Geographically-Based Infrastructure Analysis for California

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- Refueling station siting and sizing are key aspects of designing H2 infrastructure during a transition
- Initial H2 stations may be co-located with vehicle fleets
- Wider consumer adoption of H2 vehicles depends on fuel availability and cost (which are related to station number, size and location), + other factors.
- Decision when and where to deploy network of stations depends on scale and growth rate of demand, access to consumers, availability of low cost H2 supply, policy, competition

Factors in consumer decision to buy H2 vehicle

- Vehicle cost
- Vehicle performance
- Fuel cost
- Fuel availability
- Household income
- Number of household vehicles
- “Green” values
- Policies
- Others

- UC Davis researchers have employed a variety of GIS-based methods to study scenarios for H_2 station deployment
- In this talk we present results from several studies relevant to a H_2 transition in California

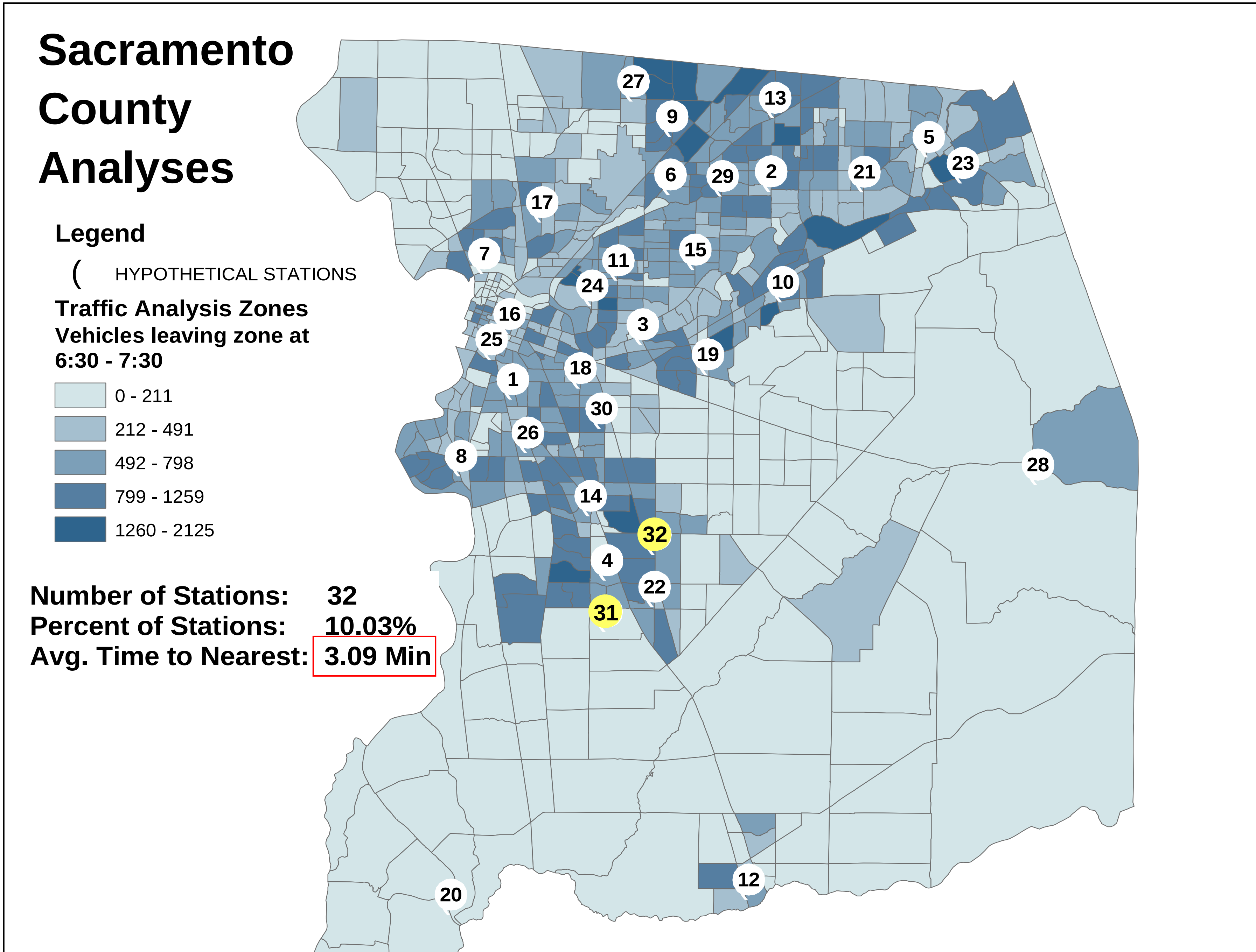
Questions:

- How many stations are needed, and where should stations be located for user convenience, for different market stages?
- How we define consumer convenience?
  - Fraction of gasoline stations offering H2?
  - ave. travel time to nearest station?
  - proximity to users?
- For specified station deployment scenario, what is the average travel time to stations, proximity to users?
- For particular demand scenarios, how might the station network change over time?
  - number of stations
  - station locations
  - station sizes
  - station type (H2 supply option)
- What is the cost of different station deployment scenarios to meet growing demand? What are lowest cost H2 supply options over time?

Study 1: How many H2 stations are needed for consumer convenience? Where should they be located? How does this with vary with average travel time and city characteristics?

H2 Station Siting Analysis for Sacramento

- H2 Stations sited to minimize the average travel time to the nearest station for commuters
- Use the existing gasoline network as a baseline for comparison to hydrogen station networks
- Utilize census and traffic data to identify customer locations



Sacramento County Analyses
Legend
HYPOTHETICAL STATIONS
Traffic Analysis Zones
Vehicles leaving zone at 6:30 - 7:30
0 - 211
212 - 491
492 - 798
799 - 1259
1260 - 2125
Number of Stations: 32
Percent of Stations: 10.03%
Avg. Time to Nearest: 3.09 Min
27
13
9
5
23
6
29
2
21
17
7
11
15
24
10
16
3
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19
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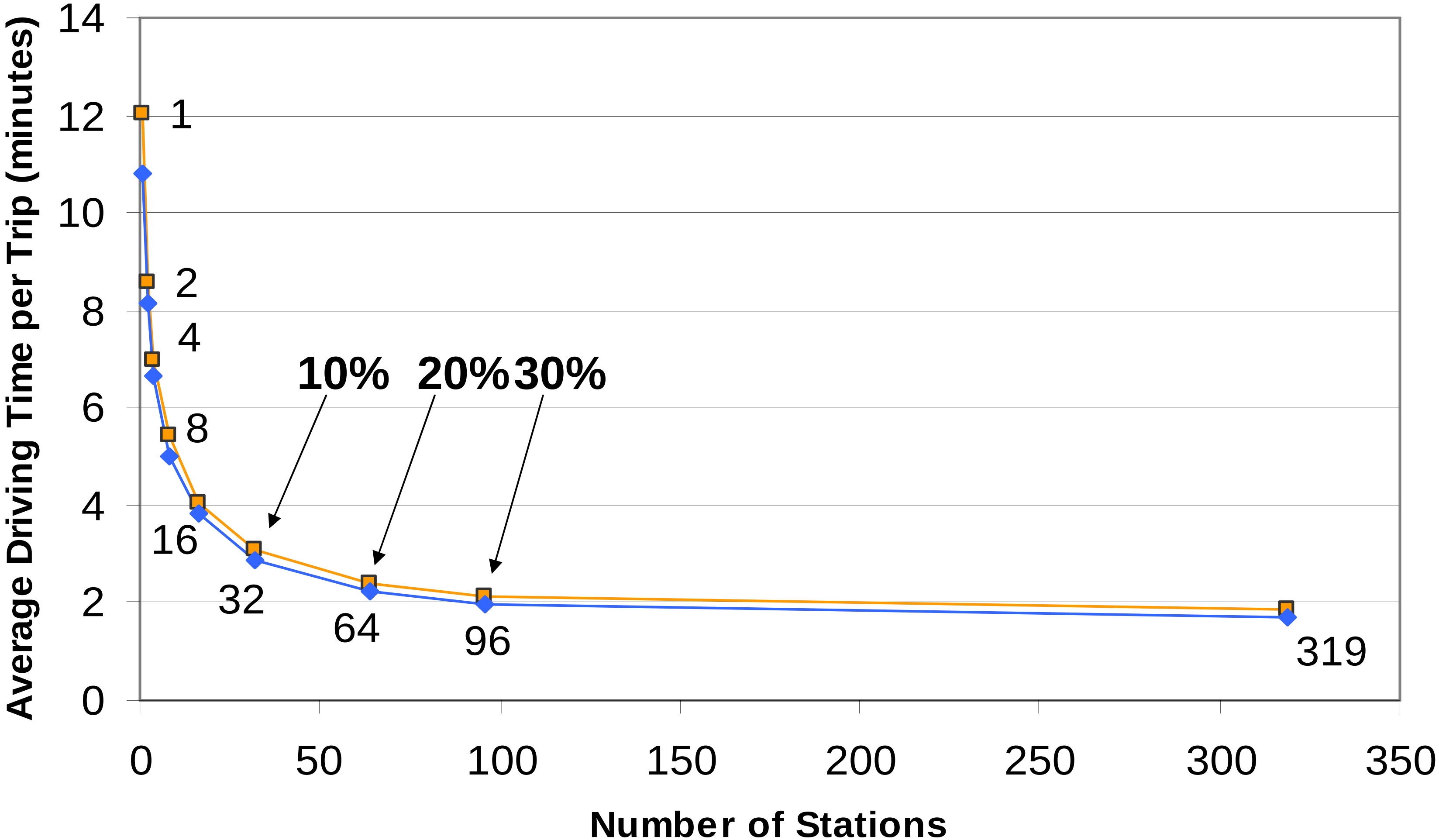


Relationship Between Number of Stations and Average Travel Time – H2 offered 10-30% of existing gasoline stations might provide adequate convenience

HOW MANY STATIONS ARE NEEDED? Characteristics of CA Urban Areas

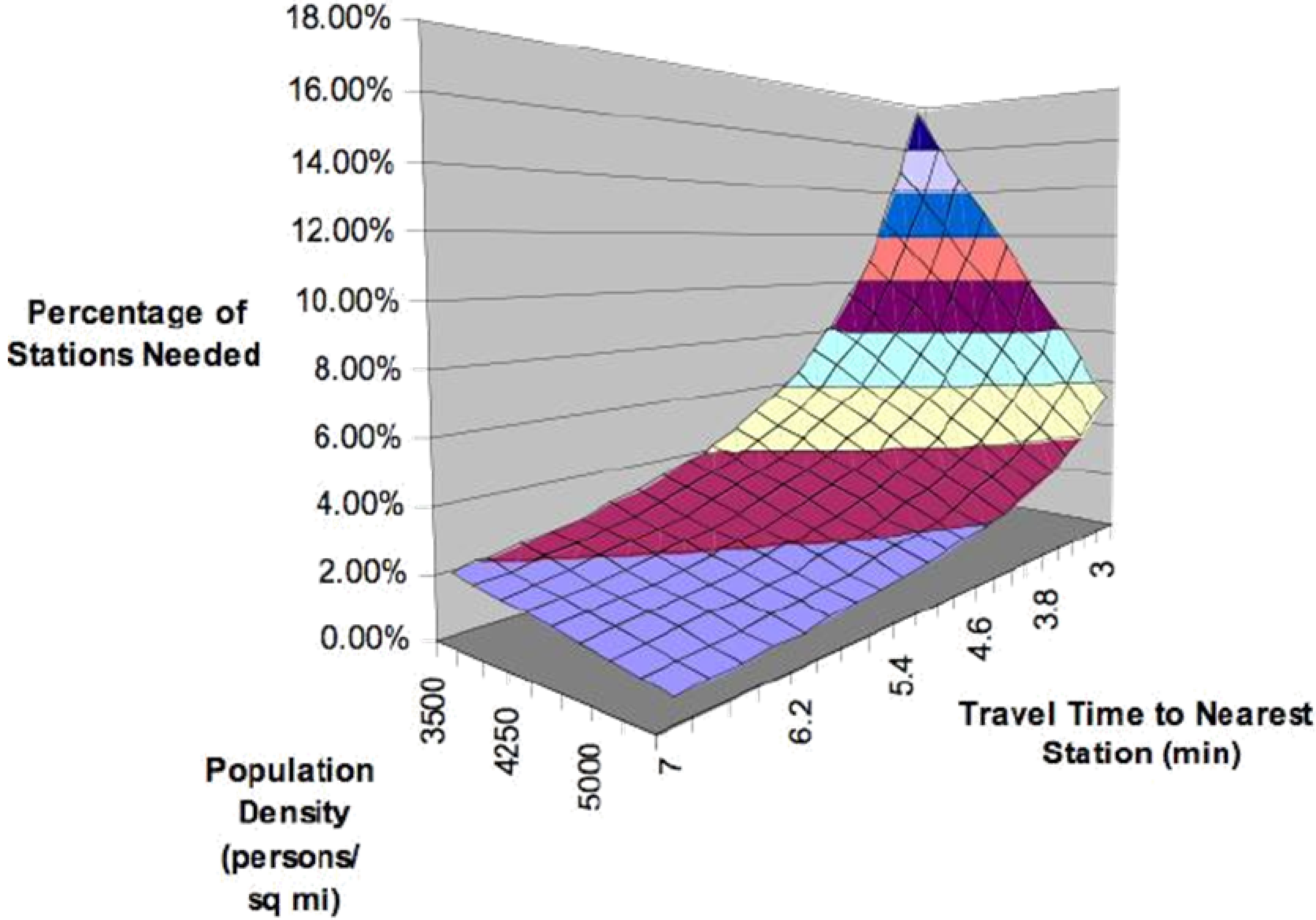
	SCAG (LA)	ABAG (Bay Area)	SANDAG (San Diego)	SACOG (Sac)
Pop. (Millions)	15.8	6.5	2.6	1.7
Density (people/km2)	1072	997	1059	718
Time to Nearest Gasoline Sta(min)	1.8	2	2.41	2.43

Fraction of Gasoline Stations Needed Varies

	SCAG	ABAG	SANDAG	SACOG
7 Minutes	1.06%	1.34%	1.80%	2.85%
6 Minutes	1.55%	1.85%	2.62%	3.86%
5 Minutes	2.42%	2.80%	4.26%	5.69%
4 Minutes	4.23%	4.72%	8.03%	9.35%

Source: Nicholas and Ogden, submitted to TRB, 2005

RESULT: Fraction of stations needed varies w/ required ave. travel time and population density of city



Study 2: What is the Average Travel Time to H2 Stations for a Particular Infrastructure Deployment Scenario?

Possible deployment scenario for 0 ->200 stations in Southern California

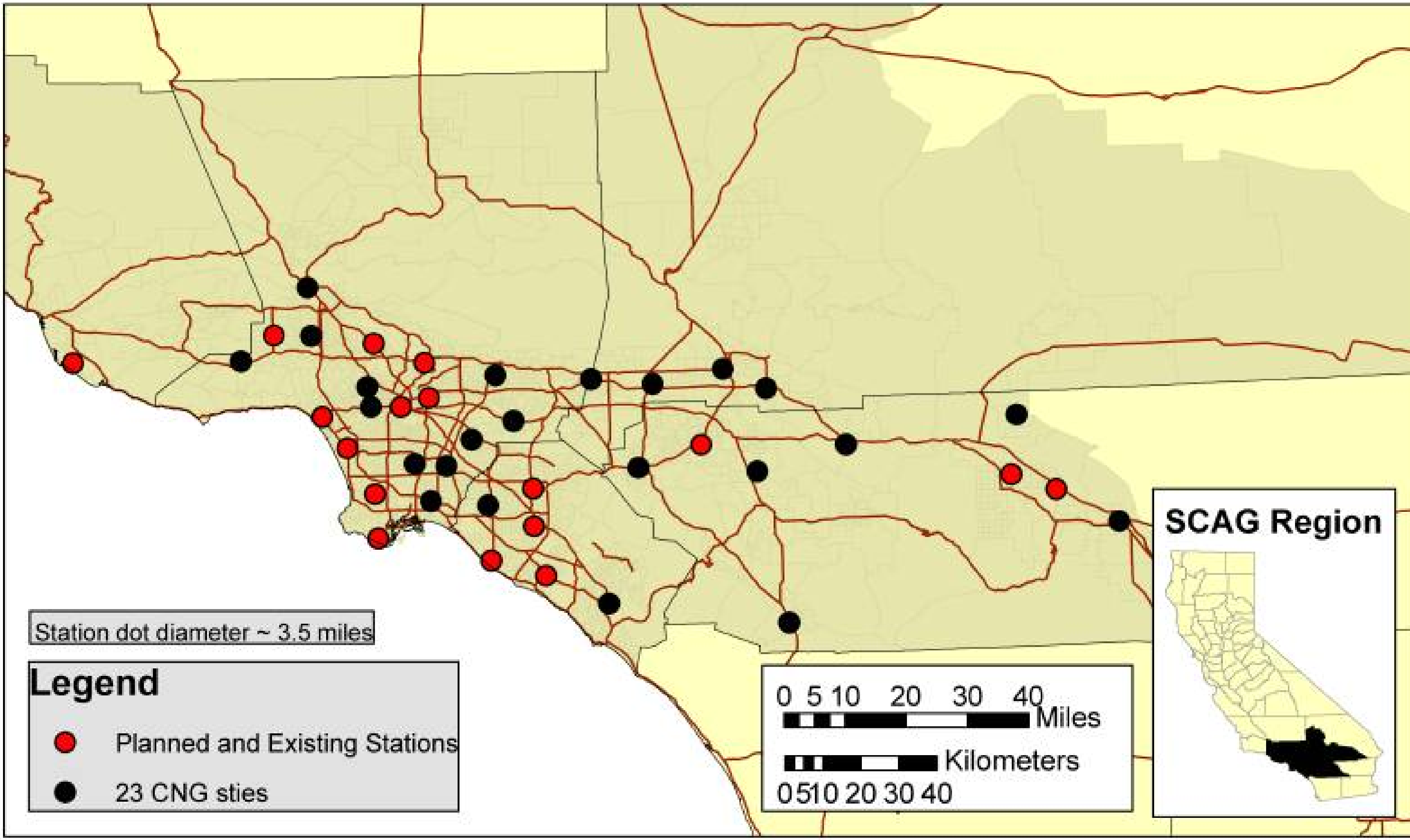
Start with existing and planned H_2 stations

+ CNG fleet stations

+ Municipal agencies with fleets

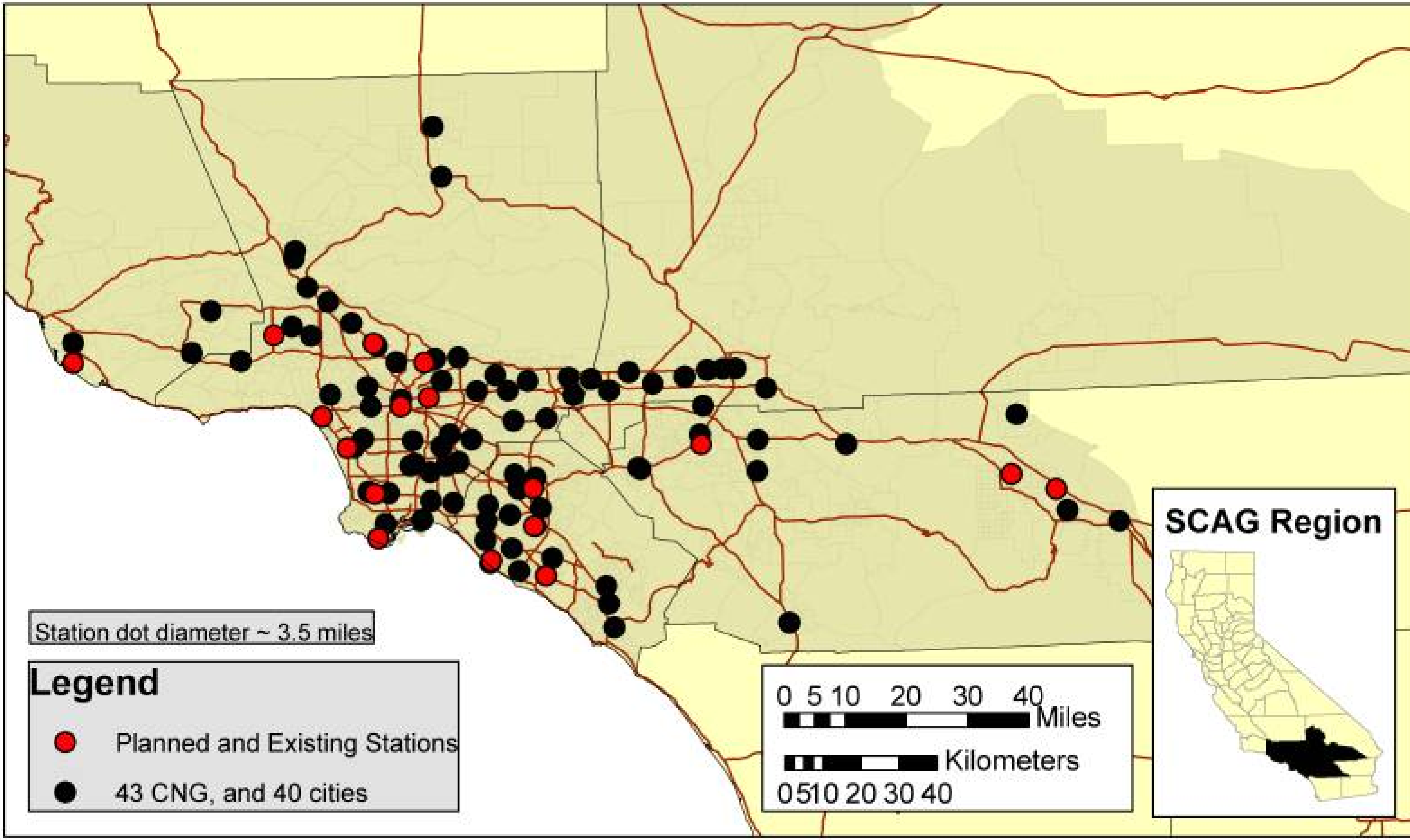
+ Gasoline retail stations sites

1% of stations in LA (40 stations total):
17 planned H2 stations + 23 (of 40 existing) CNG sites

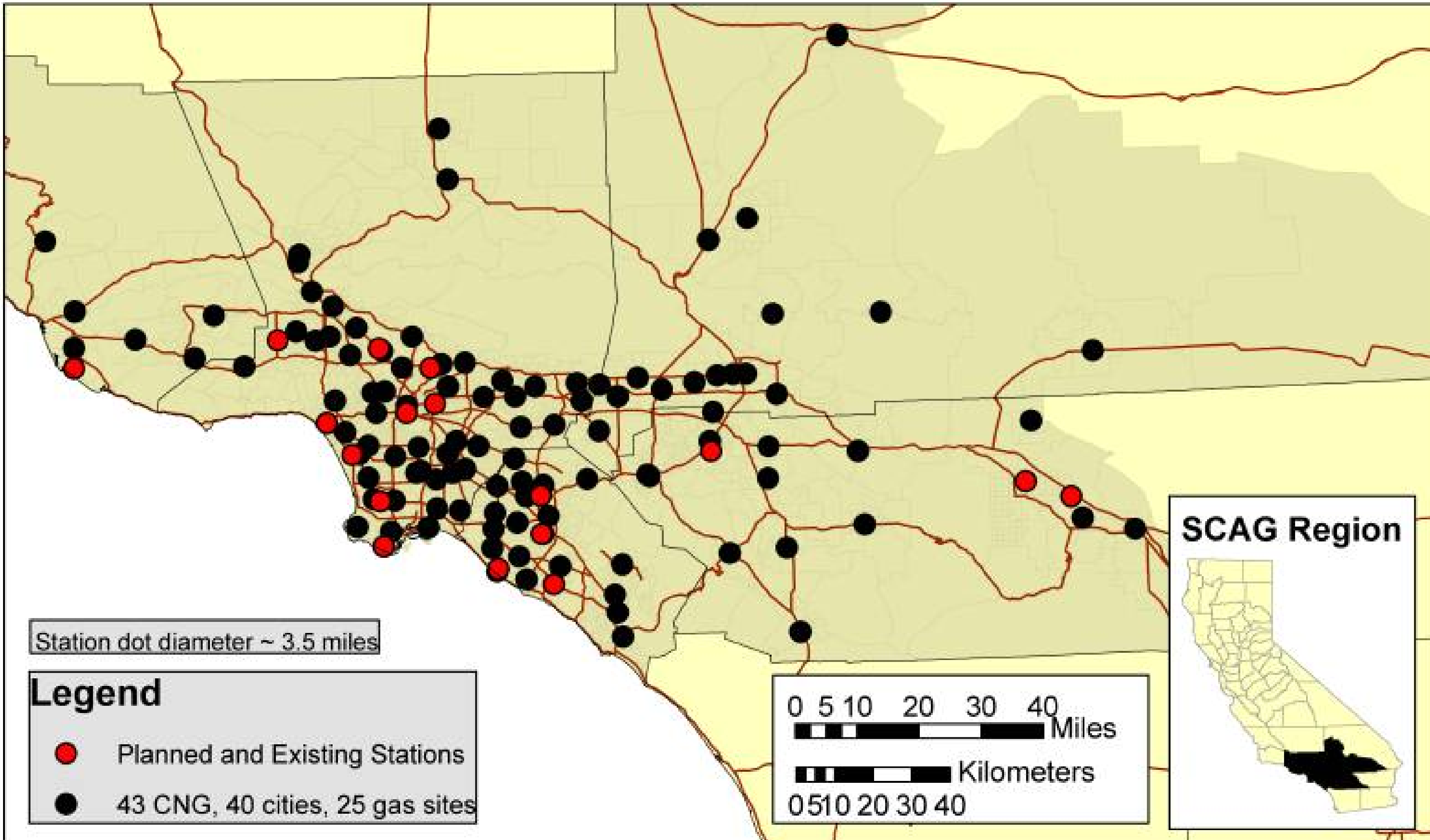


2.5% of stations in LA (100 stations total):

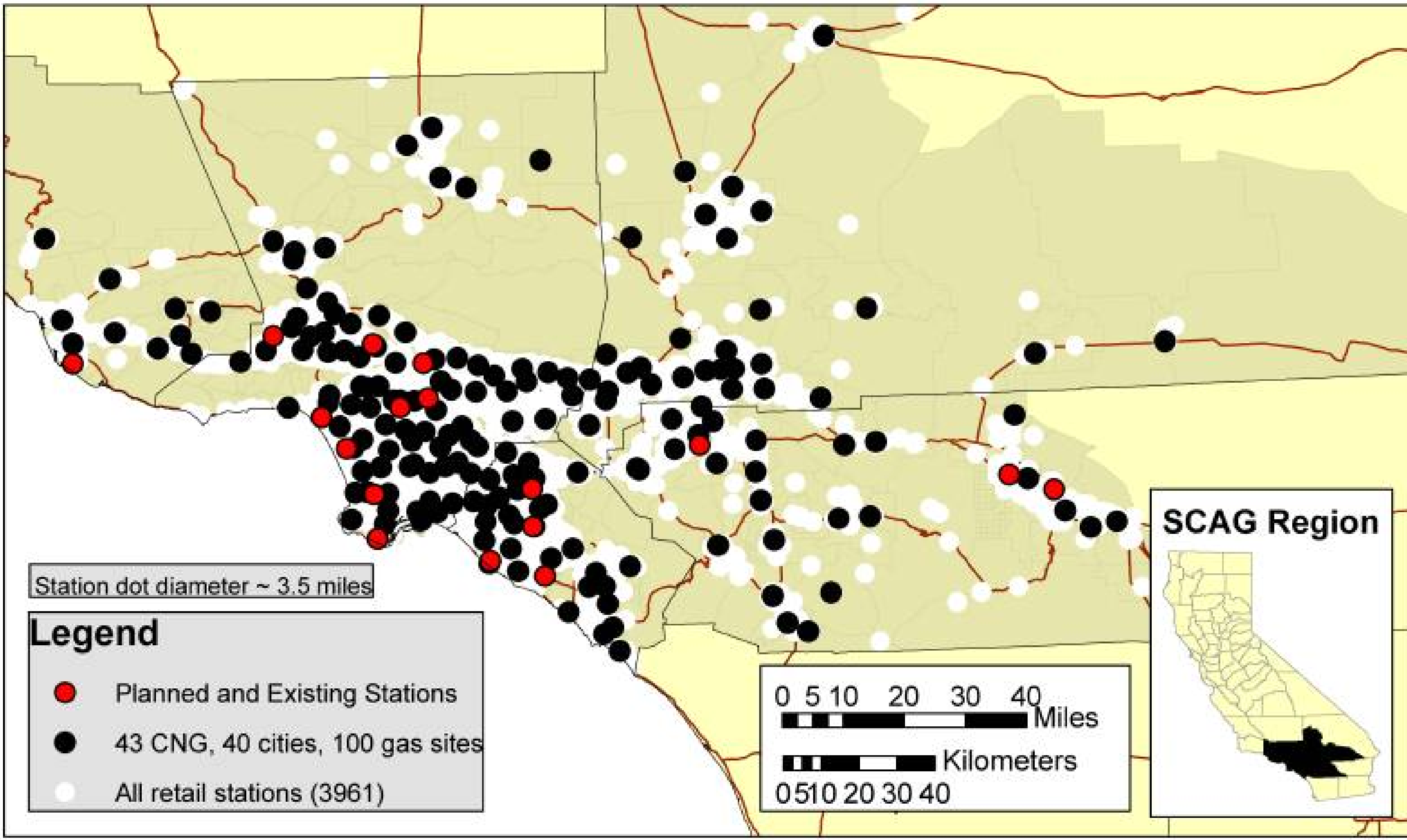
17 planned, 43 from CNG, 40 largest cites



3% of stations in LA (125 stations total):
17 planned, 43 from CNG, 40 largest cites, 25 gasoline locations

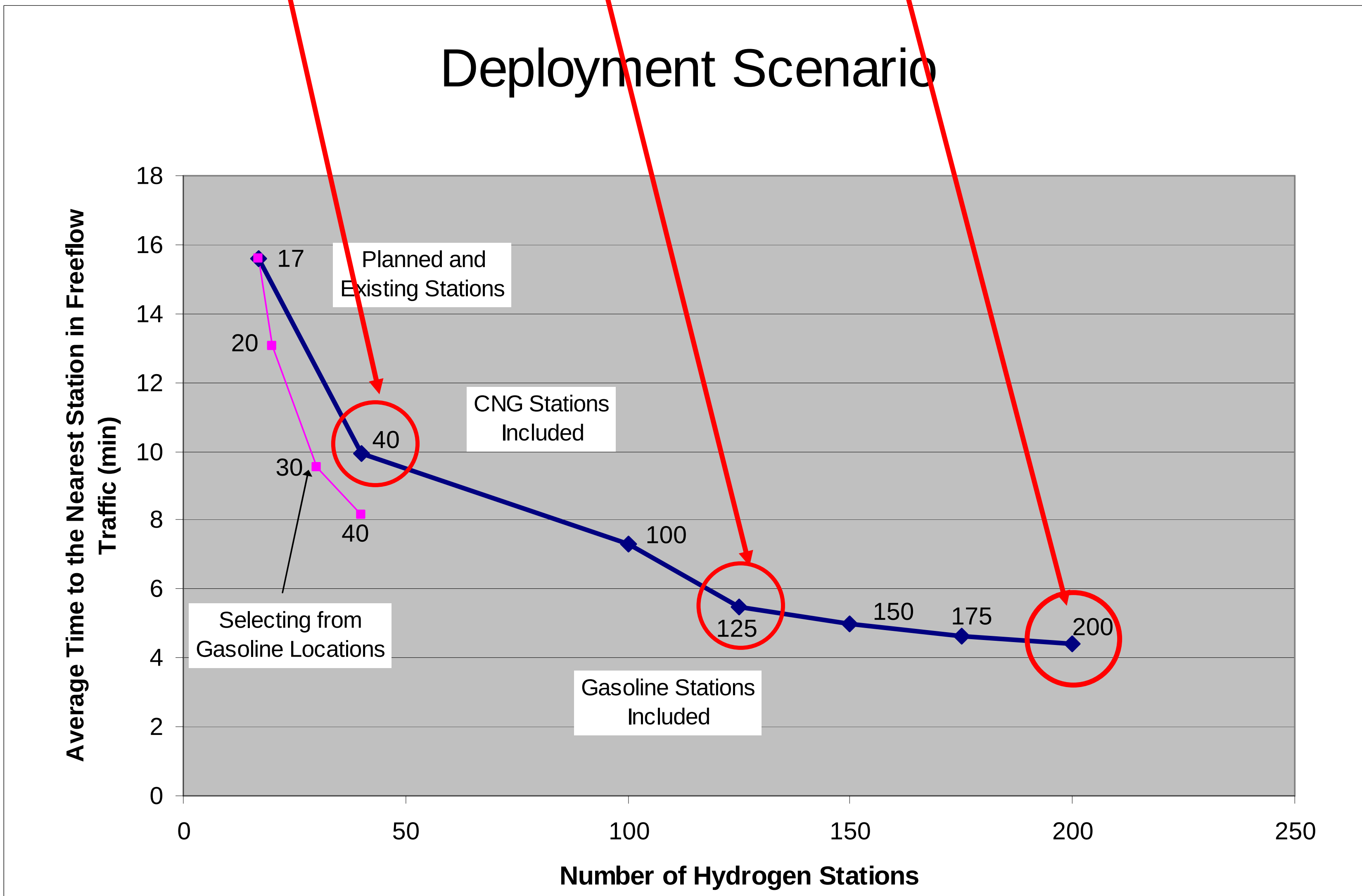


5% of stations in LA (200 stations total):
17 planned, 43 from CNG, 40 largest cites, 100 gasoline locations



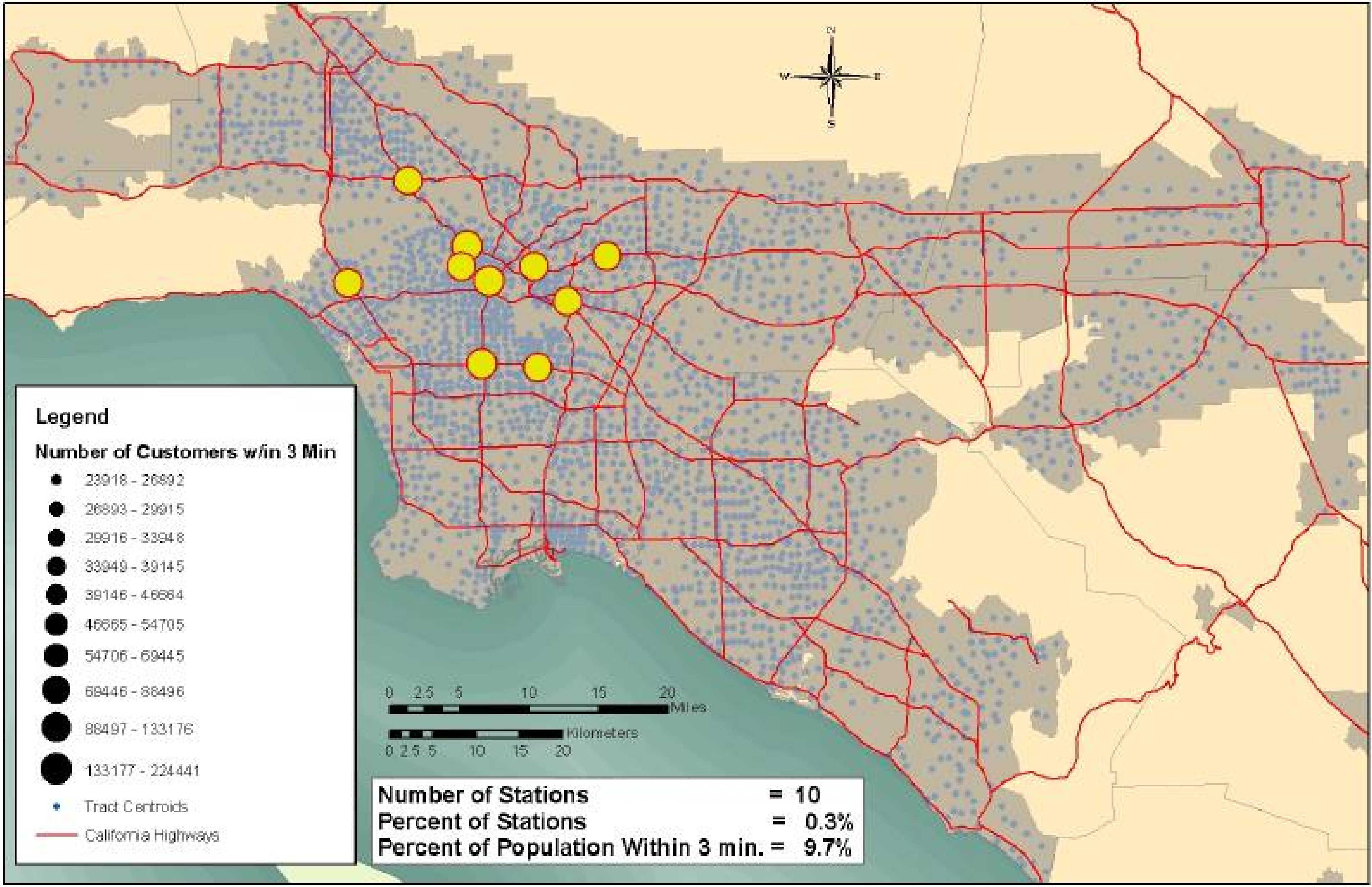
Average Travel Time to the Nearest Station:

1% ~ 10 min; 3% ~ 6 min, 5% < 5 min

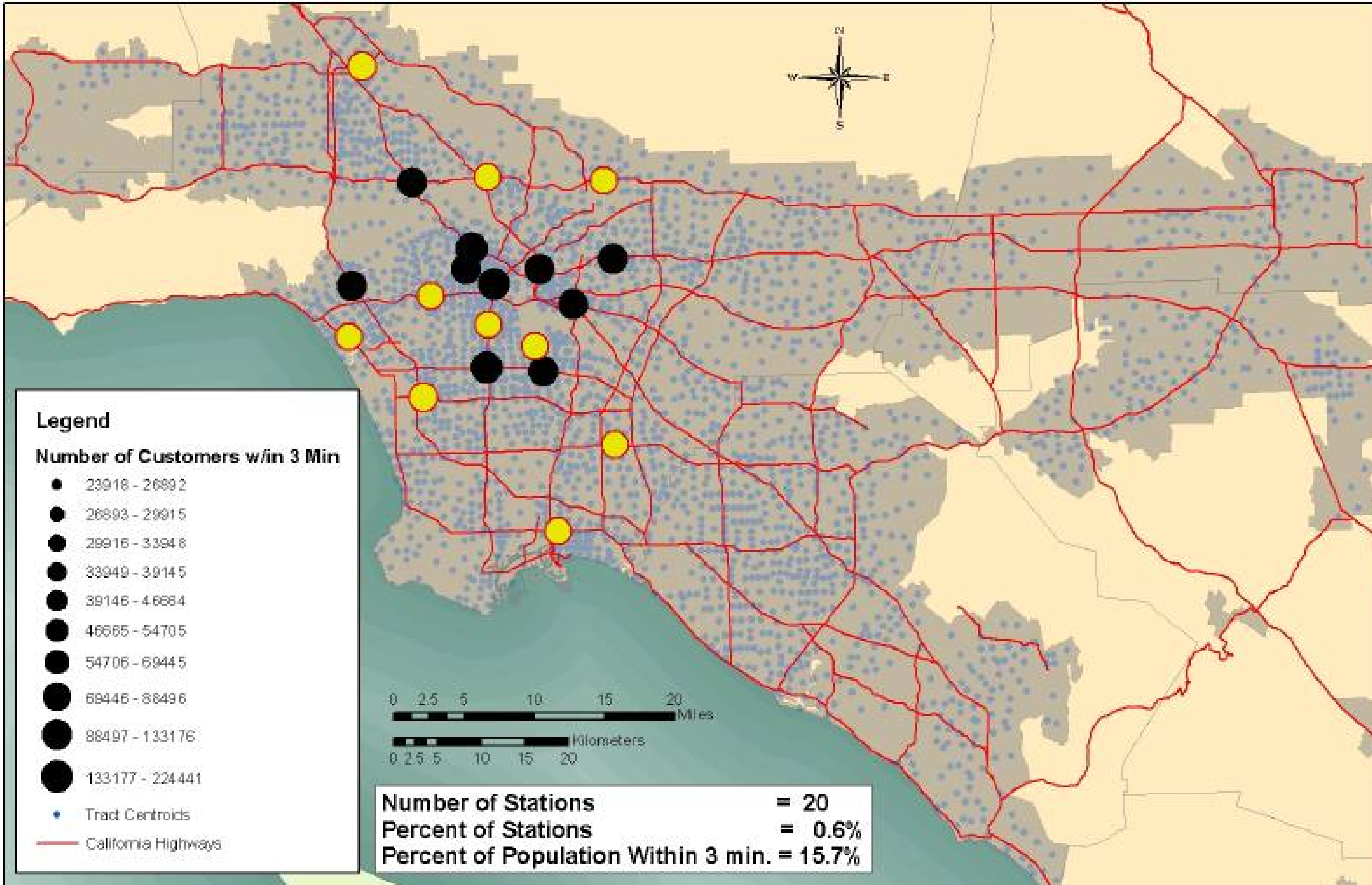


Study 3: How do we site and size stations to maximize number of consumers nearby?

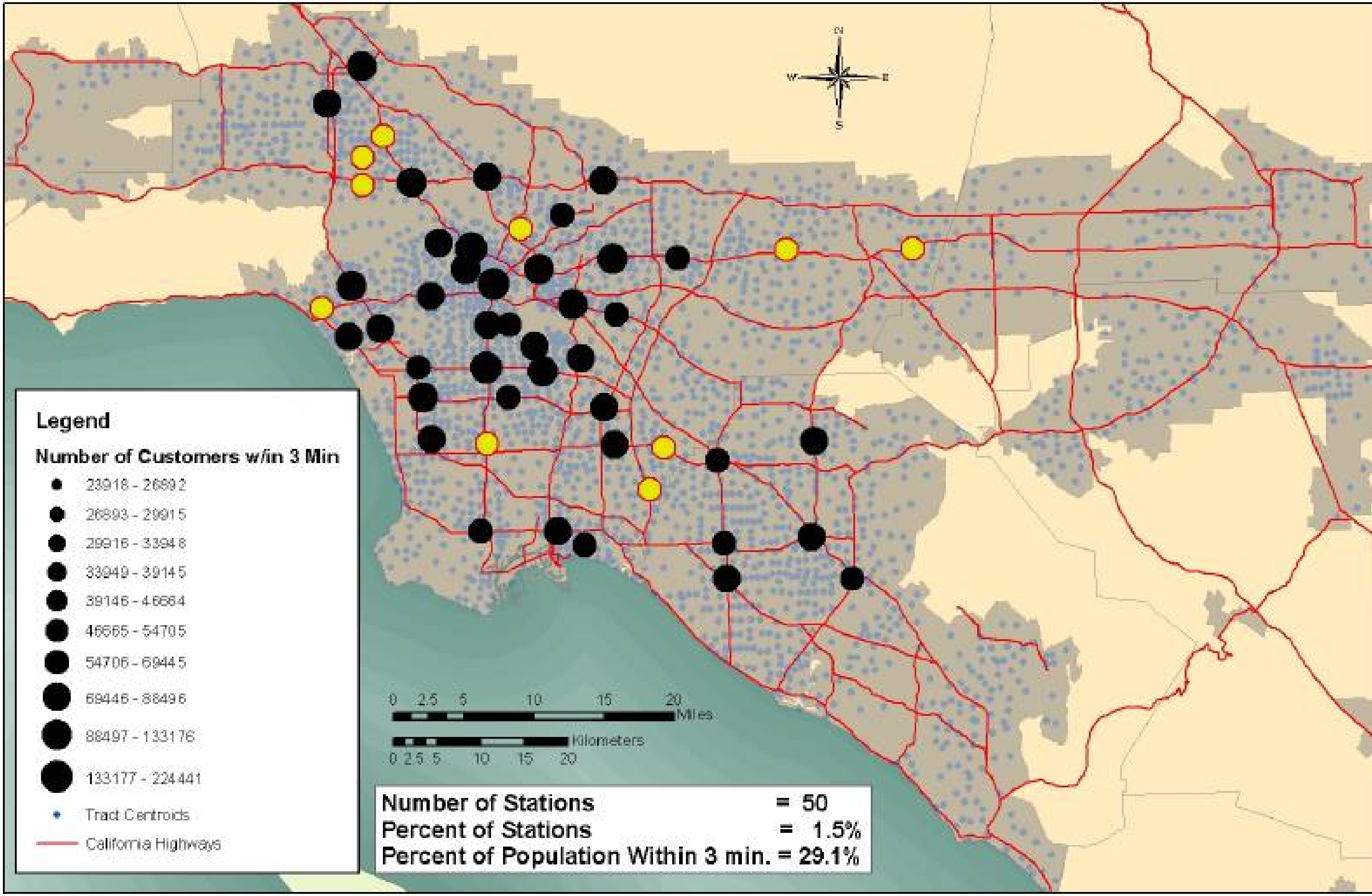
10 stations; 10% of people within 3 minutes



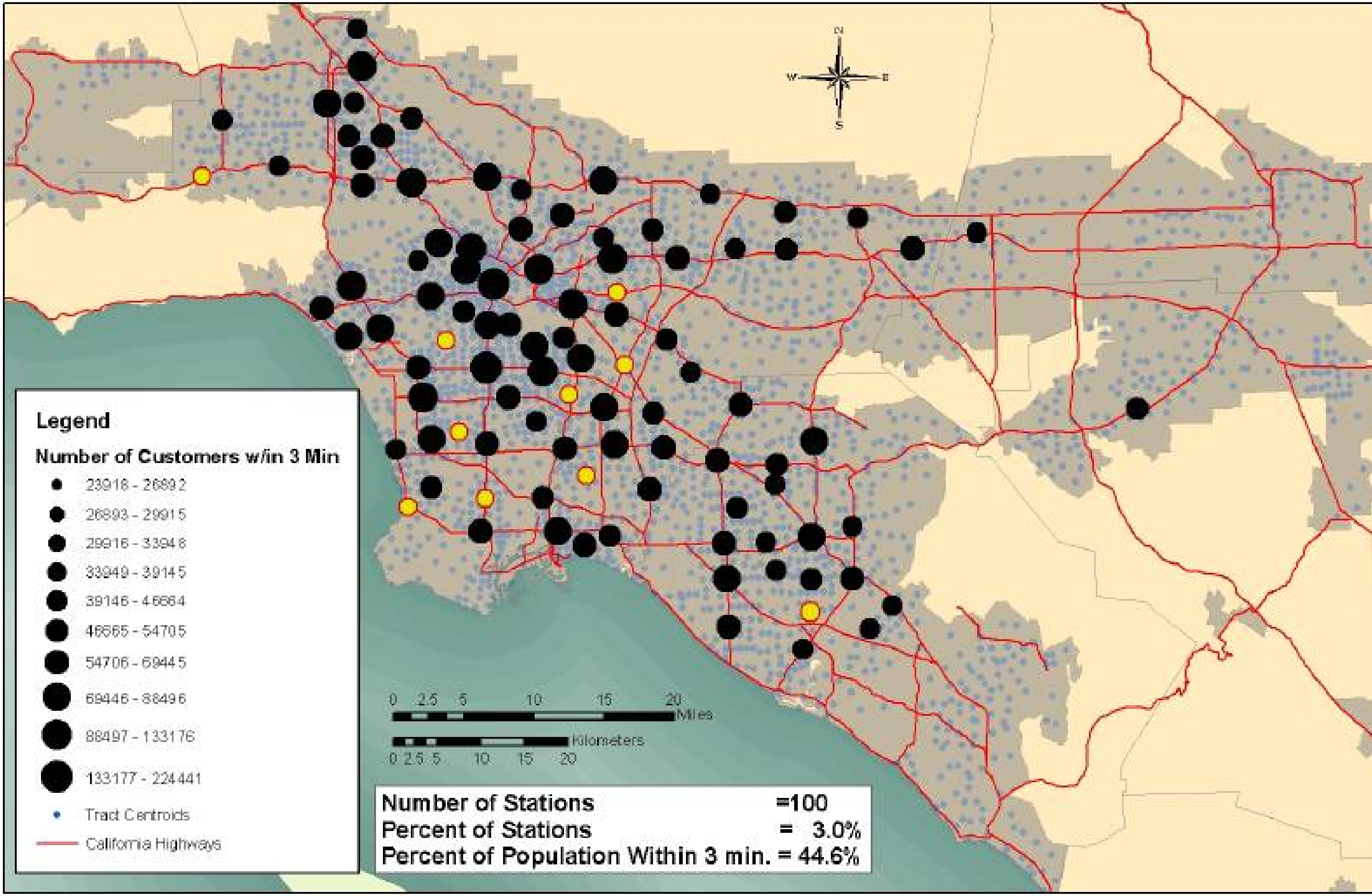
20 stations; 16% of people within 3 minutes



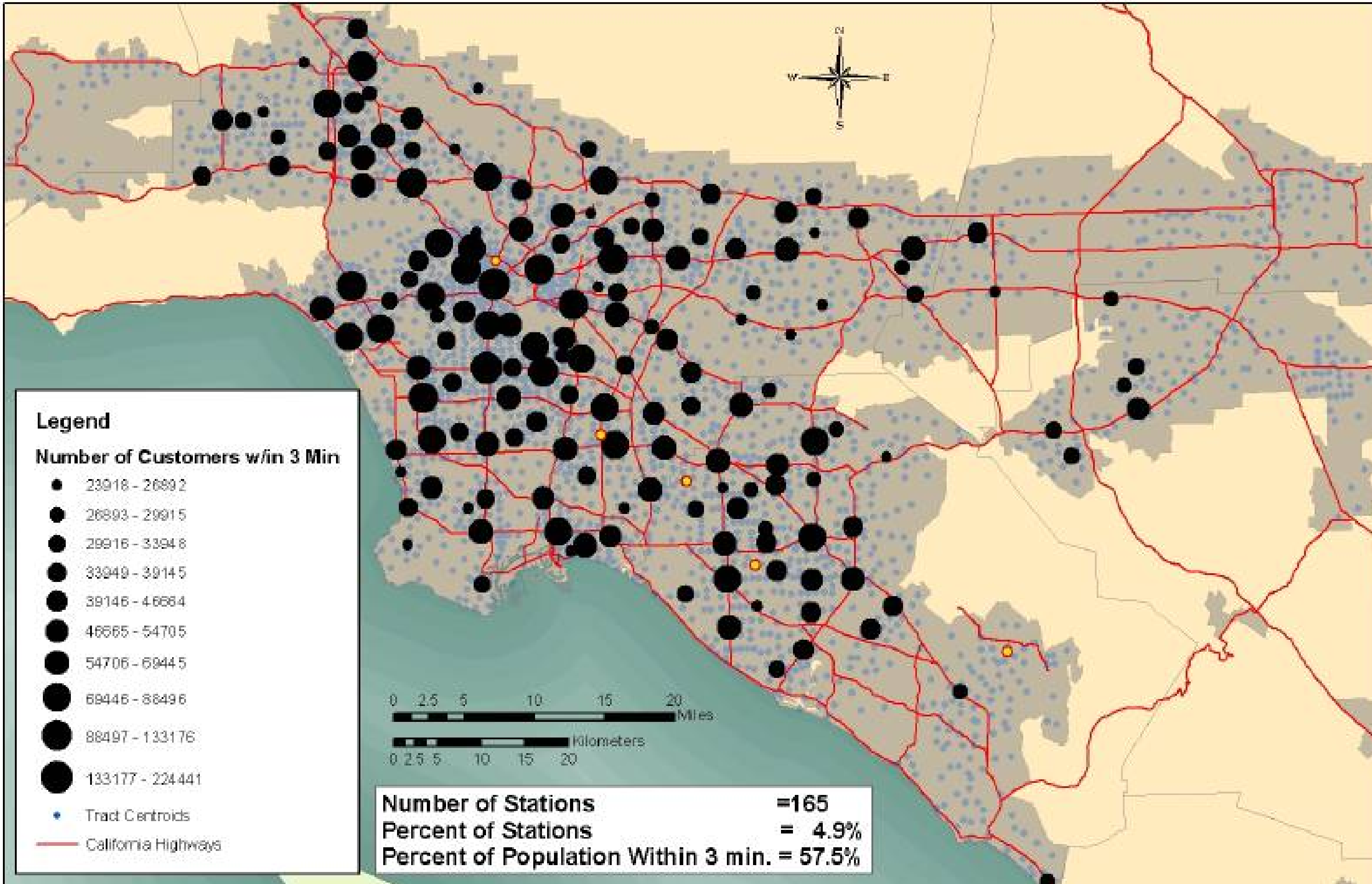
50 stations; 29% of people within 3 minutes



100 stations; 45% of people within 3 minutes



165 stations; 58% of people within 3 minutes



Station sizing

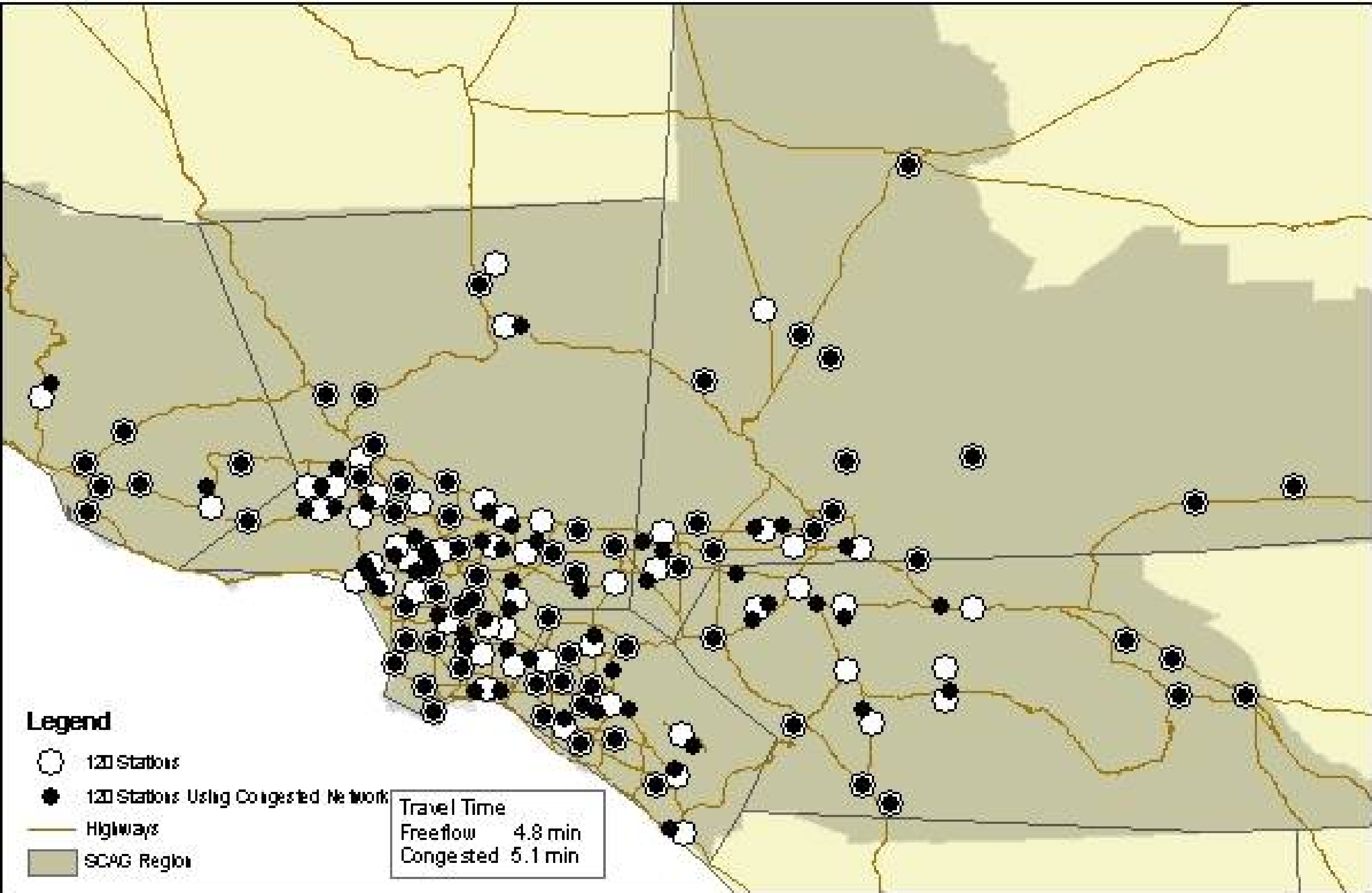
- The analysis allows us to allocate nearby consumers to optimally placed stations
- Knowing the # of consumers served at each station, we develop a *distribution of station sizes* needed for a given level of market demand

Study 3a: What is the impact of traffic congestion in Southern California on optimized station layout ?

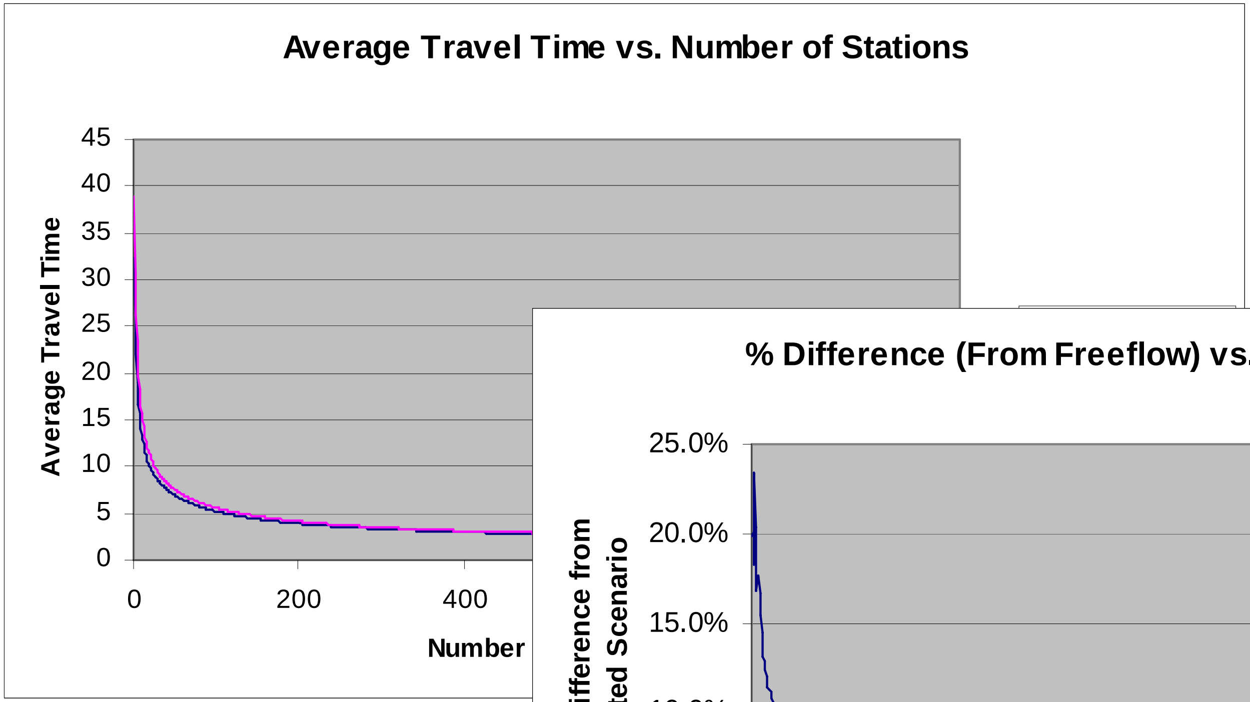
20 Stations 0.5%

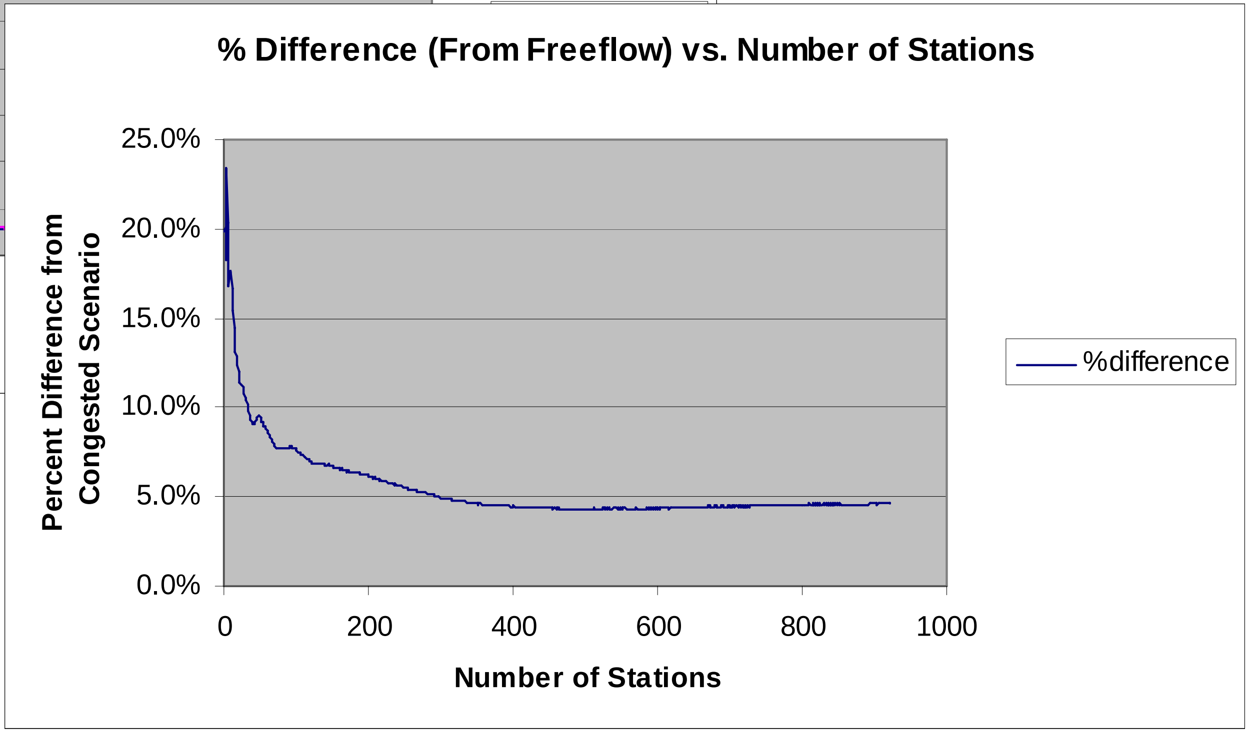
60 Stations 1.5%

120 Stations 3.0%



Difference Between Freeflow and Congested Networks





Study 4: Infrastructure deployment strategies to meet H2 demand scenarios

DOE's 3 scenarios for national rollout of H2 vehicles 2012-2025

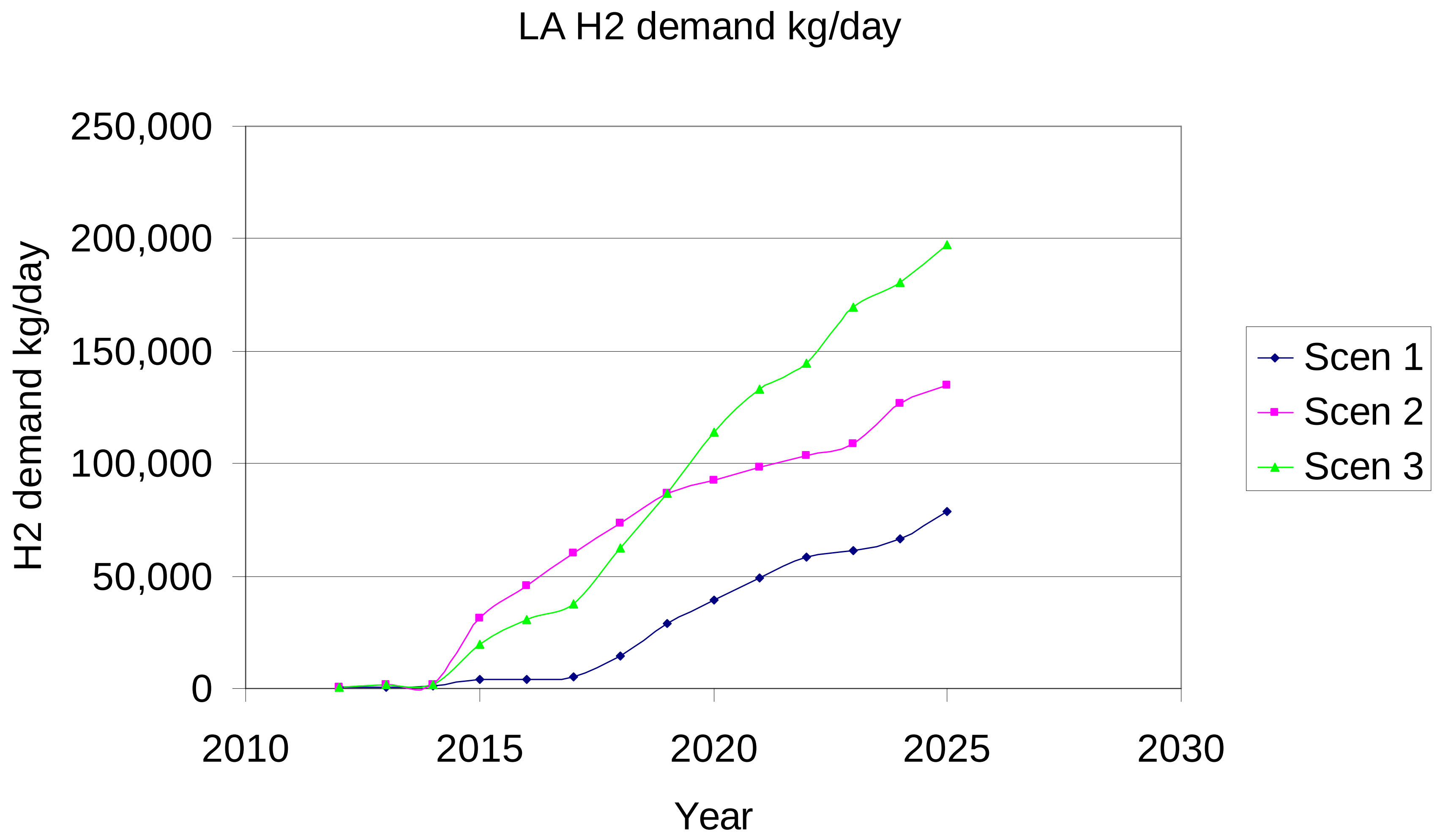
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total (M)
Scenario 1	0	0	0	5	8	12	50	100	150	200	250	300	400	500	2.0
Scenario 2	1	2	2	50	100	150	200	300	400	500	600	700	900	1000	4.9
Scenario 3	1	2	2	50	100	150	300	500	750	1000	1200	1500	2000	2500	10.1
HEV + 15	0	0	0	9	20	35	48	88	206	281	316	350	458	565	2.4

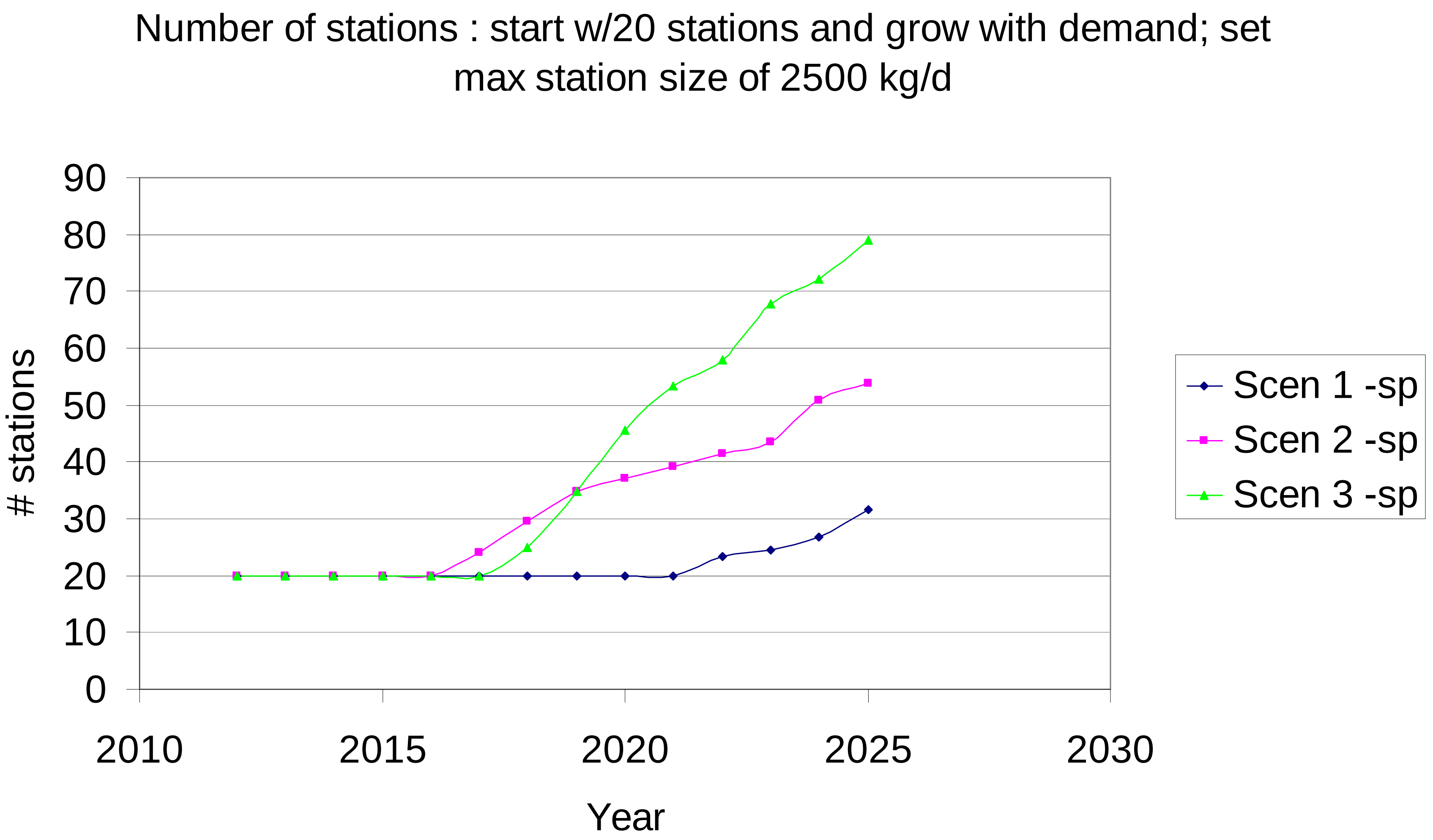
DOE's 3 scenarios for LA rollout of H2 vehicles 2012-2025

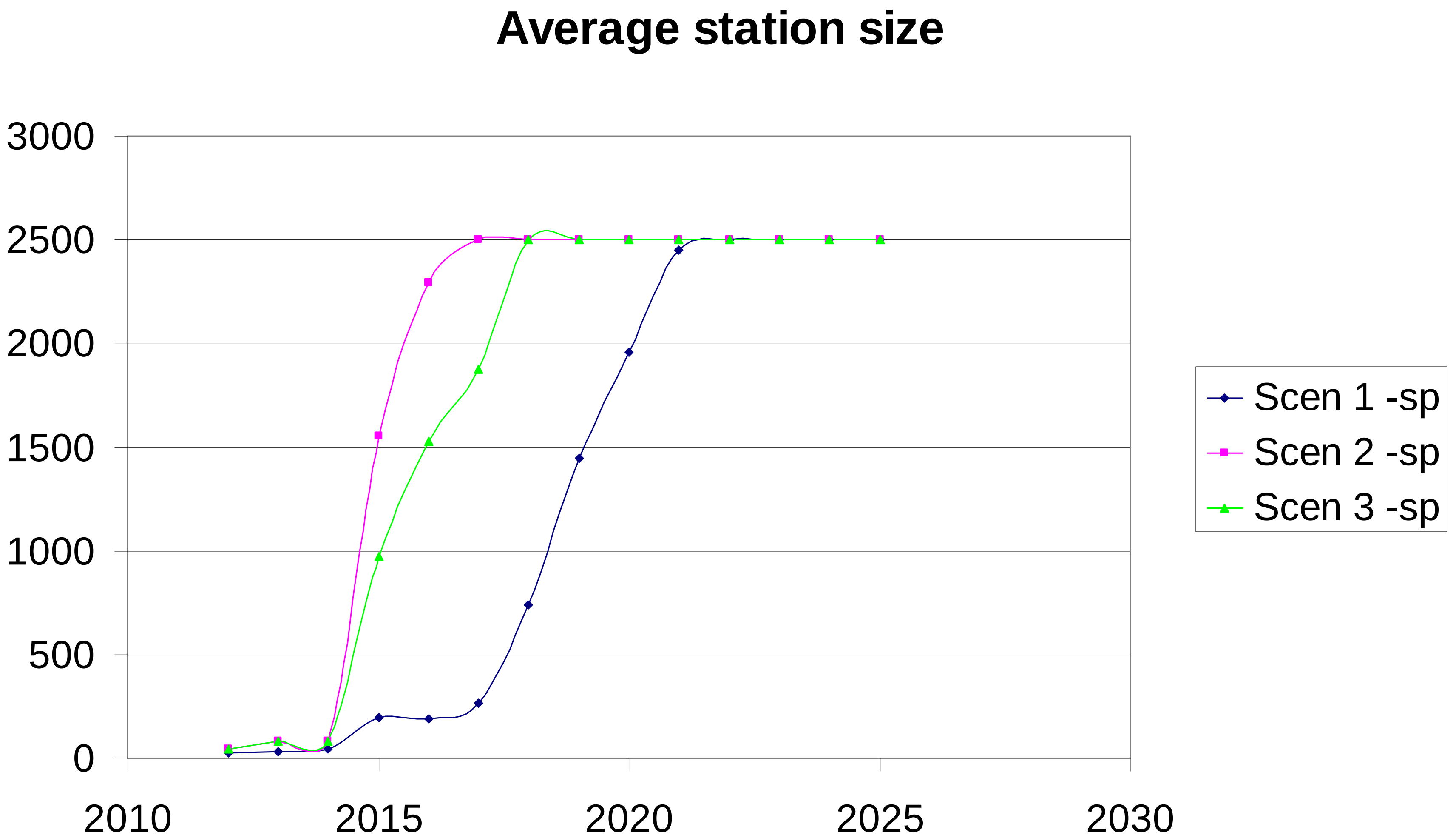
	Number of vehicles per year (:		
Year	Scen 1	Scen 2	Scen 3
2012	0.6	1	1
2013	0.8	2	2
2014	1.1	2	2
2015	5	40	25
2016	5	60	40
2017	7	80	50
2018	20	100	85
2019	40	120	120
2020	55	130	160
2021	70	140	190
2022	85	150	210
2023	90	160	250
2024	100	190	270
2025	120	205	300

Estimate H2 Demand in So. California, assuming:

- H2 Veh. Fuel economy: 40 mpg (2012) -> 50 mpg (2025)
- Average annual mileage: 12,000 miles/yr


LA H2 demand kg/day
H2 demand kg/day
250,000
200,000
150,000
100,000
50,000
0
2010
2015
2020
2025
2030
Year
Scen 1
Scen 2
Scen 3


Number of stations : start w/20 stations and grow with demand; set max station size of 2500 kg/d
stations
90
80
70
60
50
40
30
20
10
0
2010
2015
2020
2025
2030
Year
Scen 1 -sp
Scen 2 -sp
Scen 3 -sp



Average station size
3000
2500
2000
1500
1000
500
0
2010
2015
2020
2025
2030
Scen 1 -sp
Scen 2 -sp
Scen 3 -sp

Estimate number of H2 stations over time from demand and "growth factor"

N_i = Number of stations operating in year i

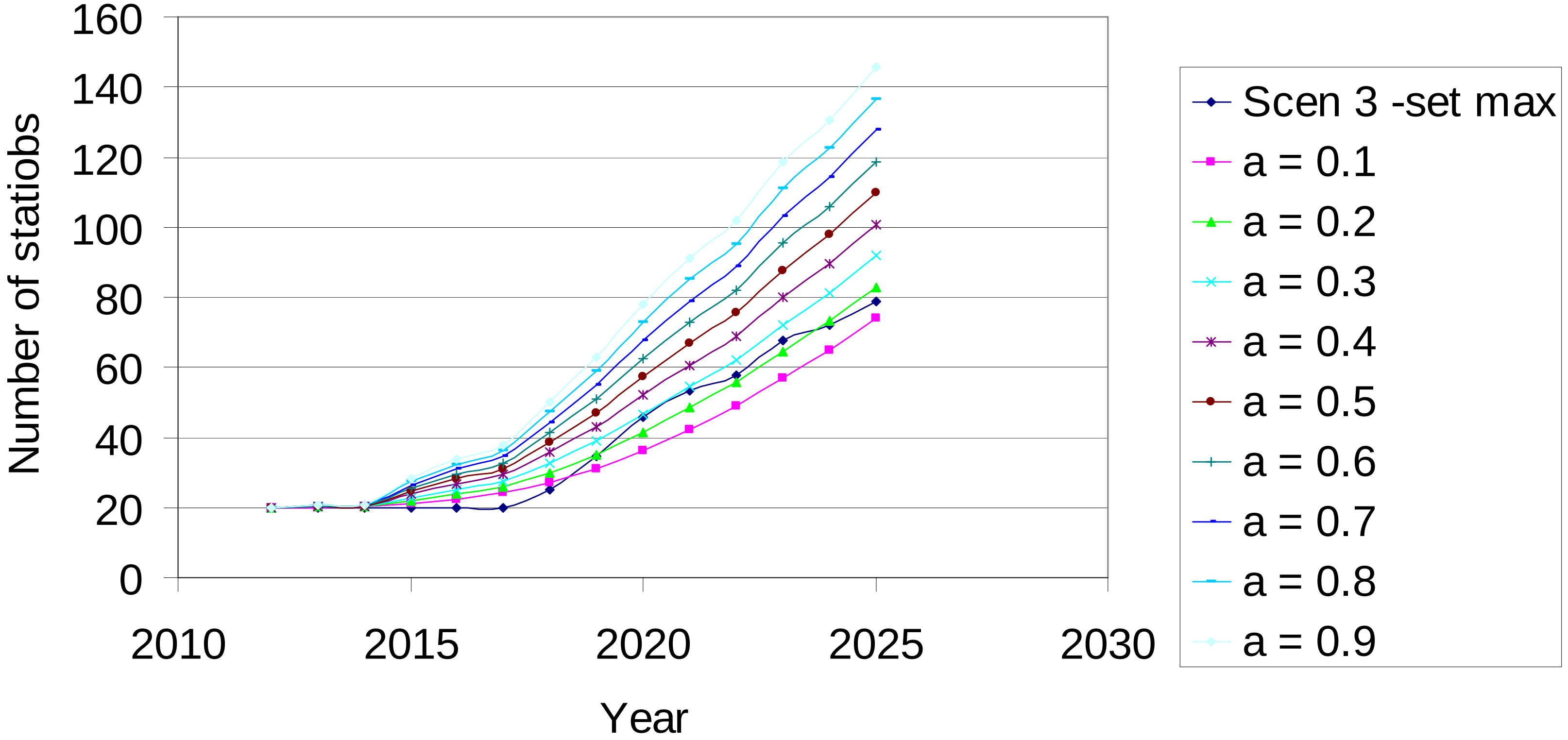
$f_{D,I}$ = total demand in year i

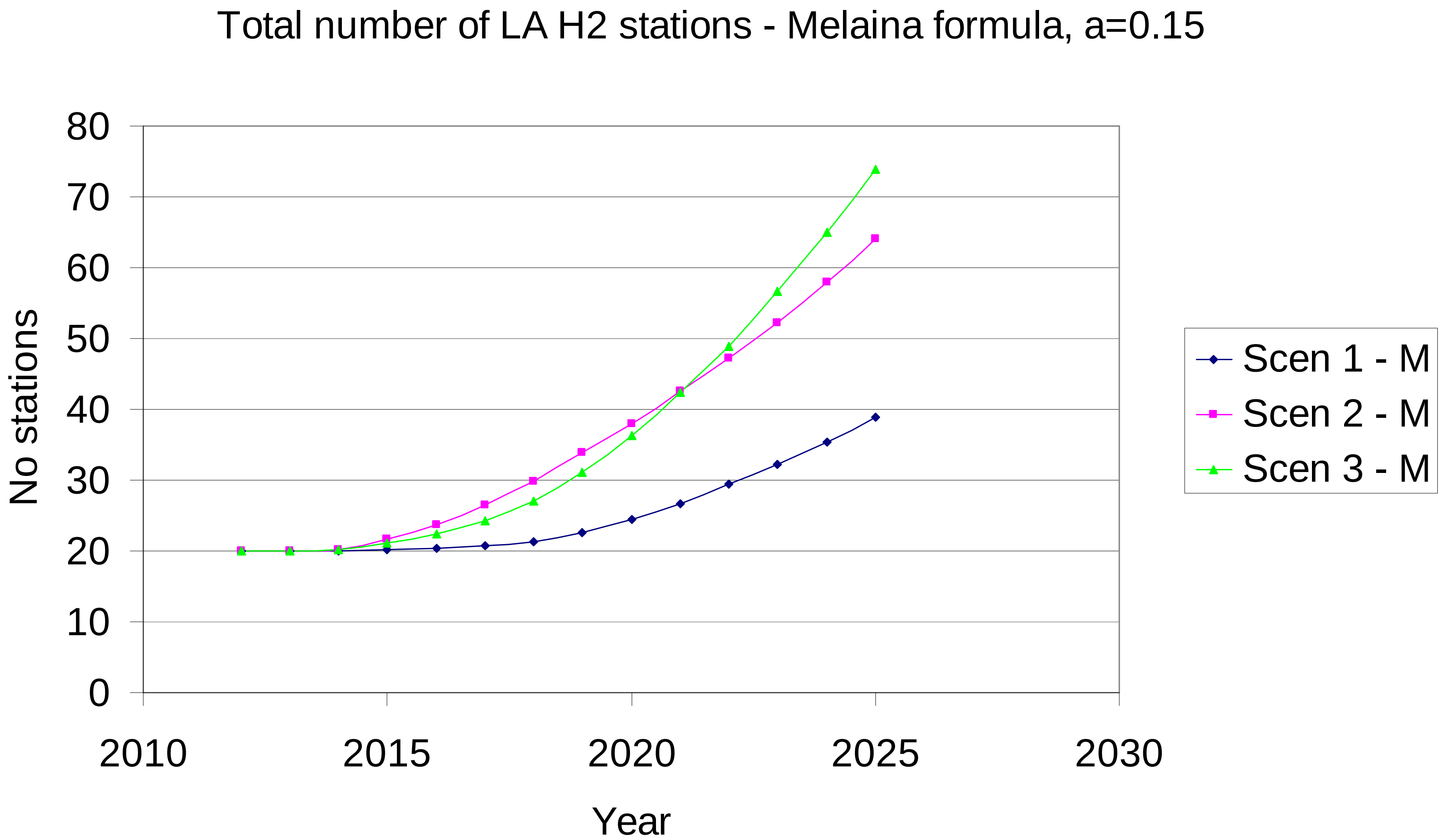
N_T = total number of stations at full market penetration

α= growth factor (= 0.1-0.9).

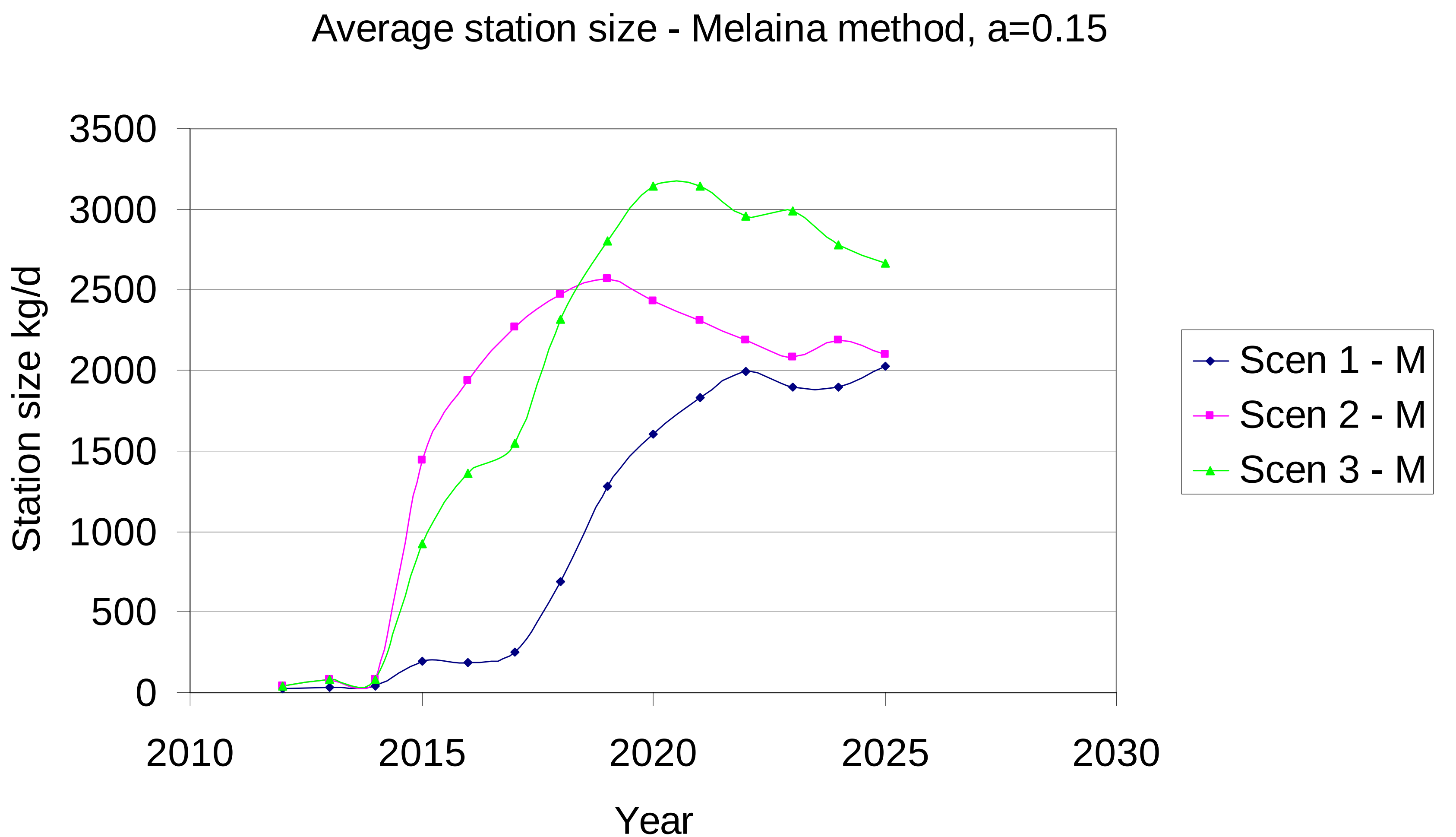
$$N_i = N_T \, \alpha \, f_{D,i} \left(1 - \frac{N_{i-1}}{N_T}\right) + N_{i-1}$$

Number of stations in LA for Scenario 3; estimated by various models





Total number of LA H2 stations - Melaina formula, a=0.15
No stations
80
70
60
50
40
30
20
10
0
2010
2015
2020
2025
2030
Year
Scen 1 - M
Scen 2 - M
Scen 3 - M



Average station size - Melaina method, a=0.15
3500
3000
2500
2000
1500
1000
500
0
Station size kg/d
2010
2015
2020
2025
2030
Year
Scen 1 - M
Scen 2 - M
Scen 3 - M

Consider range of station sizes

Mini	100 kg/d
Small	250 kg/d
Medium	1000 kg/d
Large	2500 kg/d
Super	5000 kg/d
Ultra	10,000 kg/d

Use results from GIS analysis of station H2 demand distribution, to estimate mix of station sizes over time

Future work: infrastructure cost evaluation

For various station sizes, select lowest cost supply alternatives:

- Onsite SMR
- Onsite electrolysis
- Central SMR (also depends on geog., and scale)
  - Compressed gas truck delivery
  - LH2 truck delivery
  - Pipeline delivery

Use “steady-state” cost results to guide scenario development

Scenarios for infrastructure deployment

- Divide period 2012->2025 into four 3-year build-out “phases”
- Constraints: supply always exceeds demand expected at end of current build out phase.
- Use steady-state cost results and distribution of station sizes to develop scenarios for each phase

Economic evaluation of Scenarios

- Estimate present value of costs over transition period 2012->2025
  - Capital costs
  - Operation costs
  - Count salvage costs for any equipment that is “retired”
  - Account for capital in place at 2025.
- Estimate levelized cost of H2 ($/kg) over transition period.