Siting Strategies for Early H2 Refueling Infrastructure in California: Learning from the Gasoline Experience

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Project ID #
AN 031

Overview

Timeline
(NextSTEPS program)

- Start: Jan. 1, 2011
- End: Dec 31, 2014
- 50% Complete

Budget

- Total project funding
  - DOE share: $240 K (4 years)
  - Contractor share: $ 0
- Funding received FY12: $60K
- Funding for FY13: $60K

Barriers

- Barriers addressed (from MYPP)
  - **Future Market Behavior**
  - **Inconsistent Data, Assumptions and Guidelines**
  - **Insufficient Suite of Models and Tools**
- Goal Addressed::
  - **Provide analysis to support hydrogen and fuel network development**

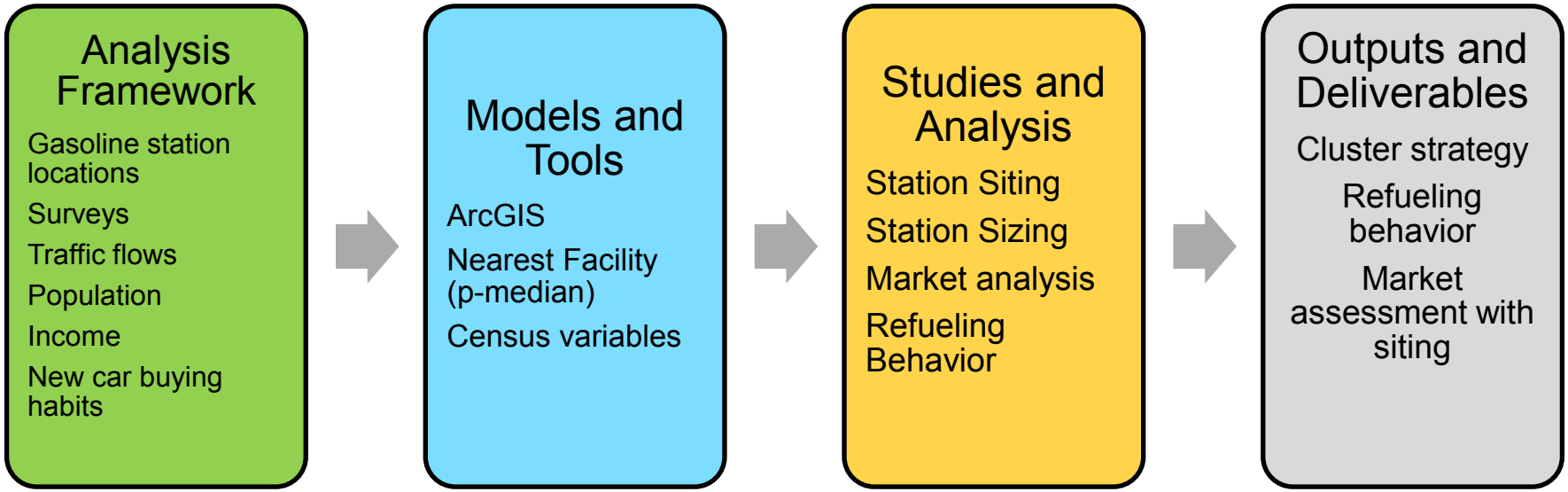
Partners

- The work was conducted at UC Davis under the NextSTEPS research consortium, which has 23 government and industry sponsors, including USDOE
- UC Davis manages NextSTEPS (see supplemental slides)

OVERALL PROJECT GOAL: Determine the minimum number of stations necessary for the maximum number of customers to reduce investment necessary

DOE BARRIERS (From Analysis Section MYPP)	**AN 031 PROJECT GOALS**
Future Market Behavior	Analyze strategies for early H2 fueling station placement, numbers and network development, to enable fuel accessibility for initial rollout of H2 fuel cell passenger cars.
Inconsistent Data Assumptions and Guidelines	Develop an understanding of refueling behavior and apply to early stations strategies for deployment.
Insufficient Suite of Models and Tools	Conduct case studies for California, utilizing GIS-based analysis for station siting and convenience from the perspective of consumers.

Project Overview



SPATIAL DESIGN FOR EARLY H2 FCV ROLLOUTS

H2 INFRASTRUCTURE SHOULD OFFER

COVERAGE: enough stations, located to provide fuel accessibility for early vehicles

CAPACITY: meet H2 demand as FCV fleet grows

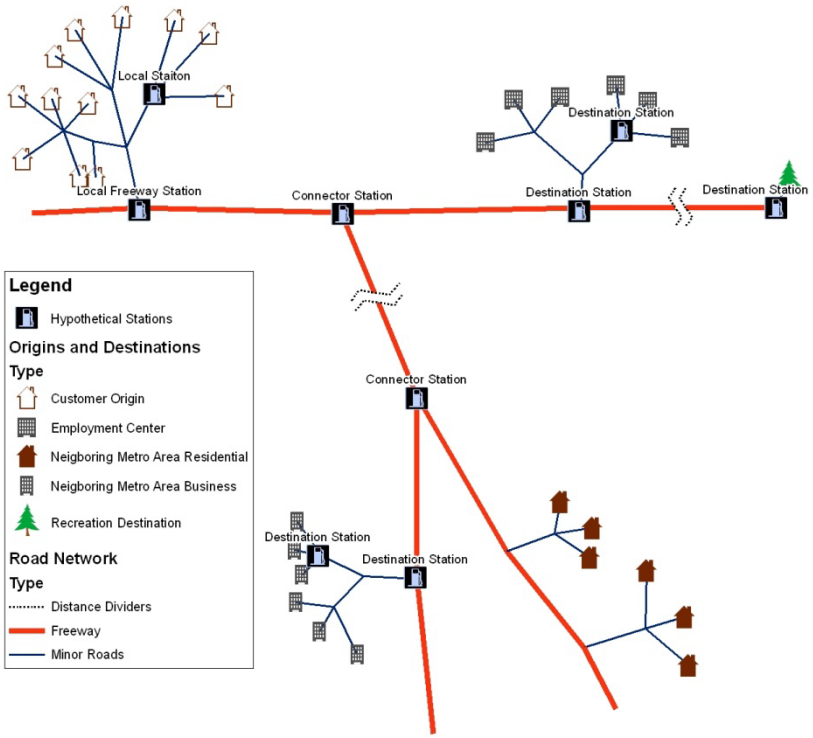
COORDINATE FCV PLACEMENT + H2 INFRASTRUCTURE BUILD-OUT, GEOGRAPHICALLY AND OVER TIME

Finding: Station distribution and size is a function of fuel price, vehicle price, and distance to station.

"Cluster Strategy" geographically dispersed clusters (2-3 stations per cluster) in a metro region can be tied together with connector stations such that relatively few stations can provide adequate coverage in an early network.

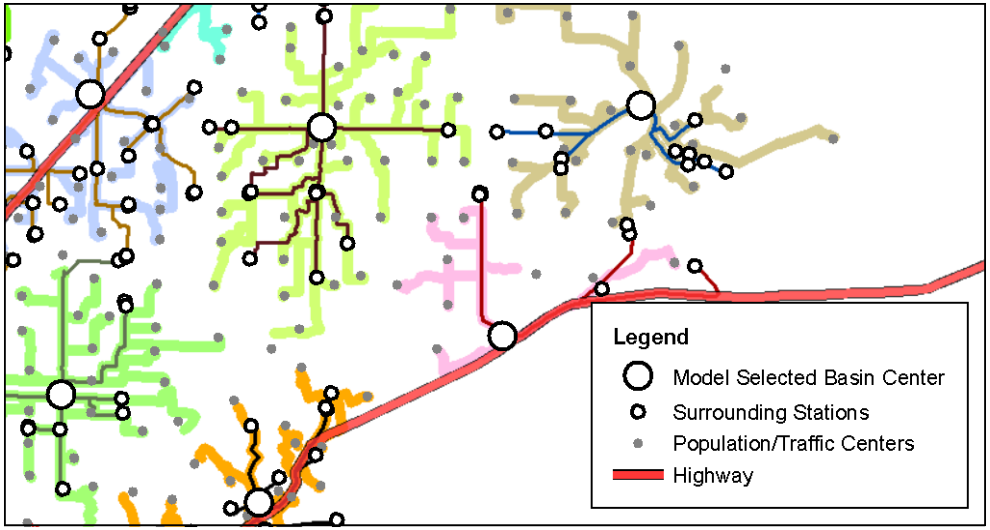
Large new stations may take time to reach full utilization due to normal vehicle buying habits.

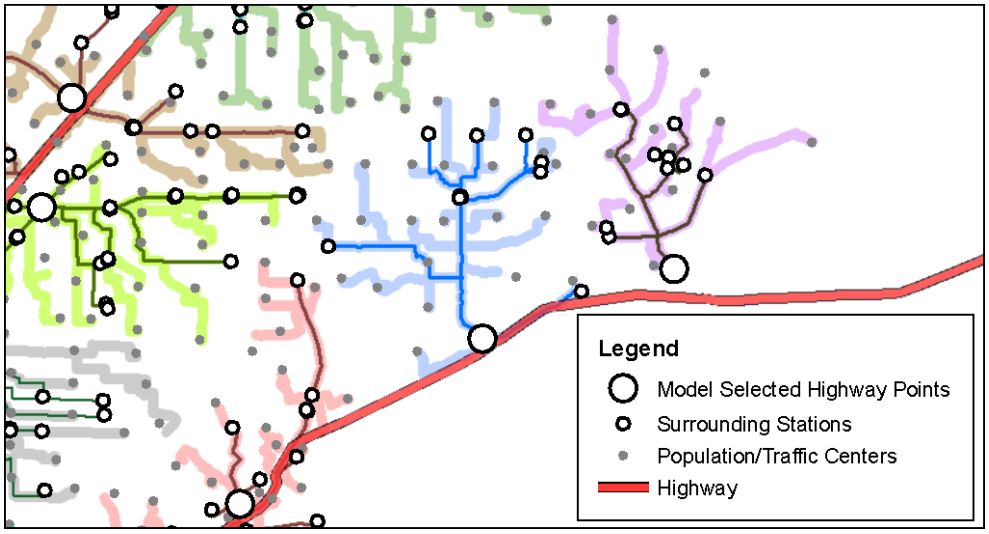
A Refueling Network is made up of "Anchor" and "Network" stations



- Local anchor stations are most likely a prerequisite for vehicle purchase
- Connector stations provide the greatest regional flexibility
- Destination stations allow a new "base" of activity and mobility.

Gasoline Refueling Takes Place Along a Route





- Many models (including some of my own) assume a closest station algorithm for convenience
- Closest station does not hold for predicting gasoline sales
- Closest station in the direction of travel such as to the highway predicts sales better
- Initial stations should be sited near the highway or other high capacity road

Nicholas, Michael. 2010. Driving Demand: What Can Gasoline Refueling Patterns Tell Us About Planning an Alternative Fuel Network? Journal of Transport Geography 18, no. 6: 738-749.

The Utility of a Station Can Independent of Usage

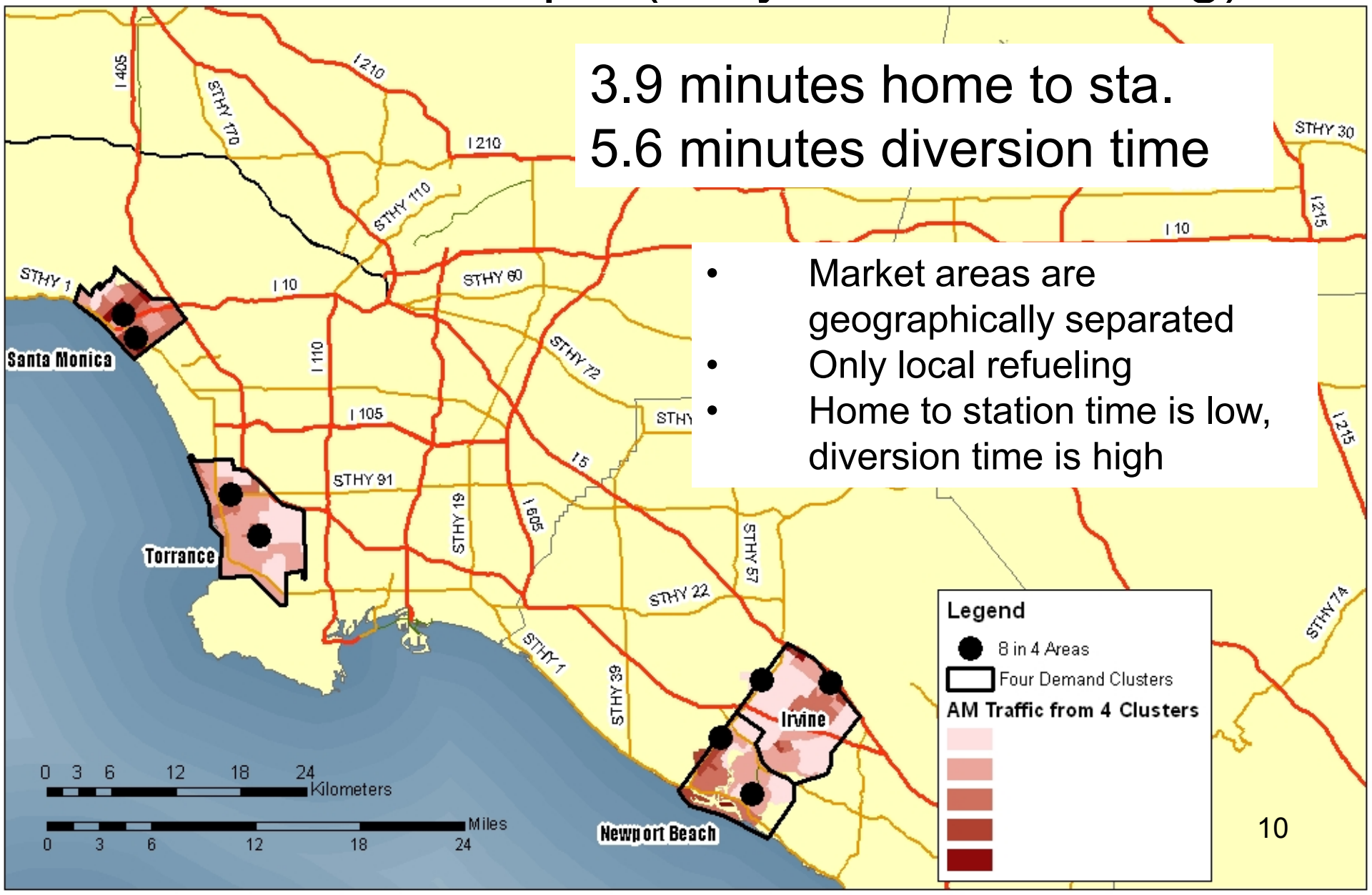
- Utility depends individual perception
  - Use (Home Stations - most used)
  - Usefulness (Home, connector-occasionally used)
  - Aspiration (Far Destinations-seldom used)

- Macro market utility
  - Vehicle Marketability (Home then connector, then destination)

12 Clusters Identified by Early California Fuel Cell Partnership Survey

- Two Ways to Measure Consumer Convenience
  - Home to the nearest station (Anchor)
  - "Diversion" time: time to nearest station while driving throughout LA Basin (Network)

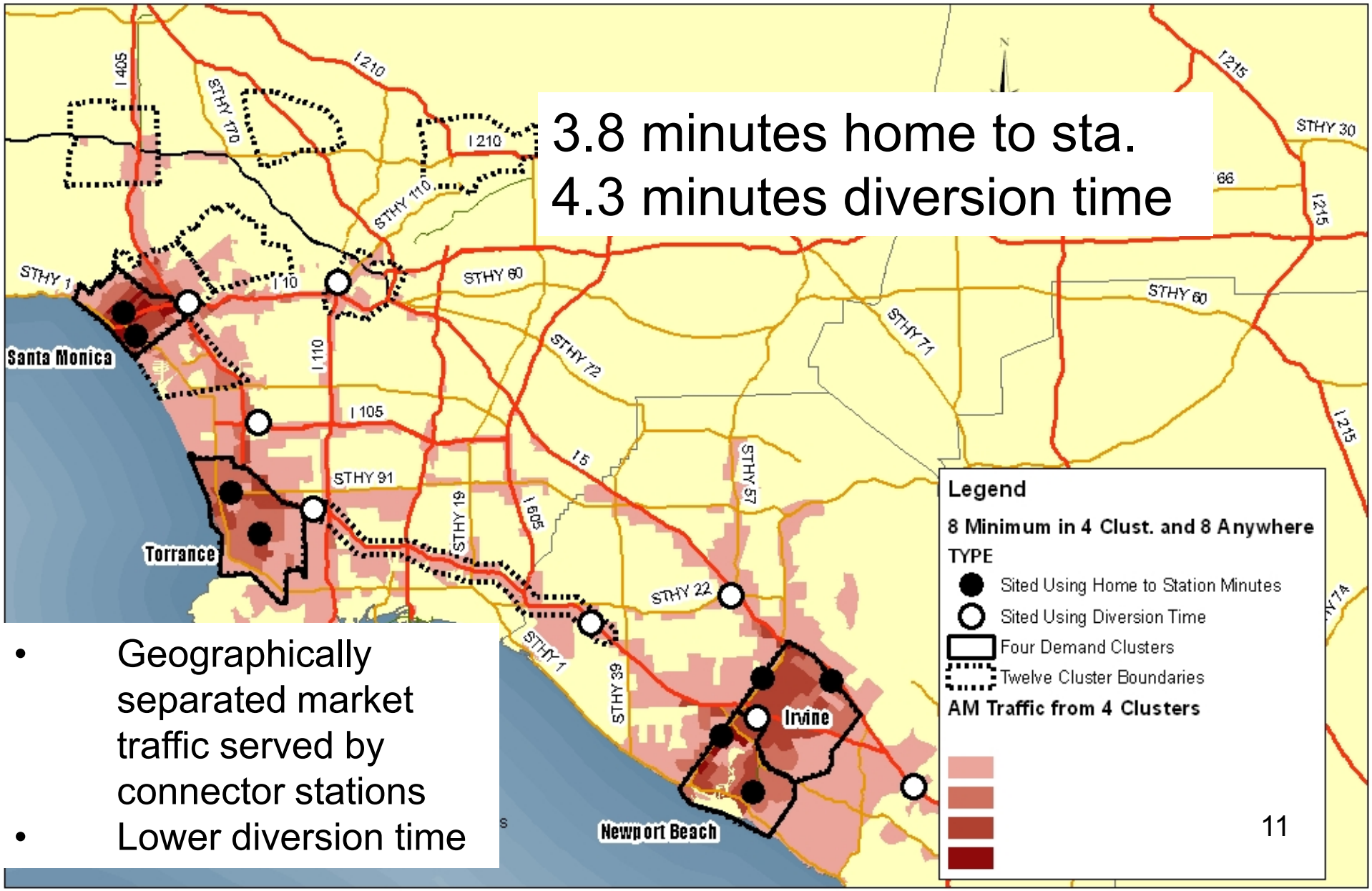
8 Station Example (Only Local Refueling)



16 Station Example

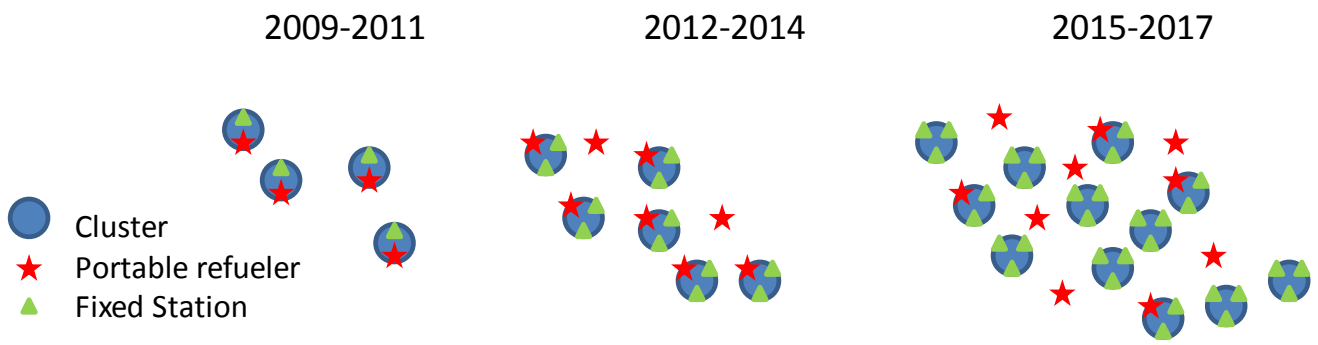
Progess/Accomplishments

Add 8 Connector Stations => Lower Diversion Time



- Geographically separated market traffic served by connector stations
- Lower diversion time

Early Network Examples



	636 FCVs	3442 FCVs	25,000 FCVs
# Stations	8	20	42
# clusters	4 (2 sta/cluster)	6 (3 sta/cluster)	12 (3 sta/cluster)
# connect.sta	0	2	6
Station Mix	4 Portable refuelers 4 SMRs (100 kg/d)	8 Portable Refuelers 12 SMRS (250 kg/d)	10 Portable refuelers 12 SMRs (250 kg/d) 20 SMRs (1000 kg/d)
New Equip. Added	4 Portable refuelers 4 SMRs (100 kg/d)	4 Portable Refuelers 12 SMRS (250 kg/d)	2 Portable refuelers 20 SMRs (1000 kg/d)
Capital Cost	$20Million	$52 Million	$98 Million
O&M Cost	3-5$Million/y	11-14 $Million/y	30-40 $Million/y
H2 cost $/kg	77	37	13
Ave travel time	3.9 minutes	2.9 minutes	2.6 minutes
Diversion time	5.6 minutes	4.5 minutes	3.6 minutes

How Many Stations Are Needed?

- How many stations you need depends on your assumptions about the market. We generally know how people would like to refuel, but we don't know the size of the market.
- Absolute minimums
- Anchor vs. Network
- Anchor station(s): how close do they have to be?
- Early market rollout study

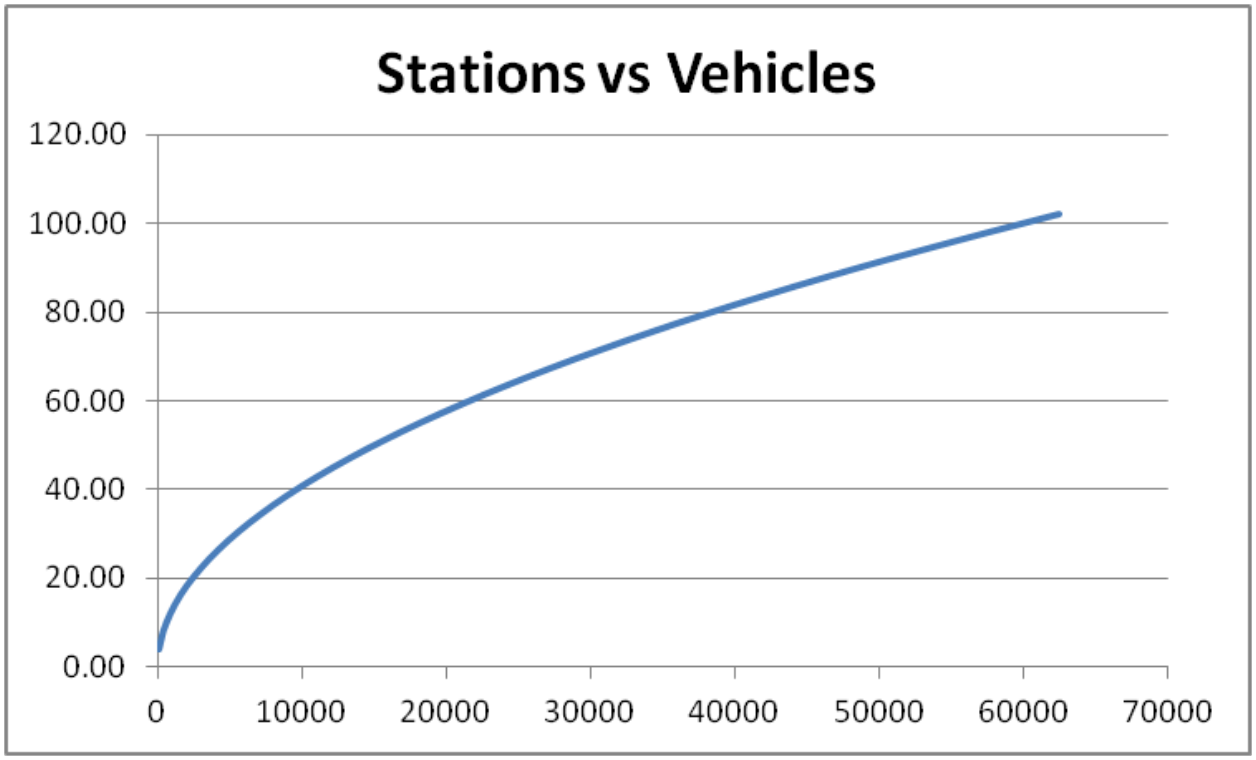
Can you Have Just One Station for 34,000 Cars?

- Give away free fuel and free cars with unlimited warranty
- Therefore the number of station necessary is not absolute but depends on outside factors

$$Utility = B_{veh} - P_{veh} - OC_{veh} - NI$$

B_{veh} = Benefit of the Vehicle
P_{veh} = Price of the Vehicle
OC_{veh} = Operation Cost
NI = Network Inconv.

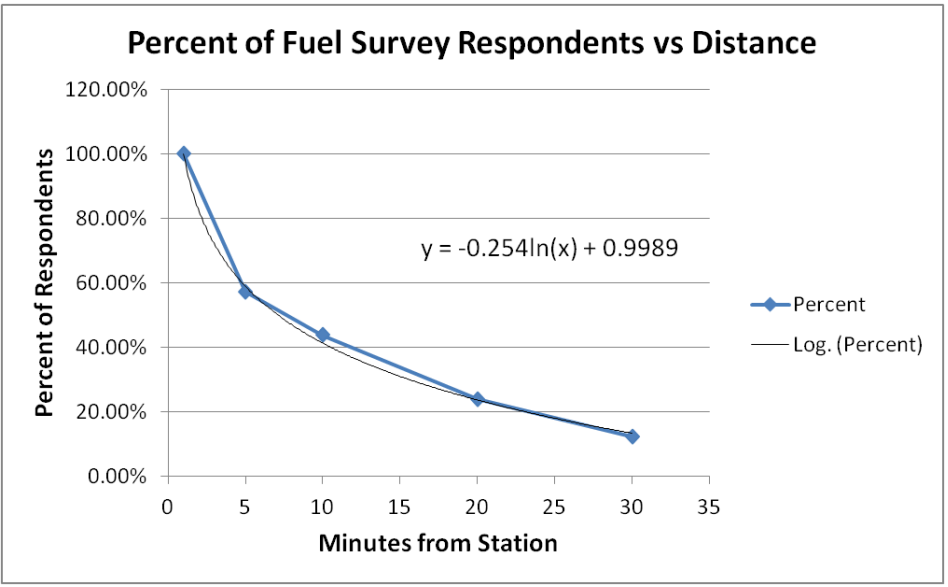
Anchor(s) + Network (Illustrative)



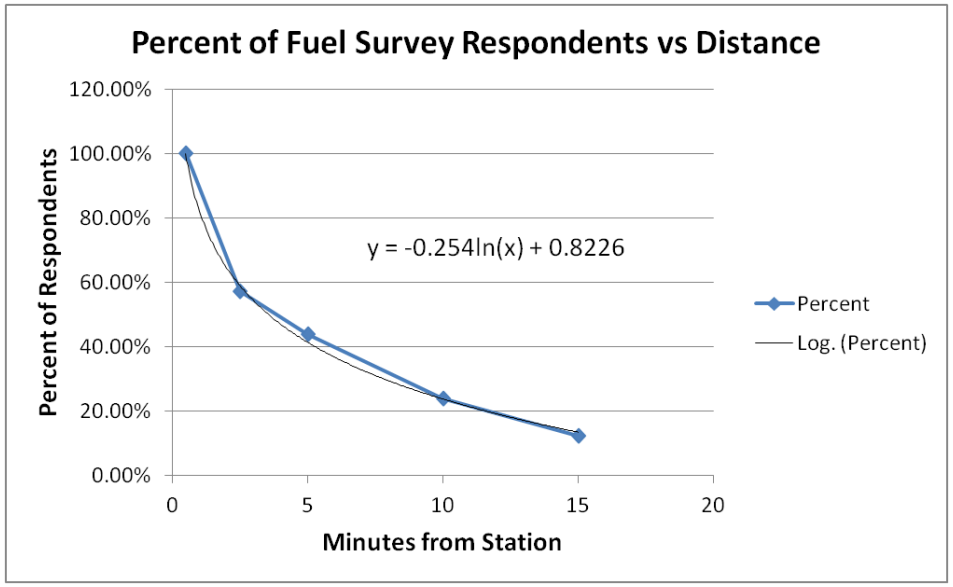
- Initially, there will be more stations per vehicle
- Other people's anchor stations become network stations, till most demand is local
- Stations become larger as well reducing overall stations/vehicle

Where People Refueled ≠ Willingness to Buy But…

Kitamura, Ryuchi. and Dan Sperling. 1987. Refueling Behavior of Automobile Drivers. *Transportation Research* 21A, no. No. 3: 235-245



Equation can be adjusted. ½?



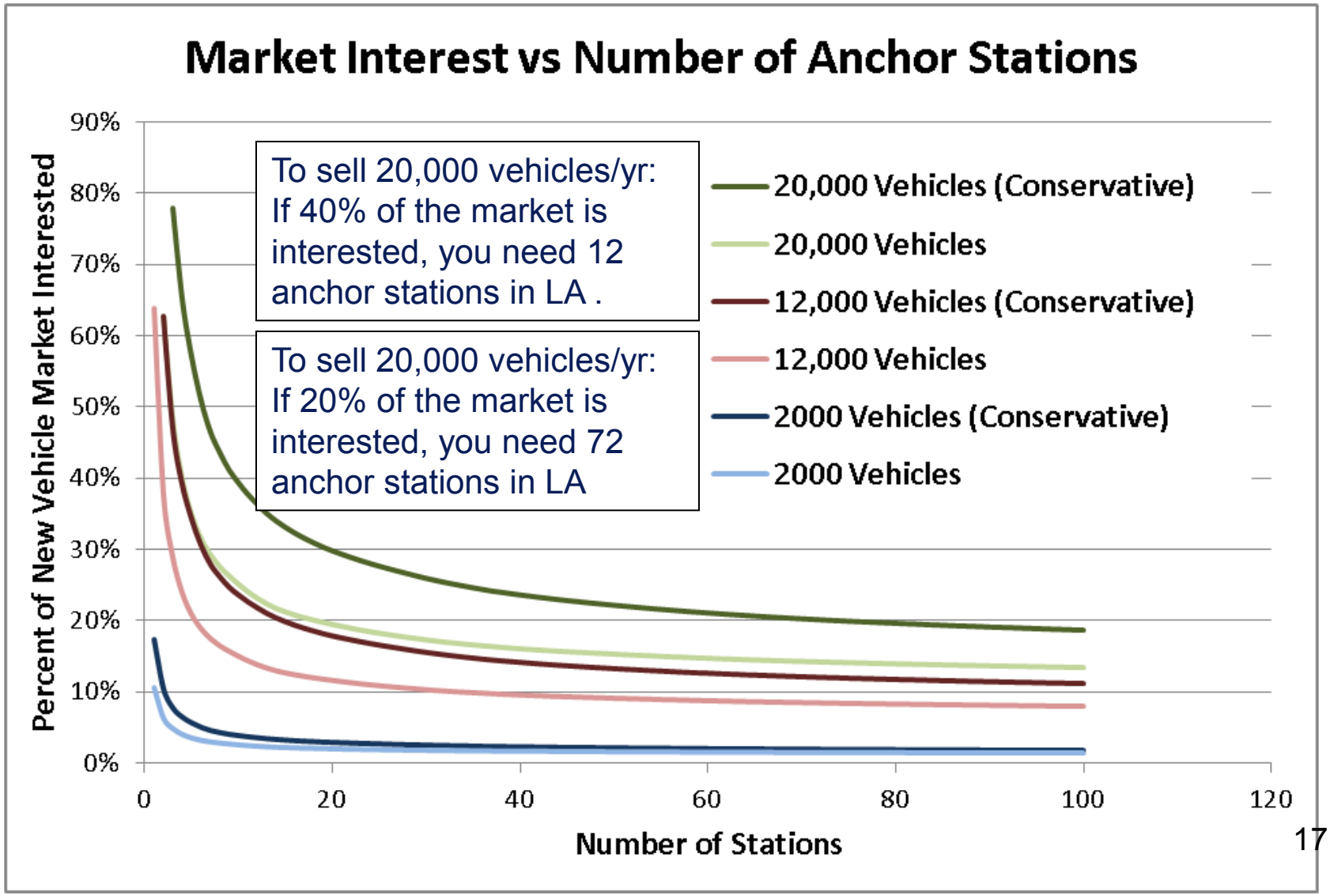
Trip time from work	Trip time from home (min) 0-5	6-10	11-20	21-30	>30	Total
0-5	238 (18.7)	53 (4.2)	92 (7.2)	52 (4.1)	33 (2.6)	468 (36.8)
6-10	95 (7.5)	51 (4.0)	37 (2.9)	11 (.9)	10 (.9)	204 (16.0)
11-20	103 (8.1)	33 (2.6)	72 (5.7)	25 (2.0)	14 (1.1)	247 (19.4)
21-30	55 (4.3)	17 (1.3)	24 (1.9)	50 (3.9)	8 (.6)	154 (12.1)
>30	54 (4.2)	16 (1.3)	28 (2.2)	9 (.7)	93 (7.3)	200 (15.7)
Total	545 (42.8)	170 (13.4)	253 (19.9)	147 (11.5)	158 (12.4)	1273 (100.0)

( ) = Percent of grand total

- If willingness to by is related to distance to anchor station, and refueling frequency, 58% of people within 2.5 minutes to a station would find no infrastructure barrier to purchace.

Future Work

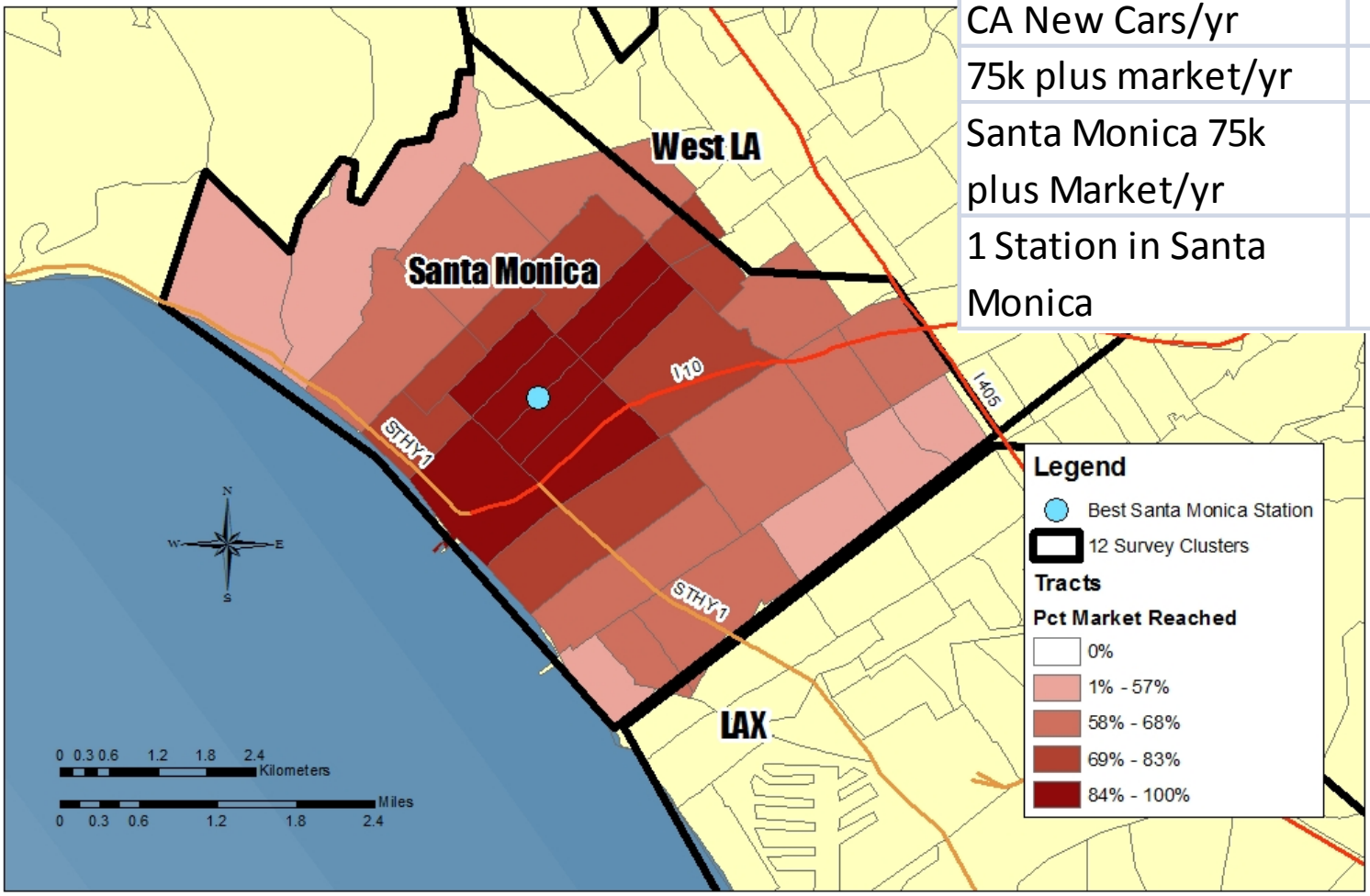
How Many Stations? Depends on How Many People are Interested



Future Work

How Much Might One Station Do? Caveat: Estimates Illustrative Only

CA Households	12,384,351.00
CA New Cars/yr	1,081,526.97
75k plus market/yr	613,215.90
Santa Monica 75k plus Market/yr	4,235.79
1 Station in Santa Monica	70%



Summary Results

- Project Goals
  - Examine existing refueling patterns
  - Apply lessons learned to the hydrogen context
  - Determine the number and spatial layout for a hydrogen refueling network that provides adequate coverage
- Key Results:
  - An “anchor” (or set of anchor stations) station is a prerequisite for many potential buyers
  - A wider network increases the marketability of the vehicle and hence increases the value of anchor stations
  - We think we know the general form of the network (anchor and network stations)
  - The number of stations necessary is not absolute because it depends on a market that is unknown
  - Going forward we need a strategy that can adapt with the market

Collaborations/Interactions

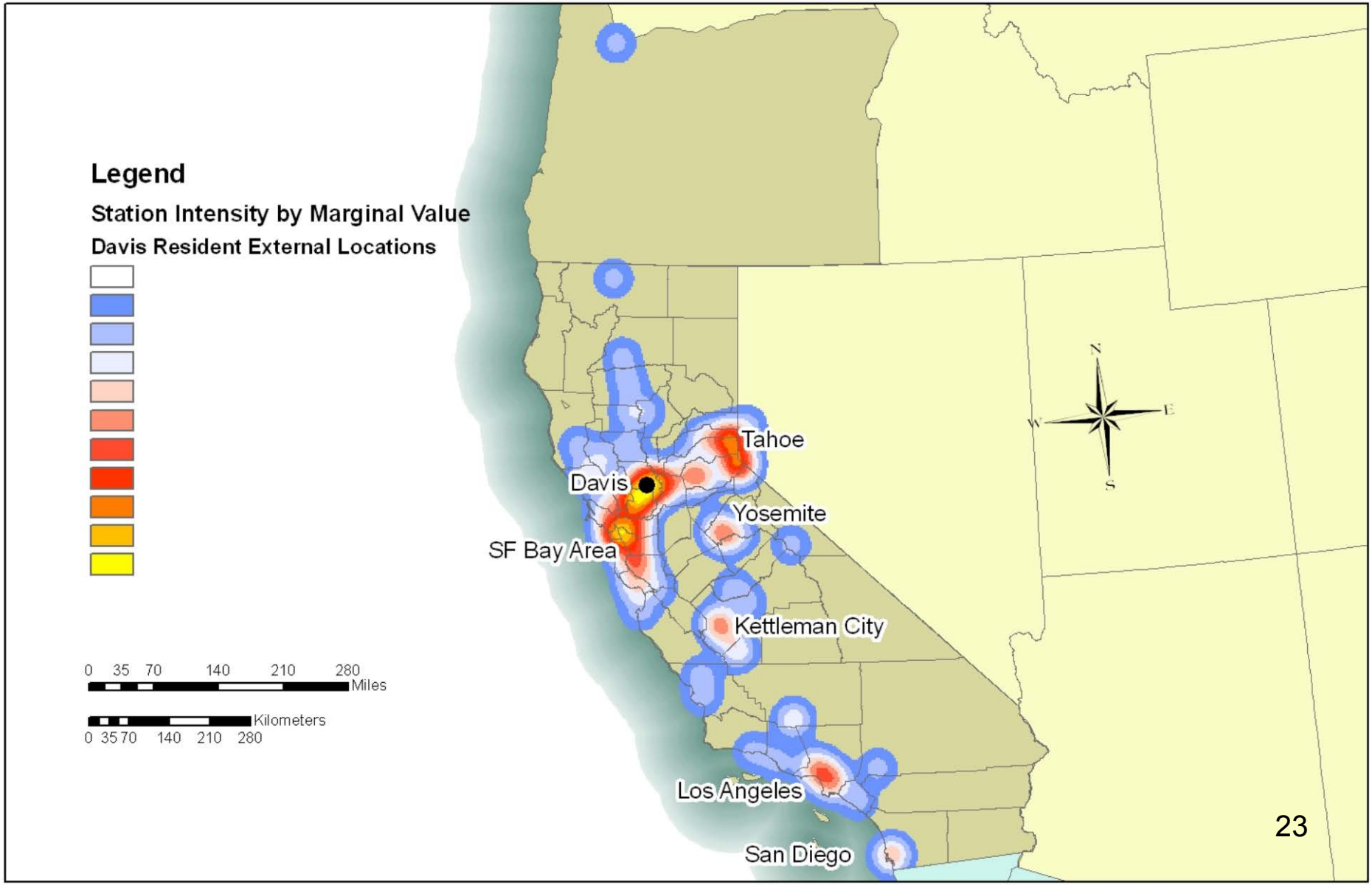
- California Fuel Cell Partnership: *provided survey data for future FCV projections; infrastructure working group discussions*
- Air Products and Chemicals, Inc., Linde, Praxair*: information on near term H2 station siting.*
- NREL (Marc Melaina, Brian Bush): *Near term station siting*
- California Air Resources Board (Joshua Cunningham) *discussions on ZEV projections, rollout strategies*
- California Energy Commission (Jim McKinney, Tim Olson) *discussions of strategies for introducing hydrogen and other fuels*
- Members of UC Davis H2 Rollout Study (Shell, Chevron, Toyota, Honda, Daimler, GM, CARB) *scenario development*
- University of California, Irvine (Tim Brown, Shane Stevens-Romero); University of California, Berkeley (Tim Lipman) *discussions on rollout strategies*
- 23 Sponsors of NextSTEPS Research Program (see supplemental slides) *for partial support*

Project Summary

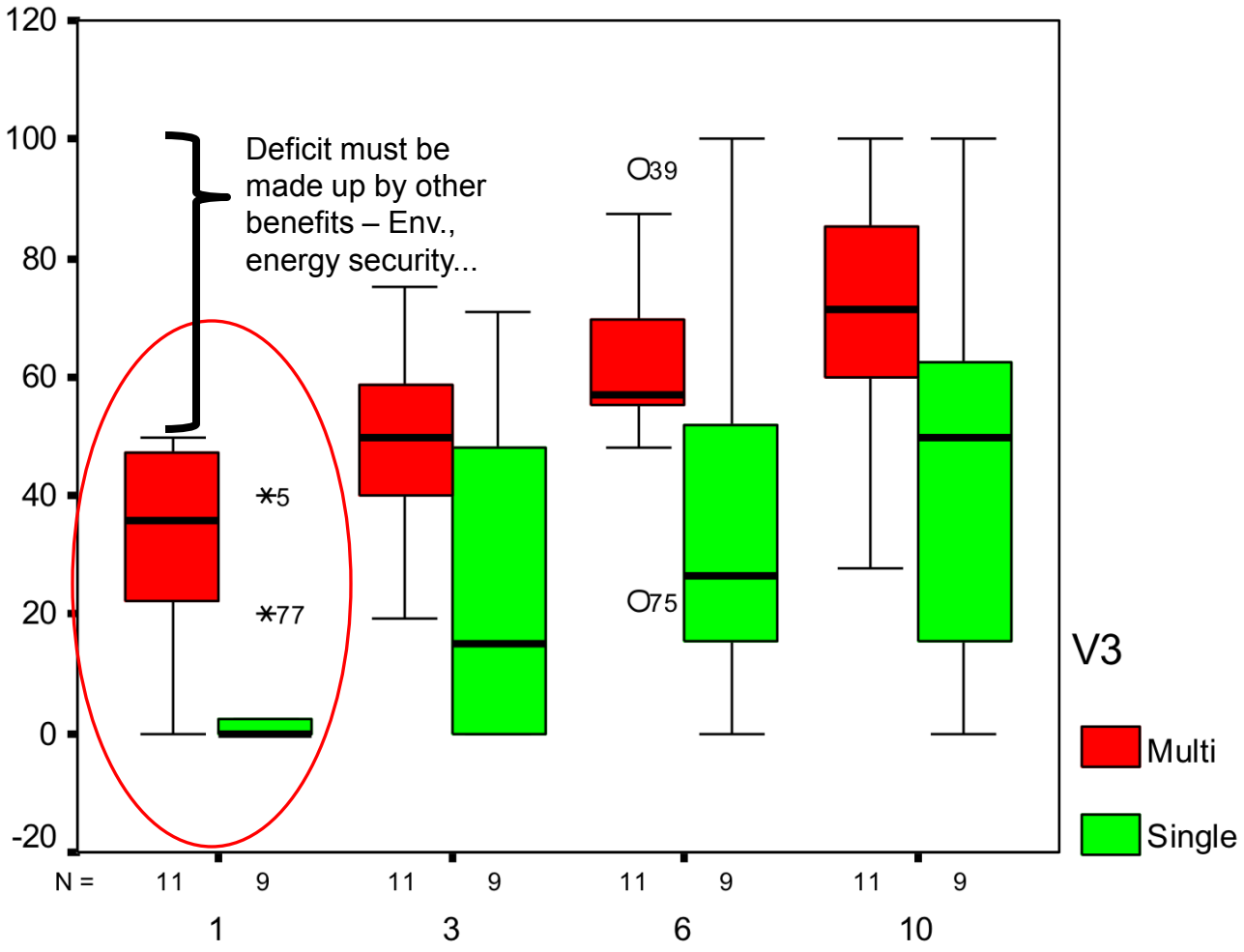
- **Relevance**: *Determine the minimum number of stations necessary for the maximum number of customers to reduce investment necessary*
- **Approach**: *Examine existing refueling patterns and apply lessons learned to the hydrogen context*
- **Technical Accomplishments and Progress**: *developed models, surveys, publications (journal papers, reports, presentations, spreadsheet model).*
- **Collaboration:** *Input/discussion w/ stakeholders (auto, energy, industrial gas, state agencies, national labs)*
- **Proposed Future Research**: *Determine the exact relationship between station placement and the purchase decision*

Technical Back-Up Slides

Given the Choice, do People Want Near or Far Stations? A: One "Anchor" and then Medium to Far.



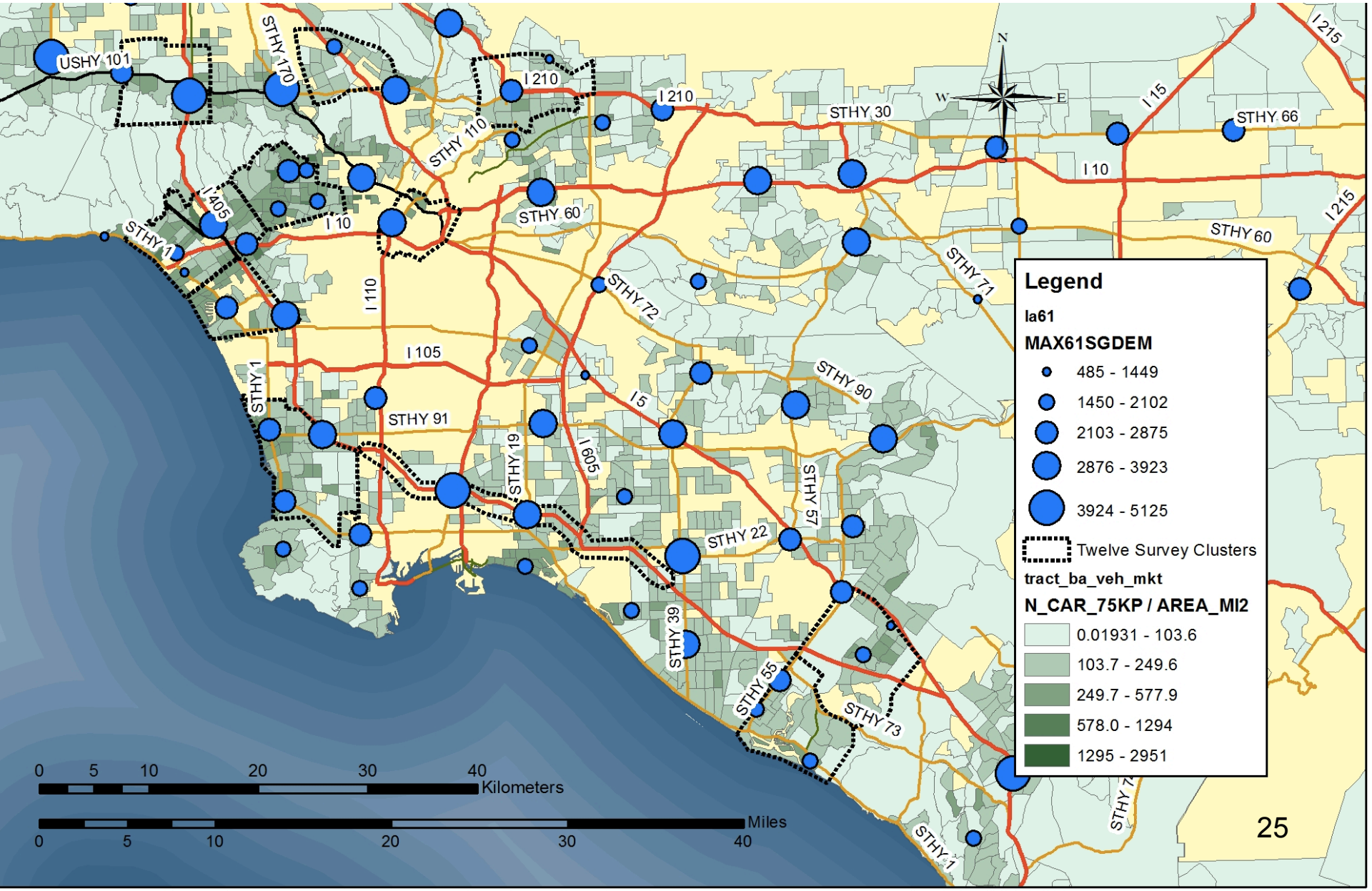
What Does Just One Station Mean to the Consumer? How Important is the Network?



Number of Stations

Example Distribution “Market Hunting”

Future Work



Future Work

Fuel Distribution in Los Angeles