Retail Marketing Analysis: Hydrogen Refueling Stations

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Overview

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- **Timeline:**
  - Start - December 17, 2013
  - Finish – December 17, 2014
  - 100% Complete

- **Barriers**
  - Systems Analysis – 4.5 Technical Challenges:
    A. Future Market Behavior
    D. Insufficient Suite of Models and Tools
    E. Unplanned Studies and Analysis

- **Budget:**
  - $90,000

- **Partners:**
  - National Renewable Energy Laboratories (NREL)
  - California Fuel Cell Partnership

Process: Retail Marketing Analysis for Hydrogen Refueling Stations

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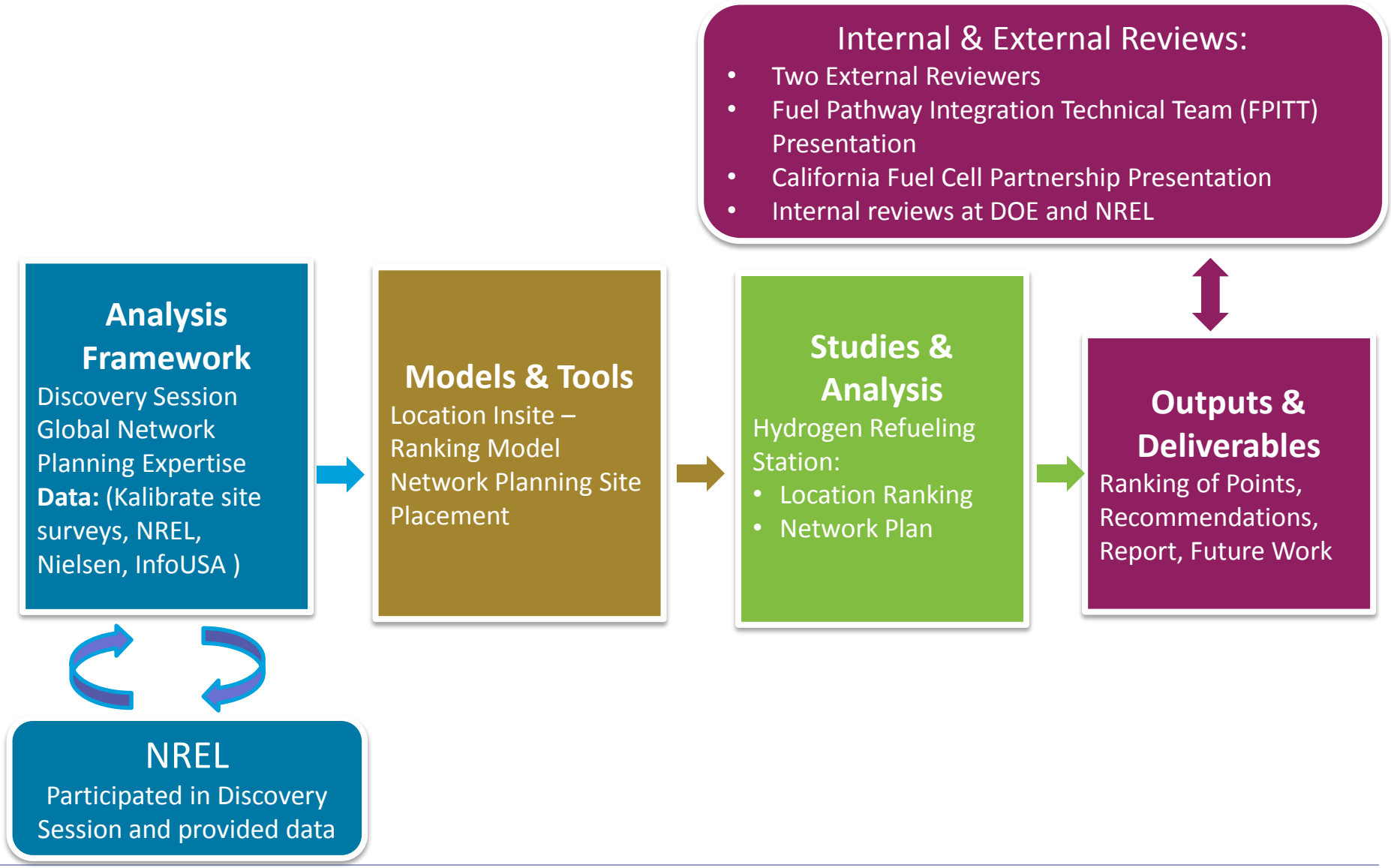

Relevance: Objectives

Objectives have been achieved and this project is complete.

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- Develop an analytic approach to prioritize and identify the best locations for hydrogen refueling stations
- Apply this framework to California to prioritize station network expansion beyond existing and planned locations

Where?

How many?

The result of this approach will be a geographic representation of a hydrogen refueling station infrastructure for the State of California.

Approach

Evaluated locations across California and recommended a network to complement existing and planned hydrogen stations

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- Objectively evaluated locations
  - Determined supply and demand variables
  - Determined dependent and independent variables
  - Identified competitive area or trading area size for aggregating data
  - Established weights on variables
  - Ranked 30,620 traffic points
- As a complement to Spatially & Temporally Resolved Energy & Environmental Tool (STREET) and cluster studies, proposed locales for refueling stations based on rankings:
  - Identified attractive areas outside a competitive distance from current/existing and planned hydrogen refueling stations (Coverage Network)
  - Identified attractive areas in the major urban areas of Los Angeles and San Francisco, offering minimal competition with current/existing and planned hydrogen refueling stations (Urban Incremental Network)

Approach: Locations Selected for Ranking

Traffic count points used to aggregate data for ranking

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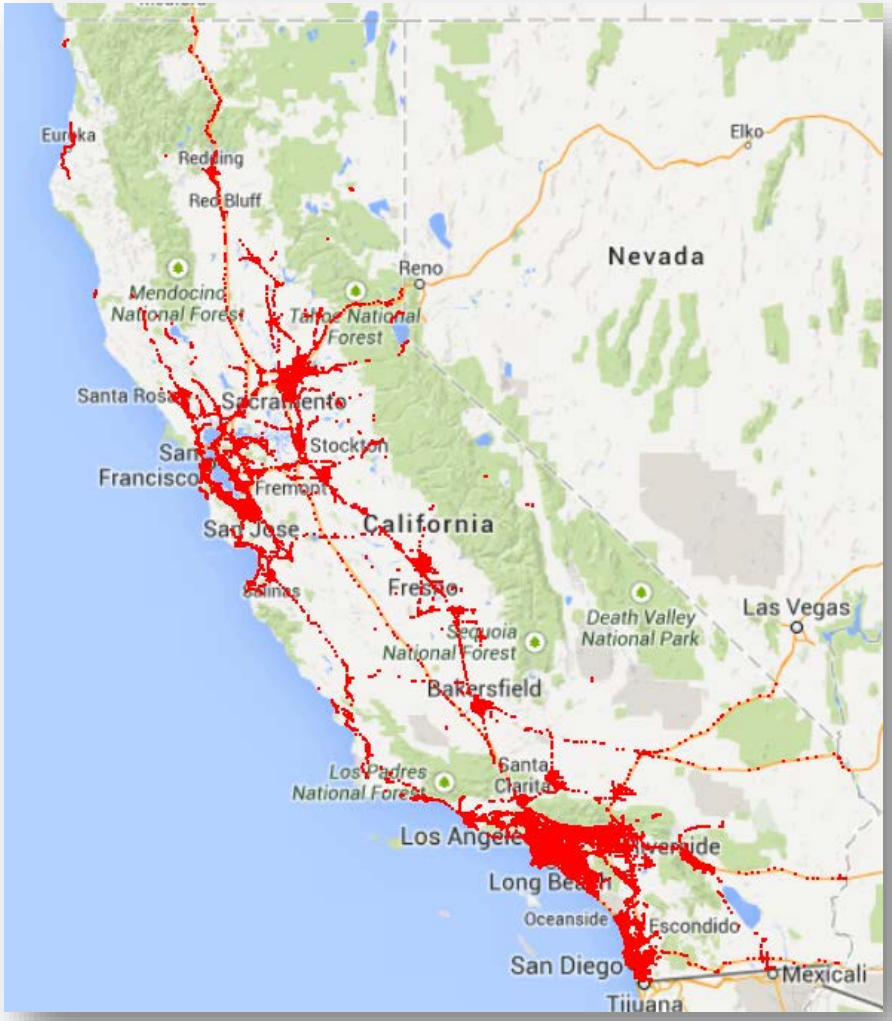
- 30,620 Traffic Count locations
  - Published Counts – 21%
  - Current Year Estimates – 79%
- Criteria
  - Traffic Counts < 10,000 cars per day were eliminated
  - Eliminated Published Counts older than 2011 and replaced with Current Year Estimates when available



Accomplishments: Variables, Weights and Thermal Map of Traffic Point Ranking

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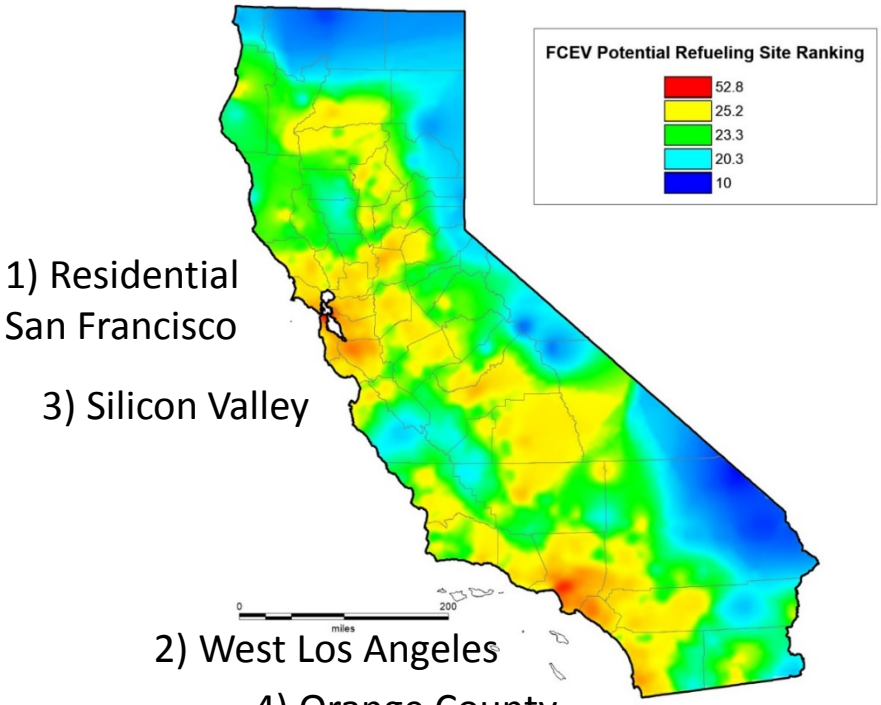
Independent Variable	Weight
Households with **income** > $100,000	7.20
No. of **gas stations**	6.74
No. of **hydrogen vehicles**	6.67
Total no. of **employees**	6.09
Hydrogen **permitting constraints**	5.55
Gas stations with sufficient **lot size**	4.08
Hydrogen stations - existing/planned	2.32
Households with **solar panels**	2.31
Average **commute time**	1.01
Distance to hydrogen **auto dealership**	-2.40

Dependent Variable
Gasoline Expenditure

Weighting of independent variables vs. dependent variable allows ranking of locations. Thermal map gives graphic representation of ranking.



Accomplishments: Ranking of Points- Most Attractive Area of San Francisco

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Applied ranking to census shapes in San Francisco. Red blocks are most attractive.

Accomplishments: Ranking of Points - Most Attractive Area of Los Angeles

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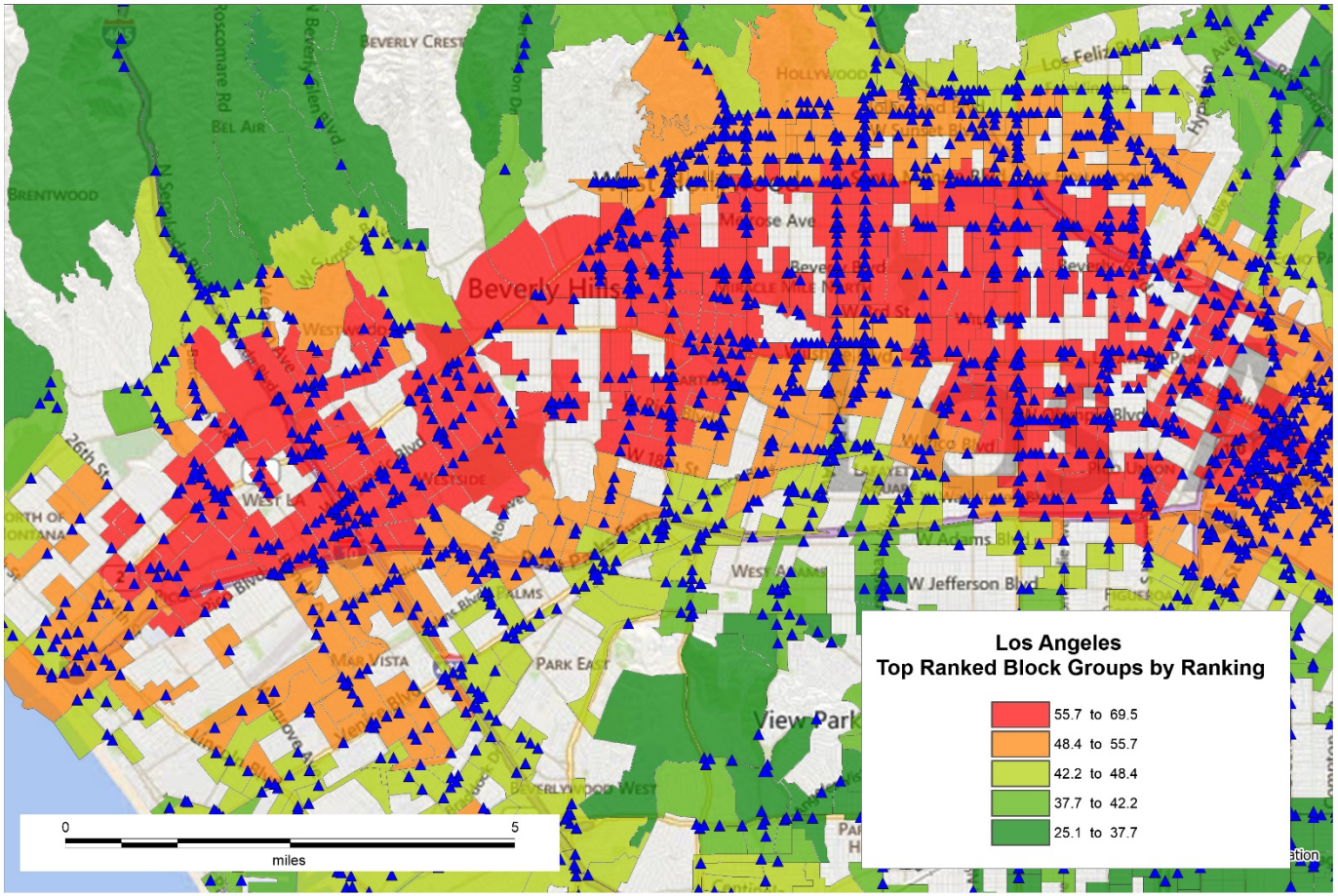
Applied ranking to census shapes in Los Angeles. Red blocks are most attractive.



Accomplishments: Comparison of Best Point in San Francisco vs. Best Point in Los Angeles

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Variable	No. 1 in Los Angeles County	No. 1 in San Francisco County	Weights for 2 Mile Radius
Location Insite Ranking	69.46	100	
Gasoline Expenditure ($000,000 per year)	222	346	Dependent Variable
Distance to Nearest Hydrogen Dealership (miles)	1.1	0.3	-2.40
Hydrogen Permit Constraints	5	5	5.55
Thousands of Households with Income over $100,000	10	67	7.20
Average Commuting Time (minutes)	31	29	1.01
Thousand Employees	217	430	6.09
Number of Gas Stations	45	35	6.74
Minimum Size Requirement Gas Stations	16	6	4.08
Households with Solar Energy in Use	0	1,293	2.31
Anticipated Fuel Cell Vehicles	143	125	6.67
Anticipated Fuel Cell Refueling Stations	0	1	2.32

Scoring higher in heavily weighted items leads to higher overall rank for S.F. point

Accomplishments: Identification of Attractive Areas for Hydrogen Refueling Stations

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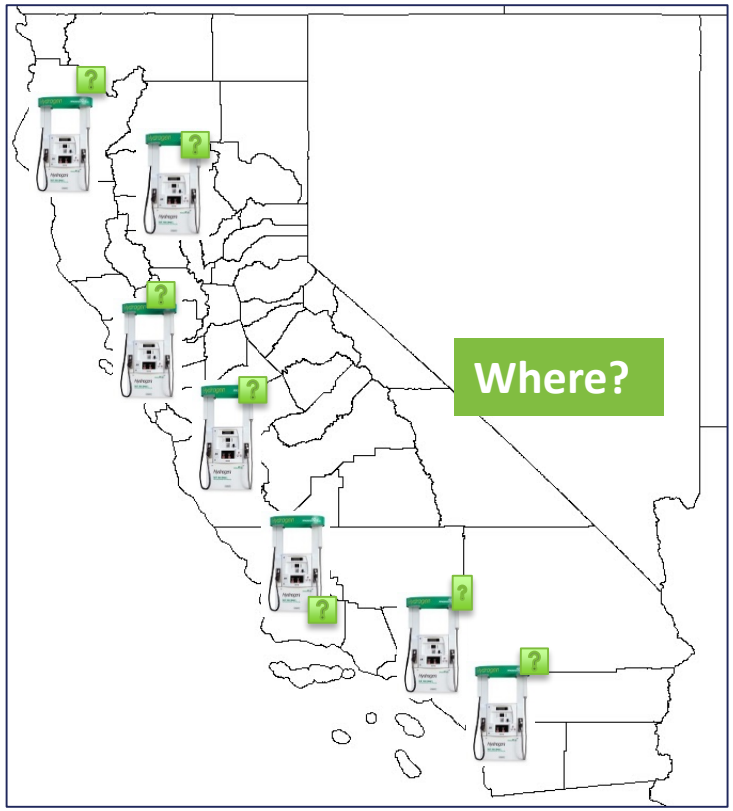
- Building on the STREET model results and cluster strategies, use the rankings of 30,620 points:
  - To identify attractive areas that are unlikely to compete with current/existing and planned hydrogen refueling stations (Coverage Network)
  - To identify attractive areas in the major urban areas of Los Angeles and San Francisco, offering minimal competition with current/existing and planned hydrogen refueling stations (Urban Incremental Network)

Using rankings, choose locations that are unlikely to compete with stations currently planned.



Accomplishments: Proposed locales for hydrogen refueling stations (Coverage Network)

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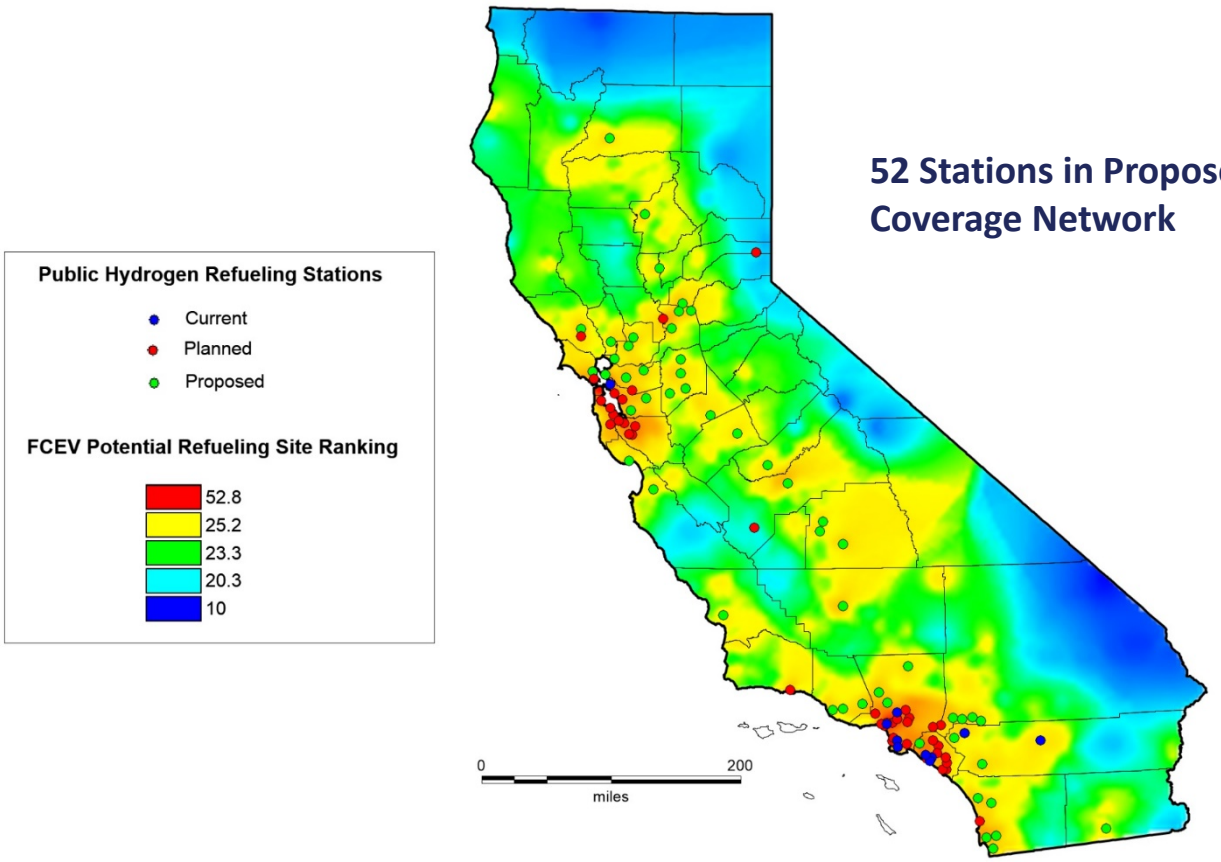

52 Stations in Proposed Coverage Network

Proposed locales (green points) are in attractive areas, but will not compete with current hydrogen refueling stations (blue points) and do not compete with planned stations (red points).

Accomplishments: Greater San Francisco - Proposed locales for hydrogen refueling stations (Urban Incremental Network)

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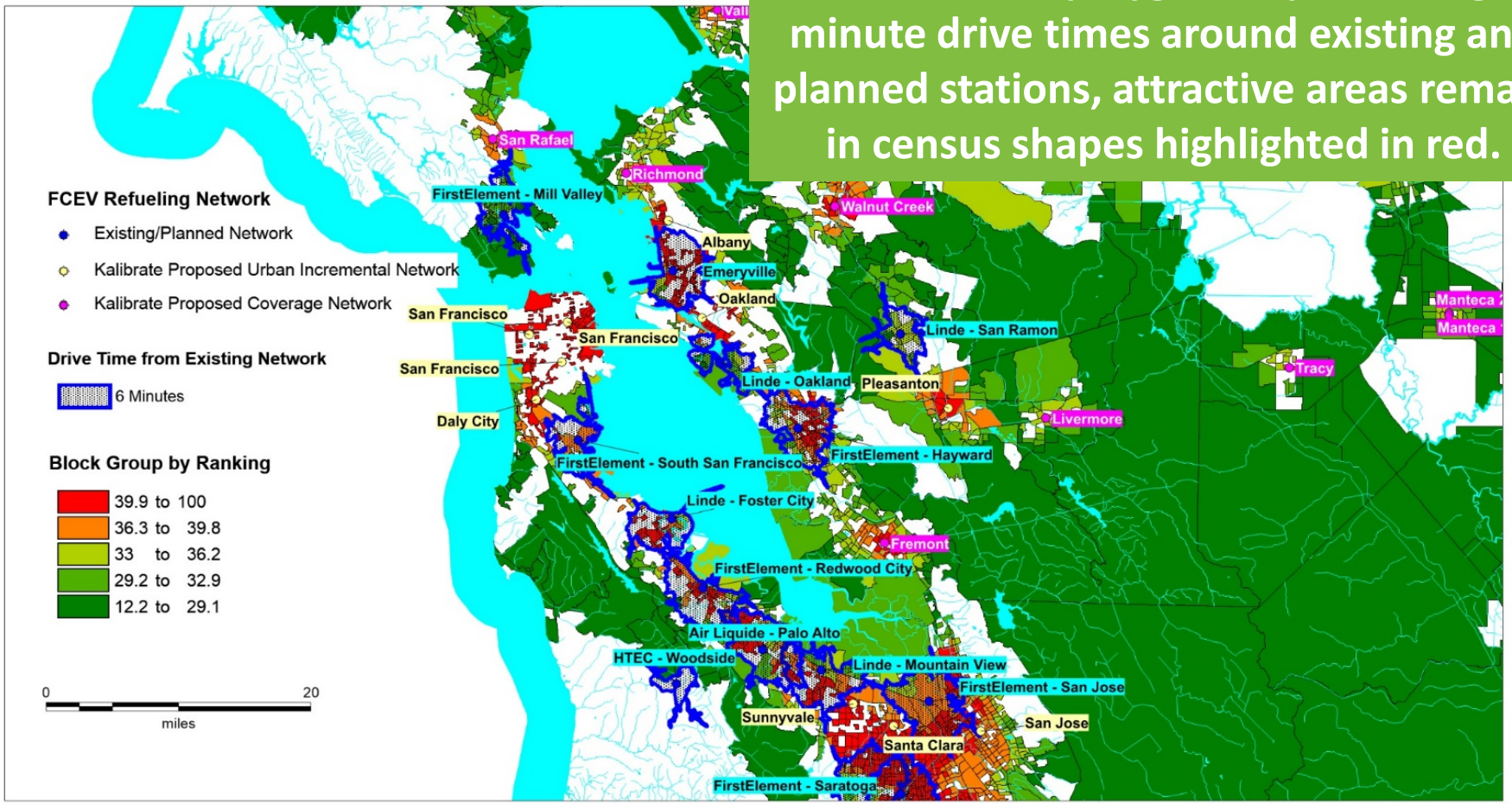
Given the blue polygons representing six minute drive times around existing and planned stations, attractive areas remain in census shapes highlighted in red.



Accomplishments: Greater Los Angeles - Proposed locales for hydrogen refueling stations (Urban Incremental Network)

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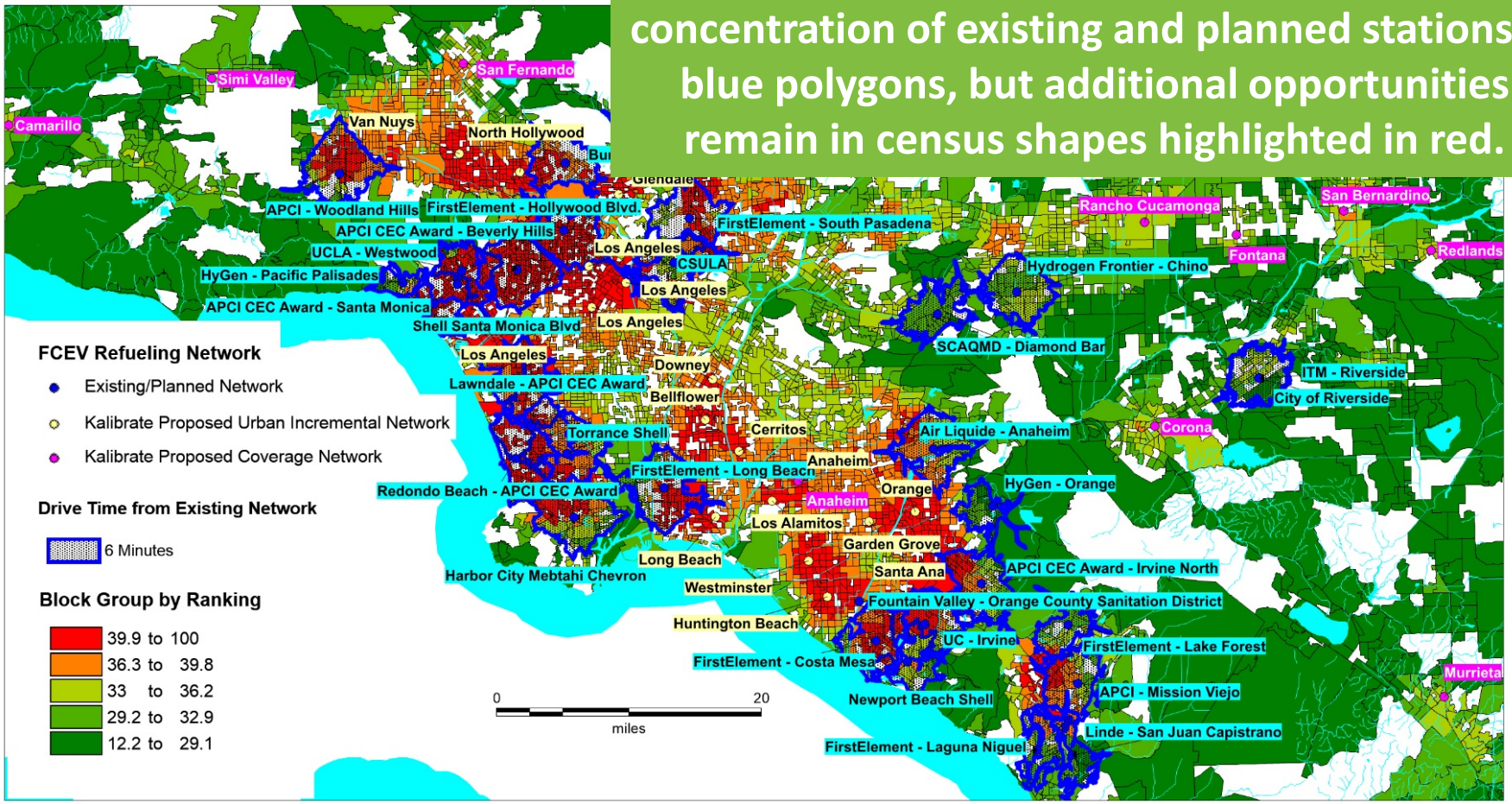
The Greater Los Angeles area shows a high concentration of existing and planned stations in blue polygons, but additional opportunities remain in census shapes highlighted in red.



Accomplishments: Proposed Hydrogen Refueling Infrastructure – State of California

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Infrastructure to provide California with geographic coverage of hydrogen refueling stations.

No. of FCEV Refueling Stations	Type of Hydrogen Refueling Stations
11	Permanent (aka existing or current)
42	Planned
29	Proposed Urban Incremental
52	Proposed Coverage Network
134	**California Total**

Response to Previous Year Reviewer's Comments; Remaining Challenges and Barriers

- Response to Previous Year Reviewer's Comments: This project was not reviewed last year
- Remaining Challenges and Barriers: This project has been completed on time and on budget

Collaborations

- National Renewable Energy Laboratory (NREL) – a national laboratory of the Department of Energy, Department of Energy Efficiency and Renewable Energy
  - NREL/Kalibrate Collaboration:
    - To determine list of candidate independent and dependent variables for ranking of points
    - Guidelines for determining and naming coverage network and urban incremental network
    - Assistance with results presentation content
- California Fuel Cell Partnership (CaFCP)
  - CaFCP/Kalibrate Collaboration:
    - Presented preliminary results
    - Collected feedback

Proposed Future Work

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- This specific project, Retail Marketing Analysis: Hydrogen Refueling Stations for the State of California, is complete
- Given the opportunity for additional work, Kalibrate can assist with:
  - Similar work in other geographies: Other US States or regions
  - Develop a tool to provide instant analysis of ranked map points.
  - Given a sufficiently developed infrastructure of hydrogen refueling stations, create of a full featured network planning tool for the industry.
  - Contribute to NREL infrastructure simulation capabilities by improving on station sizing, footprint restrictions, market saturation, and inter-station demand shifting algorithms.

Summary

- **Objectives:**
  - Prioritize and identify the best locations for hydrogen refueling stations
  - Apply this framework to prioritize station network expansion
- **Approach:**
  - Objectively evaluated locations
  - Proposed locales for refueling stations based on rankings:
- **Collaborations:**
  - National Renewable Energy Laboratory (NREL)
  - California Fuel Cell Partnership
- **Accomplishments:**
  - Ranked 30,620 geographic points
  - Identified attractive areas with distance from planned hydrogen refueling stations
  - Identified attractive areas in the major urban areas of Los Angeles and San Francisco
  - Defined a geographic representation of a hydrogen refueling station infrastructure
  - On time and on budget
- **Future Work:**
  - Similar work in other US States
  - Develop a tool to provide instant analysis
  - Create of a full featured network planning tool
  - Enhance simulation capabilities

Acronyms and Definitions

- Nielson: The Nielson Company – source for demographic information
- InfoUSA: Business and consumer data resource. Gasoline retail outlet location information used to supplement Kalibrate data
- Location InSite: Kalibrate tool used to rank locations. Uses statistical concepts of normalization, correlation and significance to determine the relationship between independent and dependent variables.
- STREET model: Spatially & Temporally Resolved Energy & Environmental Tool. Results of STREET model commonly referenced for early hydrogen refueling station development plans.
- California Fuel Cell Partnership (CaFCP): A collaboration of organizations, including auto manufacturers, energy providers, government agencies and fuel cell technology companies, that work together to promote the commercialization of hydrogen fuel cell vehicles.
- FCEV: Fuel Cell Electric Vehicles

Technical Backup Slides

Statistical Analysis

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Objectives

- Analyze the key factors for the introduction of hydrogen fueling infrastructure and fuel cell vehicles
- Identify the features of the information gathered
- Understand the importance of variables for the hydrogen fueling infrastructure
- Provide data correlations to pass through to later stages of predictive algorithms
- Calculate weights to rank the traffic points to identify the best locations for hydrogen refueling stations

Statistical Analysis - Methodology

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Statistical analyses

- ✓ Descriptive statistics
- ✓ Correlation Analysis
- ✓ T-test for independent groups
- ✓ Collinearity and multicollinearity analyses
- ✓ Multiple linear regression
- ✓ Location Insite weight calculation

Descriptive Statistics

- Mean
- Median
- Standard deviation
- Skewness
- Kurtosis

Graphical Methods

- Density plot
- Histogram
- Normal Q-Q plot

Statistical Analysis - Findings

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Multiple Linear Regression

- Measure the contribution and impact of the key factors on gasoline expenditure

Select Best Model

- Best model variables and adjusted r-squared are reported for all subsets
- 10 fold cross validation is applied to find the best minimum mean squared error

Collinearity and Multicollinearity

- Applied variance inflation factor (VIF) to best subsets
- Excluded the variables with problematic VIF values from the model

Statistical Analysis - Findings

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Multiple Linear Regression

- ❑ Evaluated the model accuracy reporting r-squared value
- ❑ Lowest r-squared reported is 0.85
- ❑ Diagnosed the model reporting
  - ✓ Detected outliers using Bonferroni outlier test
  - ✓ Used diagnostic tests of linearity, global validation test, non-constant error variance test to measure asymmetry, peakedness, linearity, and heteroscedasticity
  - ✓ Used diagnostic graphs residuals versus fitted, normal Q-Q, scale-location and residuals versus leverage graphs

Statistical Analysis - Findings

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Location Insite

All these analyses are utilized to calculate Location Insite weights

	WEIGHTS					
INDEPENDENT VARIABLES	1 Mile	2 Miles	3 Miles	5 Miles	7 Miles	10 Miles
Traffic Count	0.4846	0.7044	0.7930	0.8521	0.8313	0.7846
Distance to nearest highway ramp (miles)	-1.9367	-1.7747	-1.6866	-1.5693	-1.4648	-1.3365
Distance to nearest dealer (miles)	-2.6679	-2.4044	-2.2546	-2.0285	-1.8468	-1.6688
Household income >= $100,000	8.6878	7.1969	6.6656	6.3914	6.3686	6.3285
Average commute time (minutes)	1.1151	1.0086	0.9437	0.9541	1.1054	1.4963
Total employees	5.5209	6.0862	6.5313	6.9077	6.8957	6.7037
Total white collar employees	5.5913	6.0935	6.4408	6.7635	6.7587	6.6125
Total science/ technology employees	4.2029	4.9487	5.4431	6.0154	6.2044	6.2516
Gas stations	5.7060	6.7356	6.9196	6.9435	6.8728	6.6818
Gas stations meeting the min size req.	2.5667	4.0783	5.0248	5.8705	6.1599	6.2276
New vehicles	7.7136	7.2183	7.1181	7.0035	6.8841	6.6929
Vehicles per household	-0.0072	0.5829	1.0324	1.7418	2.2022	2.5922
Luxury vehicles	7.2034	6.4288	6.0942	5.8806	5.8764	5.9650
Households with solar panels	2.4338	2.3098	2.0799	1.7853	1.7424	1.9772
FCEV vehicles (2017)	7.1112	6.6658	6.3118	5.9234	5.8711	5.8396
Hybrid electric vehicles	8.1383	7.1589	6.7136	6.3780	6.3237	6.3067
Permit constraints	6.9550	5.5507	4.7762	3.9021	3.4169	2.9905
Incentive Influence	7.8448	6.8636	6.4202	6.0088	5.8692	5.8857
Hydrogen stations	1.8169	2.3198	2.7484	3.2340	3.6676	4.4462
High potential/ low performance outlets	6.9034	7.1253	7.0516	6.8920	6.7717	6.5497
Gas Volume	5.3758	6.7449	6.9508	6.9544	6.8664	6.6626

** Yellow and orange highlighted variables together represent the initial models with significant variables. Orange variables only represent the suggested models with the significant variables.