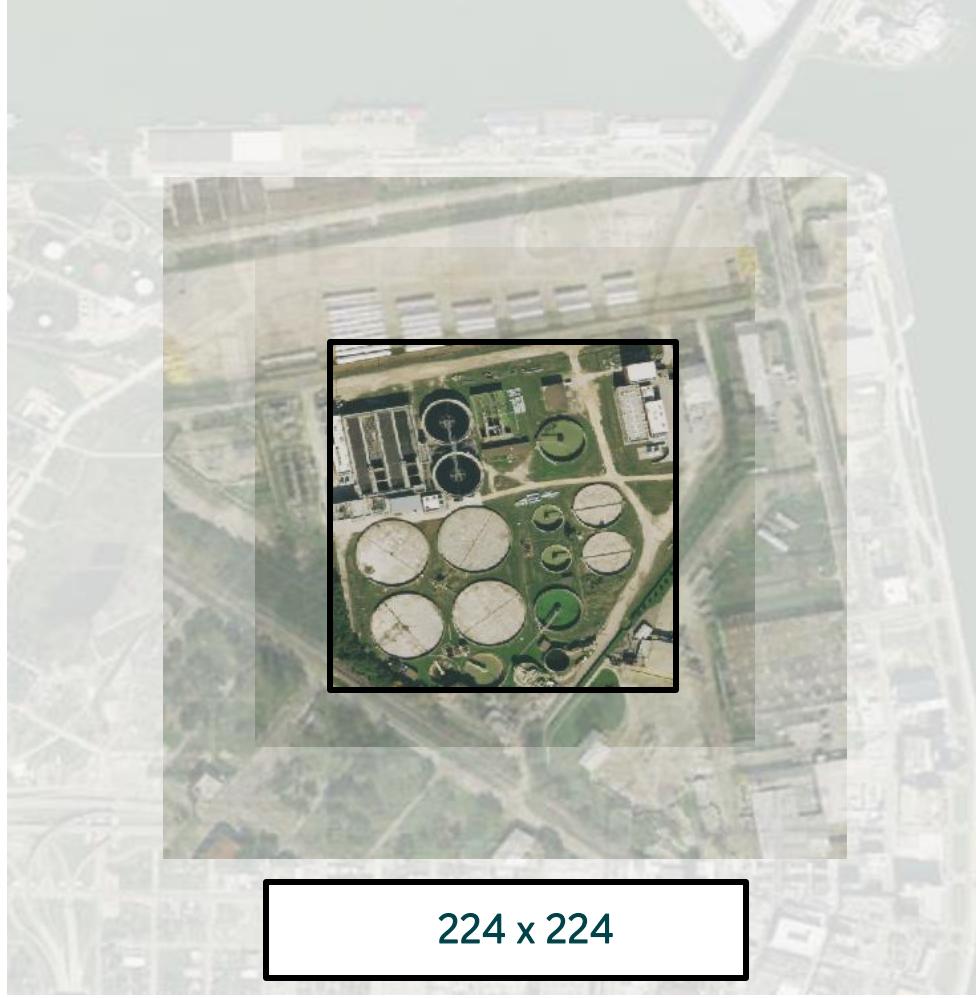


512 x 512

Experiment Stage 1 – Change Crop Size



Experiment Stage 1 – Change Crop Size

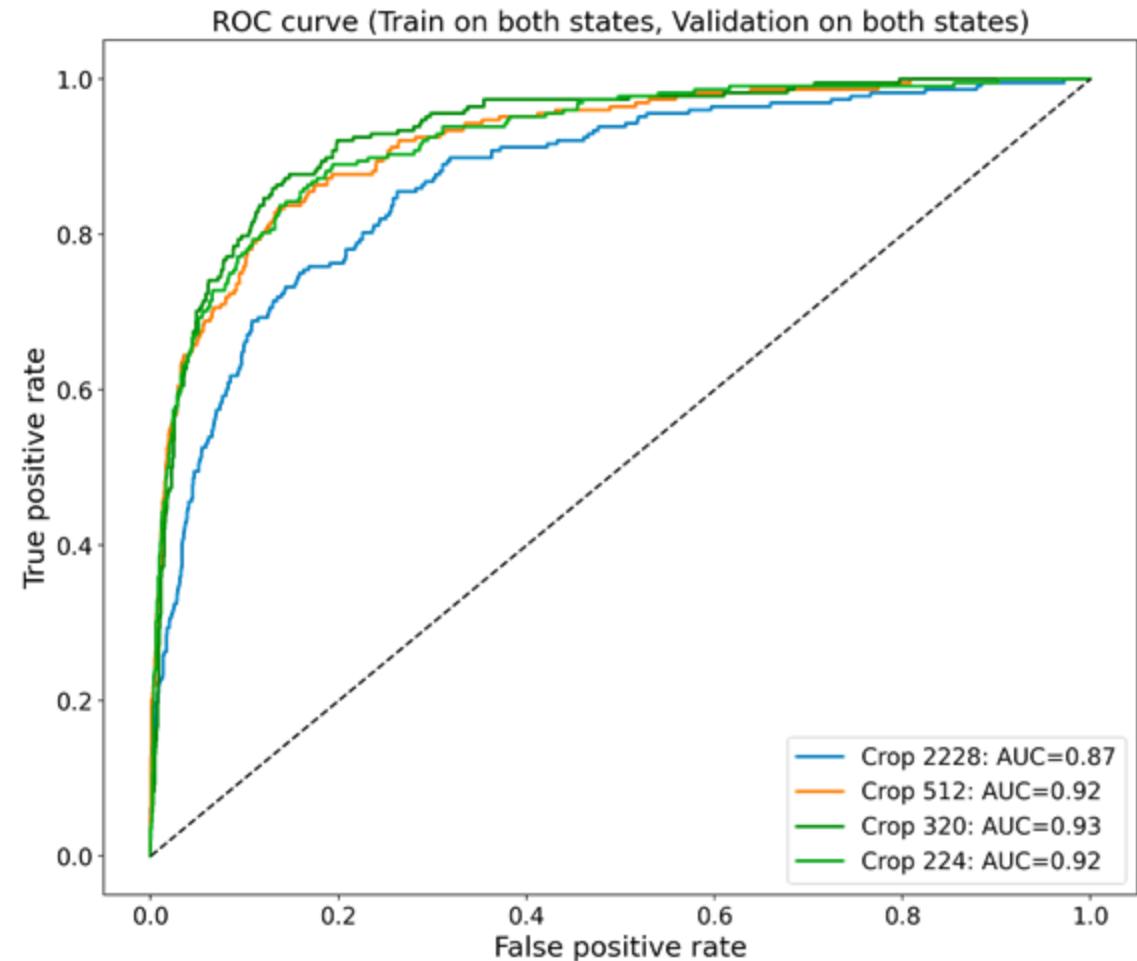


224 x 224

Experiment Stage 1 – Change Crop Size

Best Model Performance Achieved with Crop Size of 320 x 320

Center Crop Size	AUC	Max F1 score
Original (2228 x 2228)	0.87	0.5198
512 x 512	0.92	0.5075
320 x 320	0.93	0.6554
224 x 224	0.92	0.5635



Experiment Methodology

Stage 1: How good the model is?

The model DOES perform well on our data

Stage 2: Are you sure it would have decent performance when scaling up?

Within domain vs Cross domain performance check

Experiment Stage 2

Using the best model from Experiment Design (1): Pretrained ResNet50 on ImageNet Weights, Crop size: 320 x 320

		Validation On	
		Texas	California
Training On	Texas	AUC:0.93, Max F1: 0.8454	AUC:0.89, Max F1: 0.5482
	California	AUC:0.75, Max F1: 0.6175	AUC:0.91, Max F1: 0.6139

Within Domain: Train in the **same** state as the validation images

Cross Domain: Train in a **different** state from the validation images

- Despite significant changes from the training states to the validation states, **Cross Domain** training still presents significantly good performance and AUC metrics, which demonstrates our model's generalization and predictive ability across disparate WWTP sites.

Experiment Methodology

Stage 1: How good the model is?

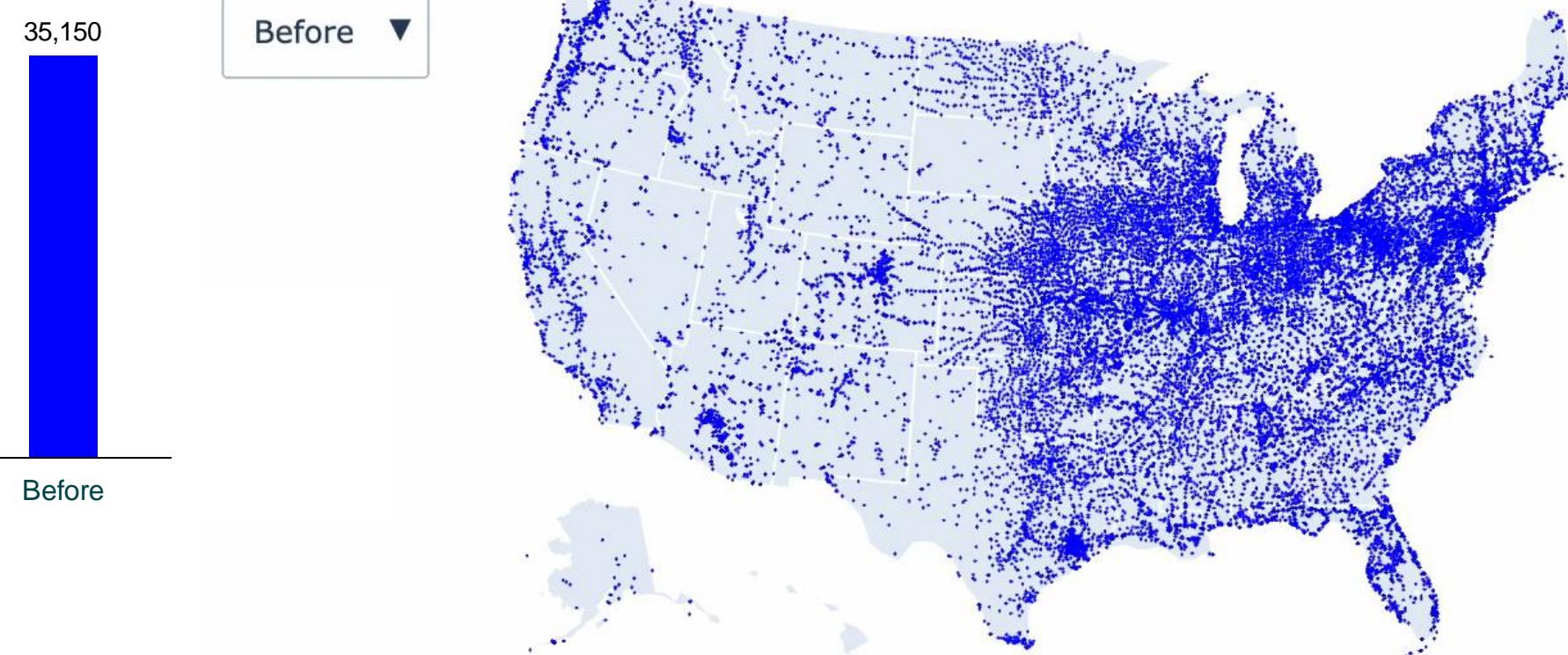
The model **DOES** perform well on our data

Stage 2: Are you sure it would have decent performance when scaling up?

The model **WOULD** perform well on other states

Inference Results

WWTPs From Source Data



Inference Results

WWTPs From Model Inference

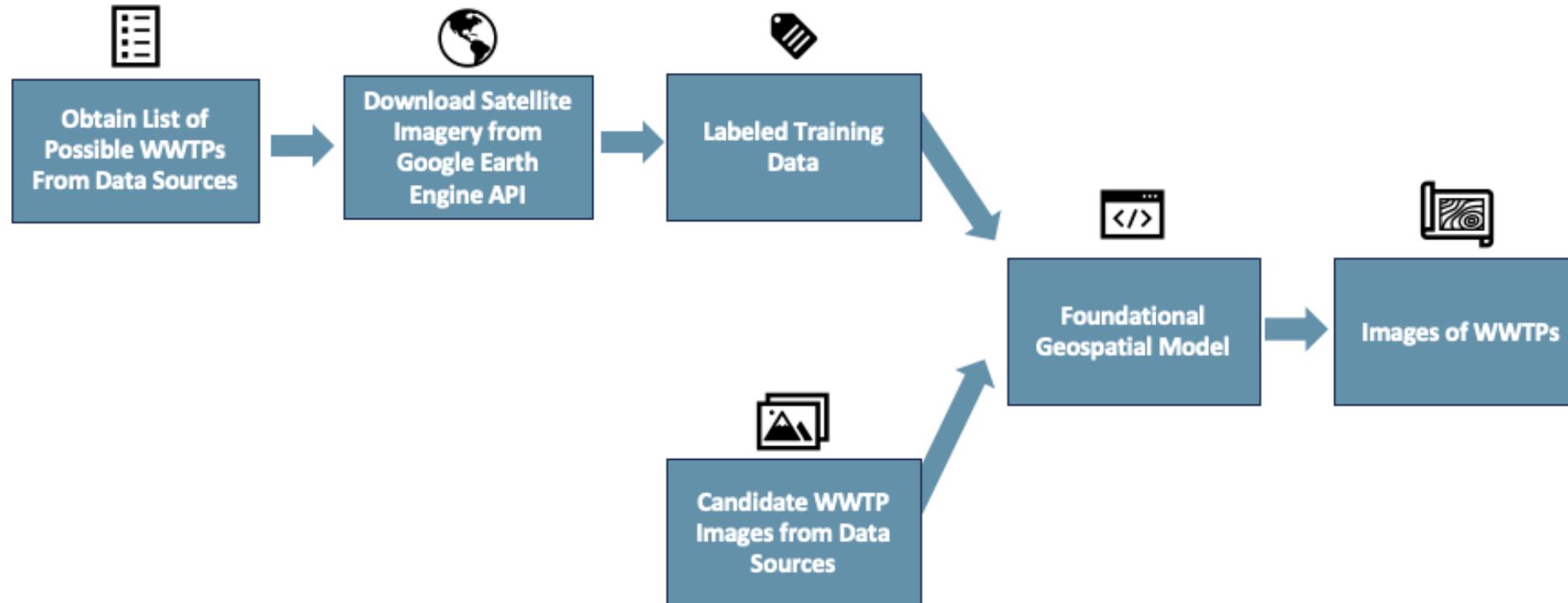


35K WWTPs – 10K WWTPs = 25K WWTPs

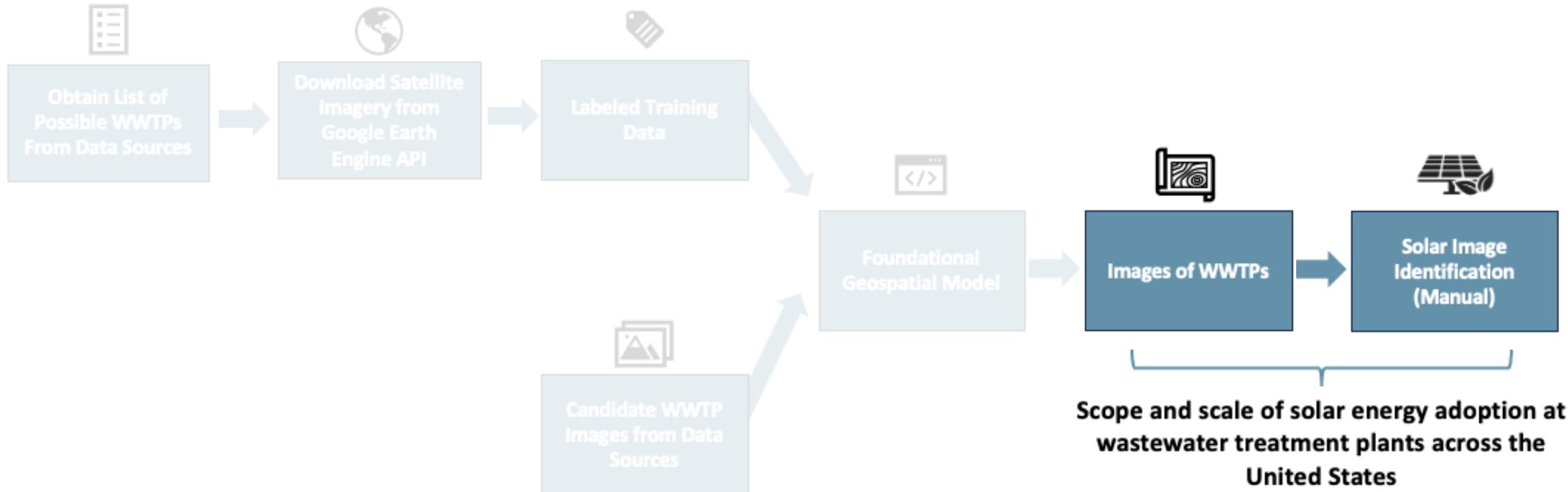
That Do Not Have to be Checked

Manual Work is Reduced by 70%

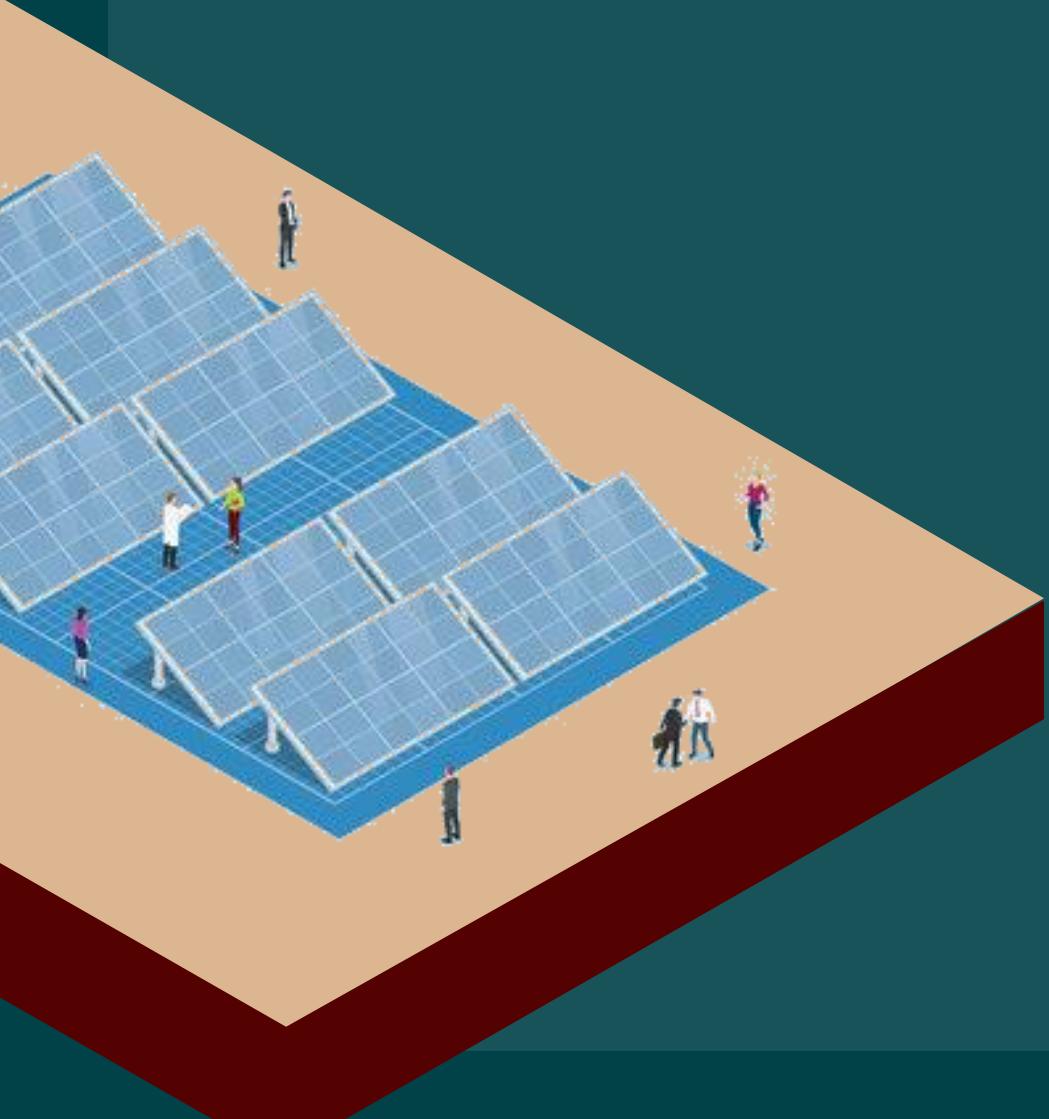
Project Approach



Project Approach



Client Impact & Value Added





Identify patterns in solar adoption at Wastewater Treatment Plants

Observations

Solar adoption is 14 percentage points greater in California than Texas

Possible Future Analyses

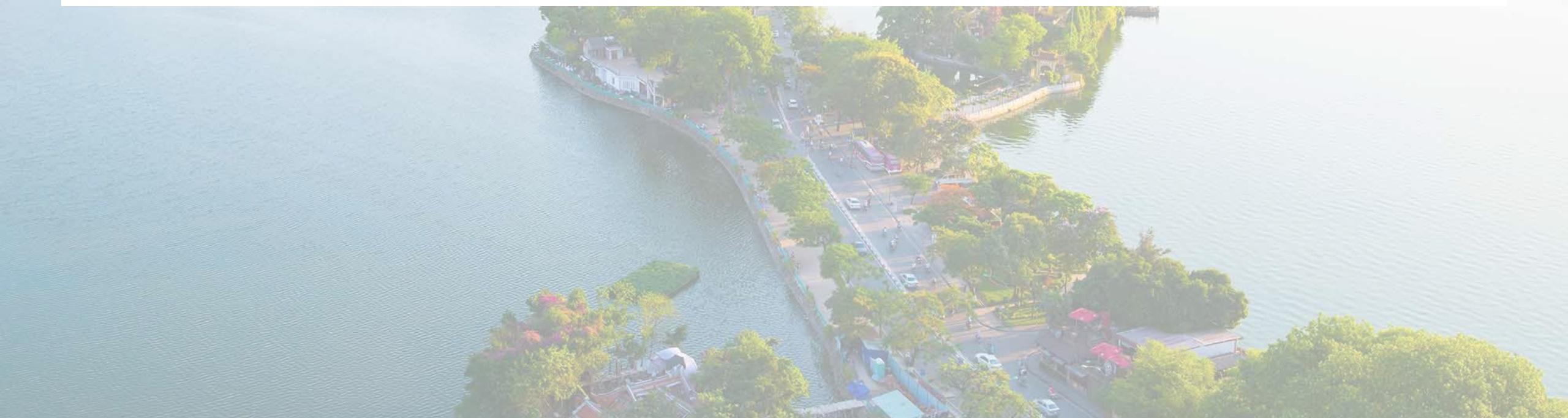
Does WWTP size and capacity play a role in solar adoption?

Does solar adoption depend on state?

If so, why and factors affect this?



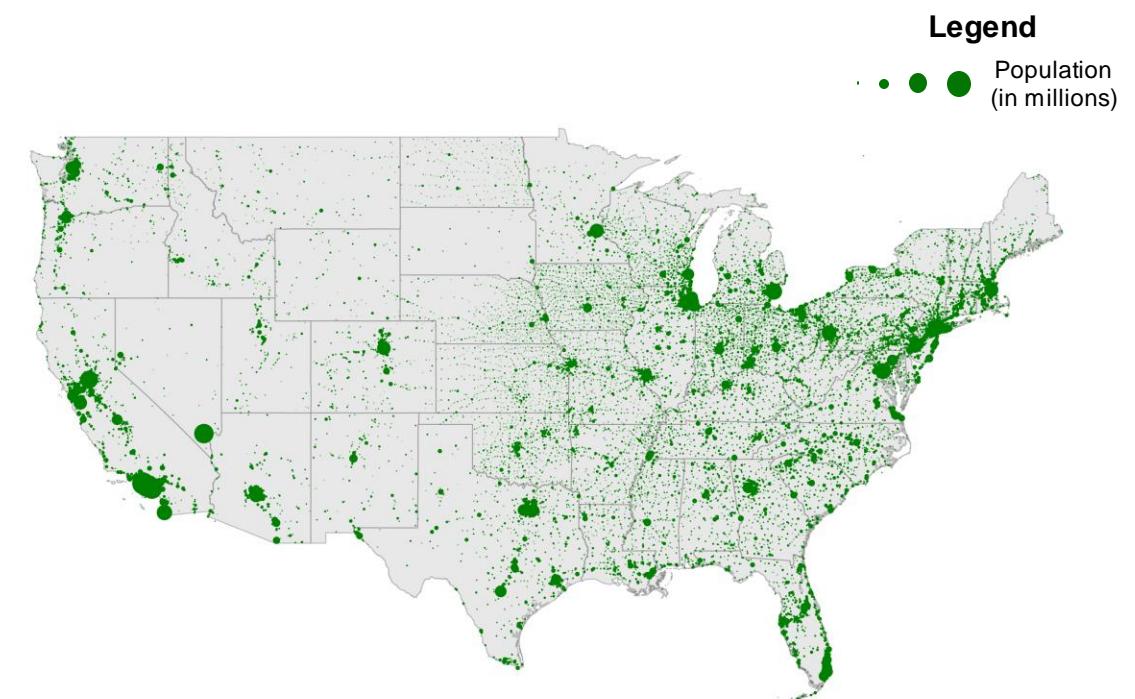
Do surrounding communities benefit from solar adoption?



Observations

258 million people live surrounding WWTPs

Combining with socio-economic and wastewater service charge data



Possible Future Analyses

Does solar adoption lower wastewater service cost?

How does solar adoption benefit surrounding communities economically?

THANK YOU!

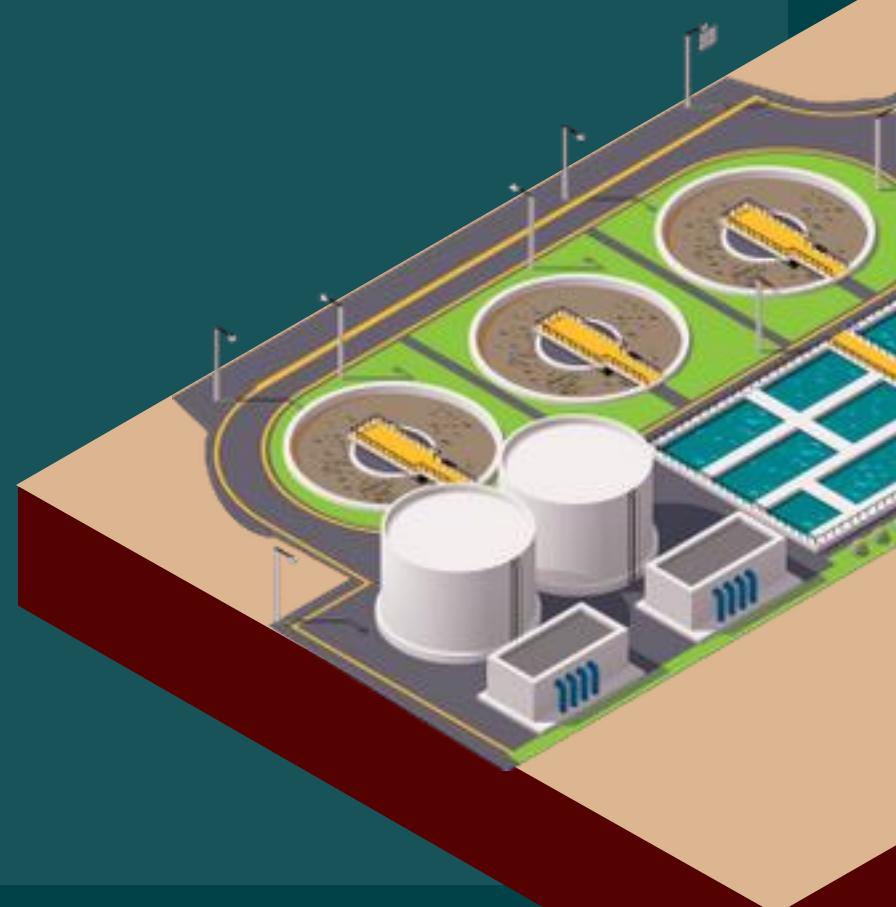
Special Thank You To Our Advisors:



Christine Kirchhoff
Ph.D, P.E.



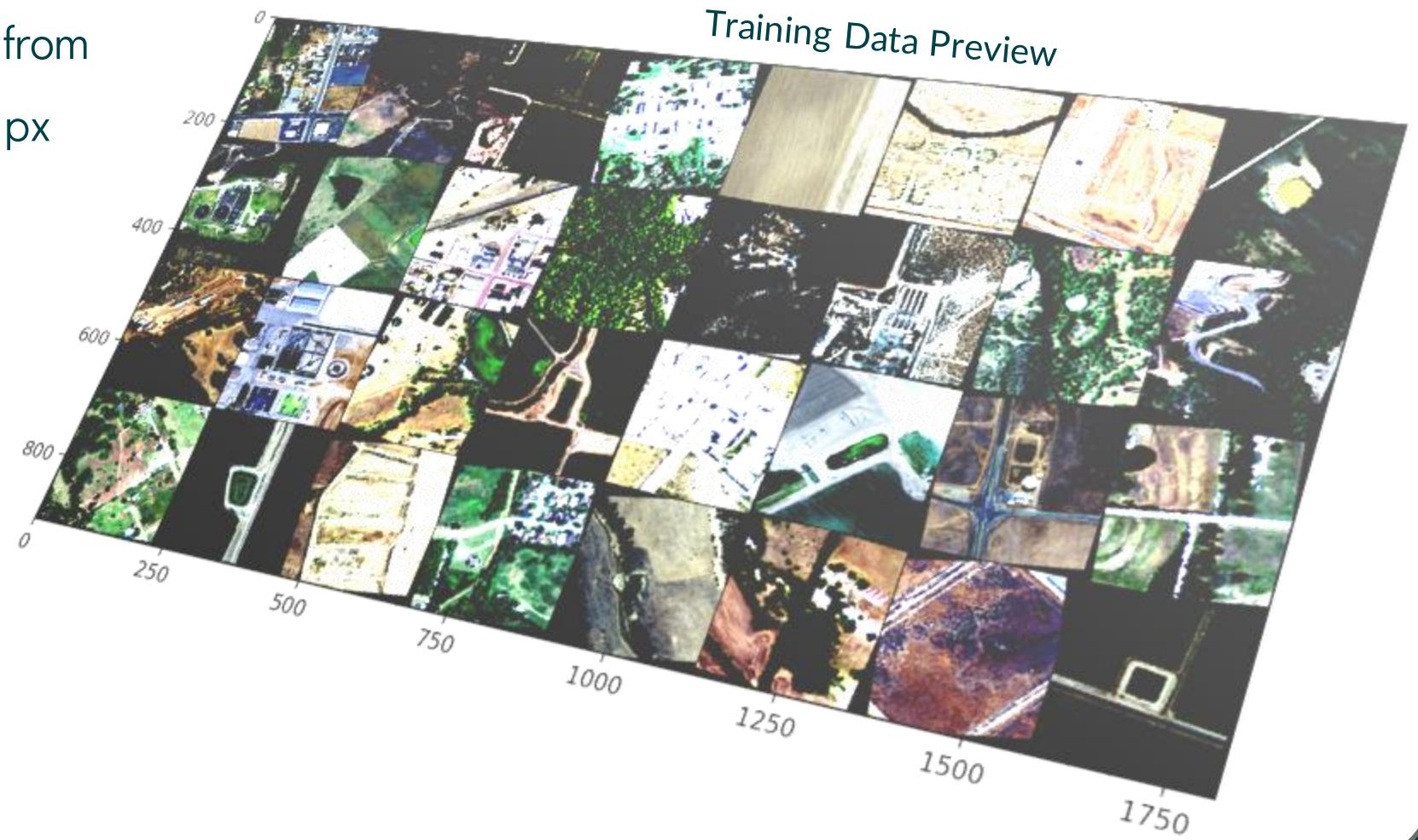
Kyle Bradbury
Ph.D.



APPENDIX

Data Pre-processing

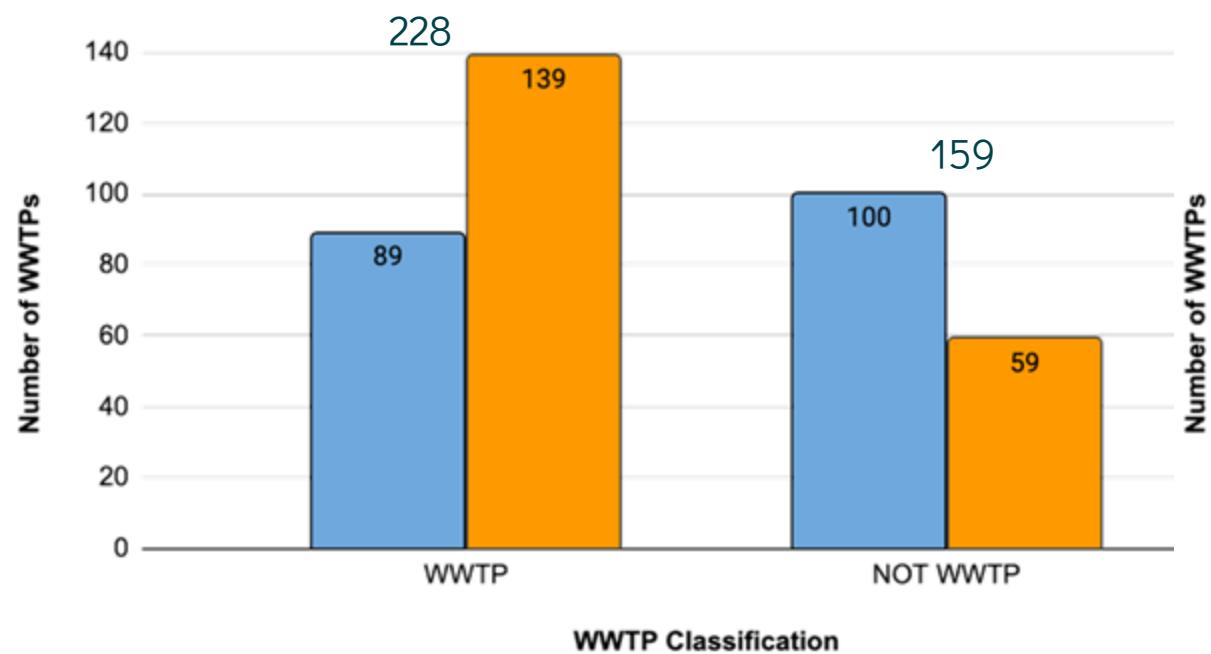
- Center crop 320x320 px from the original 2228 x 2228 px
- Resize to 224 x 224 px
- Convert to tensor
- Normalize
 - $\mu = [0.485, 0.456, 0.406]$
 - $\sigma = [0.229, 0.224, 0.225]$
- Random flip
- Random rotation



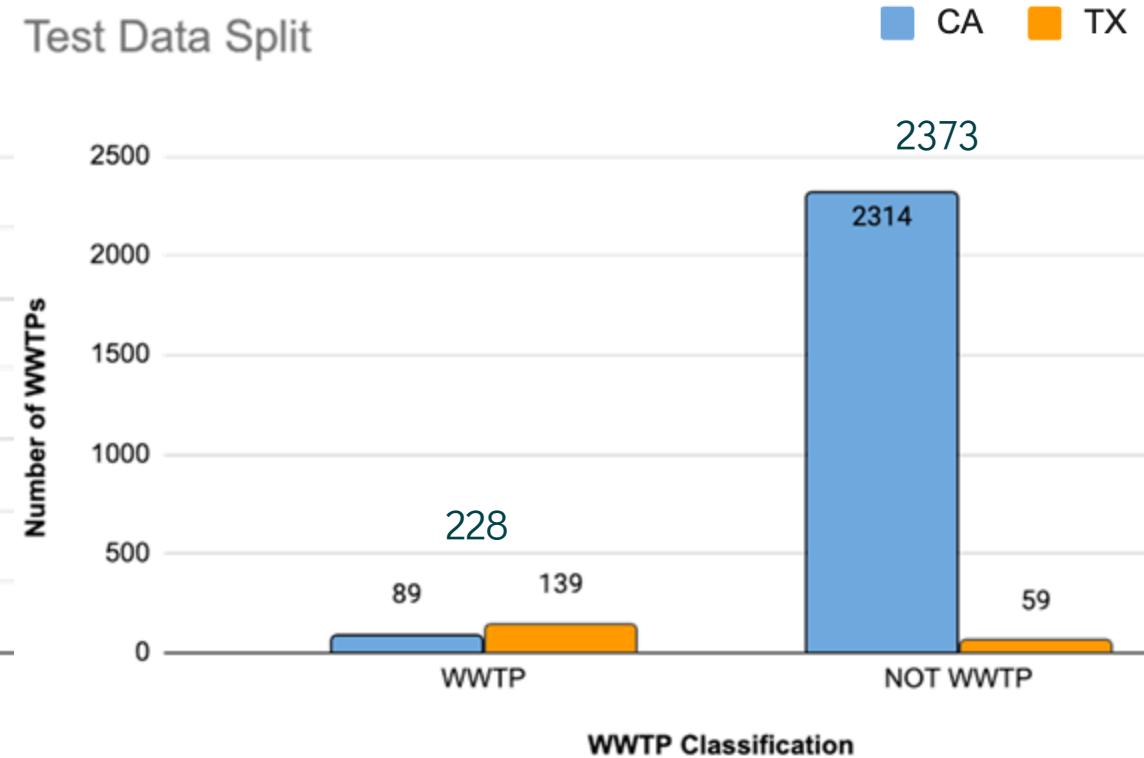
Data preparation for Experiment

Randomized Split to achieve “balanced” data

Training Data Split



Test Data Split



Model Architecture

