Application of STREET for Tri-Counties Hydrogen Readiness Plan

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Table of Contents

The Spatially and Temporally Resolved Energy and Environment Tool (STREET) was used to identify the top 20 gasoline stations in the Tri-County area based on several different sets of alternative vehicle sales registration data (IHS Automotive) that serve as proxy for fuel cell electric vehicles (FCEVs). Connectivity between northern California and southern California was also analyzed. Finally, these STREET results were compared to the Station Coverage Value given by the California Hydrogen Infrastructure Tool (CHIT). The CHIT Station Coverage Value is the ability of the proposed station to fill an identified gap in refueling coverage.

Methodology:

Three different sets of alternative vehicle sales registration data were used. Battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) combined with hybrid electric vehicles (HEVs), and BEVs combined with PHEVs and HEVs. These different set of alternative vehicle sales registration data allow comparison of different FCEV market proxy. The alternative vehicle sales registration data shows the number of a type of vehicle registered in a zip code tabulation area (ZCTA). This spatial resolution is too coarse, so another data set is combined with the alternative vehicle sales registration data, i.e., high resolution population data (1km x 1km). The population data used are LandScan Population density from Oak Ridge National Laboratory [1], [2]. Now using the combined alternative vehicle registration data and population data, a high enough spatial resolution exists to evaluate gasoline stations based on this high resolution combined data set, i.e., counting vehicles (demand points) in proximity.

The basic methodology for station siting based on demand points (vehicle proxy) is broken into three steps. First the Network Model is built including the roadways, the existing infrastructure, and the spatially distributed demand (demand points or FCEV proxy). Next, Location-Allocation algorithms are applied to the network model producing locations for stations based on the scenario parameters.

Network Model

Four datasets compose the Network Model: (1) the roadway network; (2) the existing refueling infrastructure which includes existing hydrogen refueling stations (in this case, only the station in Santa Barbara), and the existing gasoline stations which serve as candidate locations for expanding the network; and (3) the demand points that represent the FCEVs.

Roadway Network

The roadway network used comes from ESRI's database of streets in North America [3]. This network dataset includes speed limits of individual streets as well as classifications of what types of turns can be made at intersections throughout the network. This provides for usage of ESRI's Network Analyst toolset that provides implementation of the travel time algorithms leveraged for the analysis [4].

Existing Infrastructure (Existing Infrastructure and Candidate Sites)

Existing hydrogen refueling structure is modeled based on information from ARB's AB 8 Report as well as from the Governor's Office of Business and Economic Development (GOBIZ) [5], [6]. Existing gasoline refueling stations are chosen as the candidate locations for sites of future hydrogen fueling stations and were obtained from the Tri-Counties. Figure 2 shows a map of the locations of existing infrastructure.

Demand Points (Proxy FCEVs)

The demand points are derived from registrations of BEVs, HEVs and PHEVs in the Tri-Counties and LandScan Population density from Oak Ridge National Laboratory [1], [2]. The vehicle registrations are provided by IHS Automotive for Zip Code Tabulation Areas (ZCTAs). These registrations are distributed to LandScan cells (1km x 1km cell size) based on the cell's relative contribution to the population of the ZCTA using a weighted distribution methodology. This methodology assigns a weight to each LandScan cell based on its relative contribution to the population of the ZCTA in which its centroid lies.

$$Cell\ Weight = \frac{Cell\ Population}{ZCTA\ Population}$$

The final demand weight for each cell is the product of the cell weight and the number of HEV registrations in the ZCTA.

$$Demand\ Weight = ZCTA\ HEVs * Cell\ Weight = ZCTA\ HEVs * \frac{Cell\ Population}{ZCTA\ Population}$$

Finally, the LandScan cells are represented in the Network by the point location of their centroid in order to provide an exact location for the Network algorithms. The point locations combined with the underlying demand weights are referred to as *demand points*. Figure 3 shows the mapping of the weighted distribution methodology for the City of Santa Barbara.

Location-Allocation Algorithm

The stations are allocated using a Maximize Market Share algorithm in ArcGIS. This algorithm seeks to place a given number of stations to maximize the demand (i.e., FCEV proxy) on the stations. A service coverage needs to be prescribed. The service coverage is the area that is served by a station and can be defined by drive time or distance. In these analyses, drive time was used. Previous analyses [7] have shown that a 6 minute service coverage represents a tipping between an inconvenient refueling experience (driving more than 10 min to get to refueling station from house) and the current convenience of gasoline refueling (2-3 min from house to refueling station).

Six Minute Drive Time

The following analysis from [7] of past existing and planned hydrogen stations in the Santa Monica region (4 total) provide a maximum travel time from anywhere in the region to a hydrogen station in 10 minutes. The addition of just one more station (5 total) can drop this travel time down to 9 minutes. Two more stations (7 total) reduces the time to 7 minutes, and an additional station (8 total) reduces the travel time to 6 minutes. Two more (10 total) can reach coverage in just 5 minutes, and a final 9 additional stations (19 total) are required to reach 4 minute travel time in parity with the 126 existing gasoline stations. This trend is shown in Figure 1.

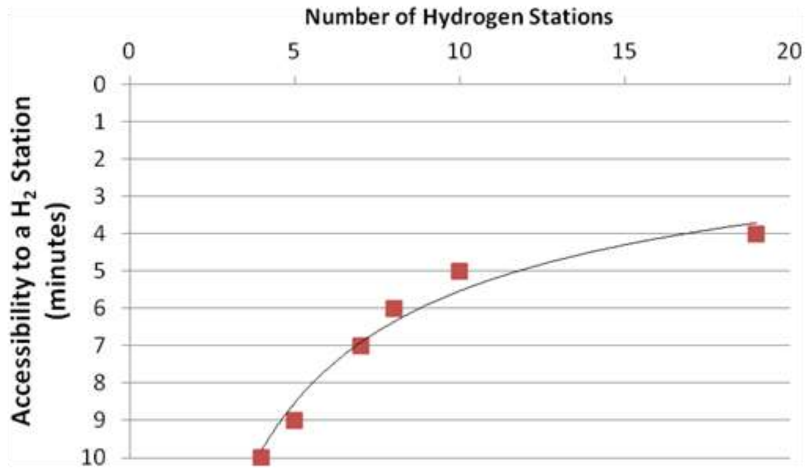

Figure 1 Decrease in maximum travel time to a hydrogen station in the Santa Monica region with increasing numbers of stations [7]

On examination of Figure 1, service coverage of 6 minutes appears to be a good compromise between parity with gasoline and minimization of infrastructure investment. With 126 existing gasoline stations in the Santa Monica region, 8 hydrogen stations represents just 6.3% of the total. This result matches well with previous research in the field of fueling infrastructure which indicate that 5% of gasoline fueling locations require alternative fuel in order to alleviate driver concerns about fuel availability [8], [9].

Figure 2 Existing Infrastructure (Gasoline and Hydrogen Stations) in Tri-Counties Area

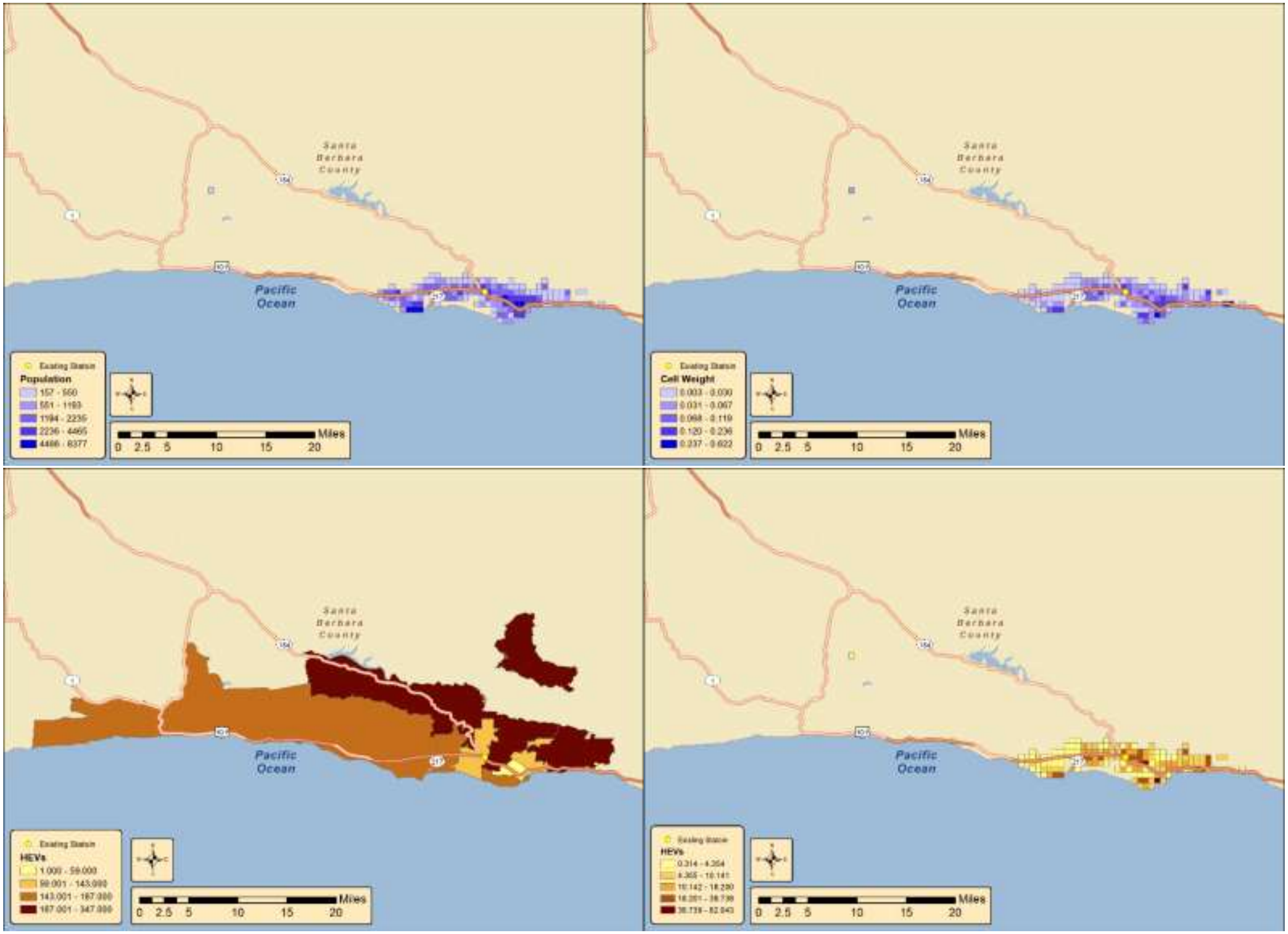

Figure 3 Weighted Distribution Methodology Example for Santa Barbara

Station Ranking

Once the station locations are allocated using the Maximize Market Share algorithm, they are ranked according to the total demand points (FCEV proxy) covered by a six minute drive time from the gasoline station. Because the Location-Allocation GIS tool applies heuristics on fringe cases, a more robust tool is used. This tool builds an Origin-Destination Cost Matrix (ODCM) for each station and all of the demand points in the stations' 6-minute service coverage, including all fringe cases. The tool has been custom adapted for usage by STREET in order to properly account for the covered demand points (FCEV proxy).

Results:

The results for the three different sets of alternative vehicle registration data sets used are shown in Figure 4 with the number of FCEV proxy covered and the California Hydrogen Infrastructure Tool (CHIT) coverage gap score shown in Table 1 (BEV as FCEV proxy), Table 2 (PHEV+HEV as FCEV proxy), and Table 3 (HEV+PHEV+BEV as FCEV proxy). Figure 4 allows comparison between using different data sets as FCEV proxy in siting hydrogen refueling stations. In general, there is not much difference between using the HEV+PHEV and HEV+PHEV+BEV data sets as FCEV proxy since the number of HEVs and PHEVs is so much larger than the BEVs. However, the BEVs as FCEV proxy is different than the other two data sets considered with more hydrogen stations being sited in San Luis Obispo county. For both the HEV+PHEV and HEV+PHEV+BEV as FCEV proxy cases, there are 13 stations located in Ventura county, 5 (4 additional) in Santa Barbara county, and 3 in San Luis Obispo county, but for the BEV as FCEV proxy case there are 11 located in Ventura county, 5 (4 additional) in Santa Barbara county, and 5 in San Luis Obispo county. This is a result of a proportionally higher occurrence of BEVs in San Luis Obispo county. In terms of ranking stations by FCEV proxy covered, there are also differences. The HEV+PHEV and HEV+PHEV+BEV as FCEV proxy cases result in the top 5 stations in terms of FCEV proxy covered being in Ventura county. However, the BEV as FCEV proxy case results in the top 5 stations being in Ventura and Santa Barbara counties with two in Ventura county and three in Santa Barbara county.

BEVs as FCEV Proxy

20 additional stations plus the existing La Cumbre station cover 738 of Tri-Counties' 868 BEVs (85%). 11 are located in Ventura county, 5 (4 additional) in Santa Barbara county, and 5 in San Luis Obispo county. Table 1 shows the FCEV proxy (as BEVs) covered within a 6 minute drive time from each station. The CHIT coverage gap score is also shown.

HEVs and PHEVs as FCEV Proxy

20 additional stations plus the existing La Cumbre station cover 6665 of Tri-Counties' 8355 HEVs & PHEVs (80%). 13 are located in Ventura county, 5 (4 additional) in Santa Barbara county, and 3 in San Luis Obispo county. Table 2 shows the FCEV proxy (as HEV+PHEVs) covered within a 6 minute drive time from each station. The CHIT coverage gap score is also shown.

BEVs, HEVs, and PHEVs as FCEV Proxy

20 additional stations plus the existing La Cumbre station cover 7386 of Tri-Counties' 9223 BEVs, HEVs, & PHEVs (80%). 13 are located in Ventura county, 5 (4 additional) in Santa Barbara county, and 3 in San Luis Obispo county. Table 3 shows the FCEV proxy (as HEV+PHEV+BEVs) covered within a 6 minute drive time from each station. The CHIT coverage gap score is also shown.

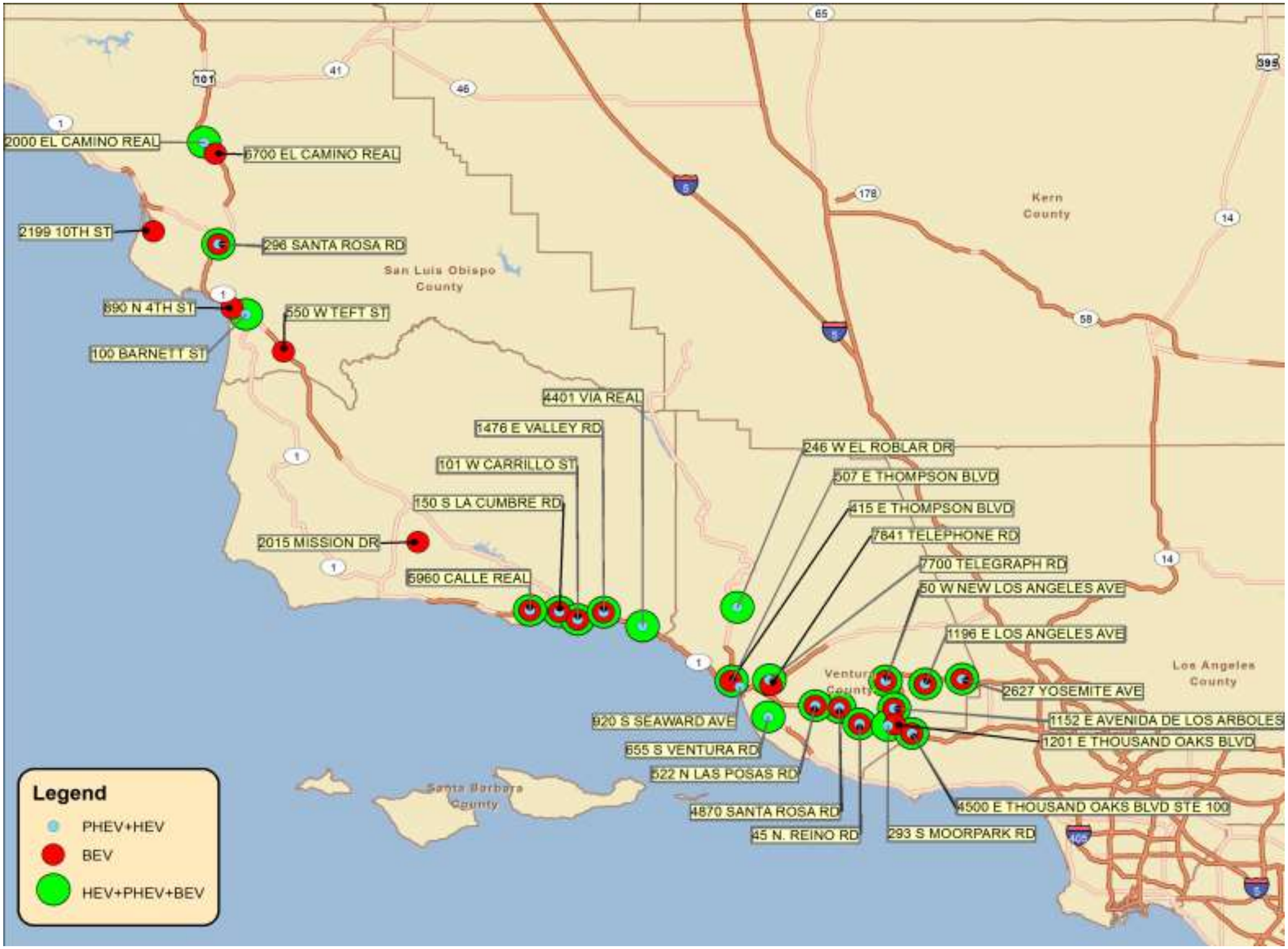

Figure 4: Siting of 20 additional Hydrogen stations (21 in total including the existing La Cumbre station in Santa Barbara) to the tri-county hydrogen refueling network using three different alternative vehicle registration datasets (BEV, HEV, and HEV+BEV)

Table 1: Tabulation of Maximize Market Share algorithm siting of 20 additional hydrogen stations based on BEVs as FCEV proxy ranked in order of FCEV proxy within 6 minute drive time (Note: 150 S La Cumbre Rd is an existing hydrogen station)

Street Name	City	County	Zip Code	BEVs Covered	CHIT Coverage Gap Score [x100]
1201 E THOUSAND OAKS BLVD	Thousand Oaks	Ventura County	91362	65	1.9224
1476 E VALLEY RD	Montecito	Santa Barbara County	93108	65	0.5375
45 N. REINO RD	Thousand Oaks	Ventura County	91320	60	1.7843
101 W CARRILLO ST	Santa Barbara	Santa Barbara County	93101	59	1.2389
150 S LA CUMBRE RD	Santa Barbara	Santa Barbara County	93105	57	0.2603
1152 E AVENIDA DE LOS ARBOLES	Thousand Oaks	Ventura County	91360	47	1.895
4500 E THOUSAND OAKS BLVD STE 100	Thousand Oaks	Ventura County	91362	45	1.8683
5960 CALLE REAL	Goleta	Santa Barbara County	93117	42	0.1546
1196 E LOS ANGELES AVE	Simi Valley	Ventura County	93065	42	1.1712
4870 SANTA ROSA RD	Camarillo	Ventura County	93012	36	0.8419
890 N 4TH ST	Pismo Beach	San Luis Obispo County	93449	34	0.4227
2627 YOSEMITE AVE	Simi Valley	Ventura County	93063	29	0.8417
296 SANTA ROSA RD	San Luis Obispo	San Luis Obispo County	93401	29	0.7755
50 W NEW LOS ANGELES AVE	Moorpark	Ventura County	93021	28	0.349
7841 TELEPHONE RD	San Buenaventura (Ventura)	Ventura County	93004	23	1.3381
522 N LAS POSAS RD	Camarillo	Ventura County	93010	20	0.9674
415 E THOMPSON BLVD	San Buenaventura (Ventura)	Ventura County	93001	15	0.3905
2015 MISSION DR	Solvang	Santa Barbara County	93463	13	0.1949
2199 10TH ST	Los Osos	San Luis Obispo County	93402	10	0.3924
6700 EL CAMINO REAL	Atascadero	San Luis Obispo County	93422	10	0.1791
550 W TEFT ST	Nipomo	San Luis Obispo County	93444	8	0.1454

Table 2: Tabulation of Maximize Market Share algorithm siting of 20 additional hydrogen stations based on HEVs+PHEVs as FCEV proxy ranked in order of FCEV proxy within 6 minute drive time (Note: 150 S La Cumbre Rd is an existing hydrogen station)

Street Name	City	County	Zip Code	HEV+PHEVs Covered	CHIT Coverage Gap Score [x100]
1196 E LOS ANGELES AVE	Simi Valley	Ventura County	93065	636	1.1712
45 N. REINO RD	Thousand Oaks	Ventura County	91320	552	1.7843
293 S MOORPARK RD	Thousand Oaks	Ventura County	91361	540	1.451
1152 E AVENIDA DE LOS ARBOLES	Thousand Oaks	Ventura County	91360	520	1.895
4500 E THOUSAND OAKS BLVD STE 100	Thousand Oaks	Ventura County	91362	478	1.8683
101 W CARRILLO ST	Santa Barbara	Santa Barbara County	93101	447	1.2389
4870 SANTA ROSA RD	Camarillo	Ventura County	93012	384	0.8419
150 S LA CUMBRE RD	Santa Barbara	Santa Barbara County	93105	377	0.2603
2627 YOSEMITE AVE	Simi Valley	Ventura County	93063	317	0.8417
50 W NEW LOS ANGELES AVE	Moorpark	Ventura County	93021	311	0.349
1476 E VALLEY RD	Montecito	Santa Barbara County	93108	286	0.5375
522 N LAS POSAS RD	Camarillo	Ventura County	93010	283	0.9674
5960 CALLE REAL	Goleta	Santa Barbara County	93117	273	0.1546
100 BARNETT ST	Arroyo Grande	San Luis Obispo County	93420	241	0.2215
7700 TELEGRAPH RD	San Buenaventura (Ventura)	Ventura County	93004	225	1.5554
296 SANTA ROSA RD	San Luis Obispo	San Luis Obispo County	93401	184	0.7755
920 S SEAWARD AVE	San Buenaventura (Ventura)	Ventura County	93001	179	0.7797
655 S VENTURA RD	Oxnard	Ventura County	93030	128	2.1266
2000 EL CAMINO REAL	Atascadero	San Luis Obispo County	93422	111	0.1791
246 W EL ROBLAR DR	Meiners Oaks	Ventura County	93023	100	0.2665
4401 VIA REAL	Carpinteria	Santa Barbara County	93013	94	0.5422

Table 3: Tabulation of Maximize Market Share algorithm siting of 20 additional hydrogen stations based on HEV+PHEV+BEVs as FCEV proxy ranked in order of FCEV proxy within 6 minute drive time (Note: 150 S La Cumbre Rd is an existing hydrogen station)

Street Name	City	County	Zip Code	HEV+PHEV+BEVs Covered	CHIT Coverage Gap Score [x100]
1196 E LOS ANGELES AVE	Simi Valley	Ventura County	93065	678	1.1712
45 N. REINO RD	Thousand Oaks	Ventura County	91320	607	1.7843
293 S MOORPARK RD	Thousand Oaks	Ventura County	91361	596	1.451
1152 E AVENIDA DE LOS ARBOLES	Thousand Oaks	Ventura County	91360	571	1.895
4500 E THOUSAND OAKS BLVD STE 100	Thousand Oaks	Ventura County	91362	534	1.8683
101 W CARRILLO ST	Santa Barbara	Santa Barbara County	93101	505	1.2389
150 S LA CUMBRE RD	Santa Barbara	Santa Barbara County	93105	434	0.2603
4870 SANTA ROSA RD	Camarillo	Ventura County	93012	419	0.8419
1476 E VALLEY RD	Montecito	Santa Barbara County	93108	350	0.5375
2627 YOSEMITE AVE	Simi Valley	Ventura County	93063	346	0.8417
50 W NEW LOS ANGELES AVE	Moorpark	Ventura County	93021	339	0.349
5960 CALLE REAL	Goleta	Santa Barbara County	93117	315	0.1546
522 N LAS POSAS RD	Camarillo	Ventura County	93010	303	0.9674
100 BARNETT ST	Arroyo Grande	San Luis Obispo County	93420	275	0.2215
7700 TELEGRAPH RD	San Buenaventura (Ventura)	Ventura County	93004	266	1.5554
296 SANTA ROSA RD	San Luis Obispo	San Luis Obispo County	93401	213	0.7755
507 E THOMPSON BLVD	San Buenaventura (Ventura)	Ventura County	93001	173	0.3905
655 S VENTURA RD	Oxnard	Ventura County	93030	136	2.1266
2000 EL CAMINO REAL	Atascadero	San Luis Obispo County	93422	118	0.1791
246 W EL ROBLAR DR	Meiners Oaks	Ventura County	93023	106	0.2665
4401 VIA REAL	Carpinteria	Santa Barbara County	93013	102	0.5422

STREET Compared to CHIT

The CHIT Station Coverage Value is the ability of the proposed station to fill an identified gap in refueling coverage. Figure 5 shows the STREET suggested hydrogen station sites on top of the CHIT Station Coverage Values. The CHIT Station Coverage Values are also shown for each suggested STREET stations in Table 1 through Table 3.

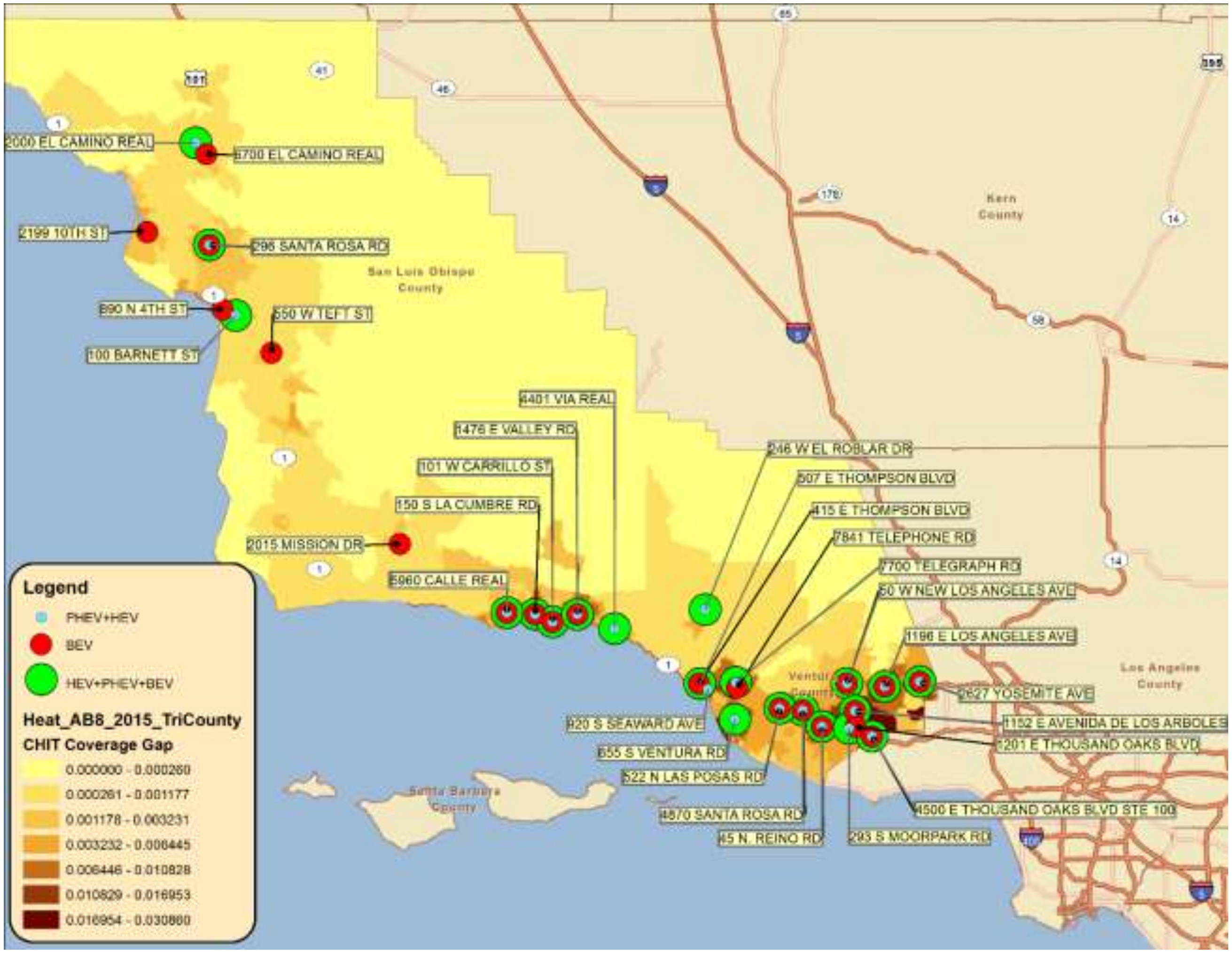

Figure 5 Suggested STREET hydrogen refueling stations overlaid on top of the CHIT Station Coverage Value map

Figure 6 CHIT Station Coverage Value map

Connectivity

Figure 7 and Figure 8 show the existing and potential future connectivity along Highway 101 provided by the existing Santa Barbara hydrogen station on 150 S La Cumbre Rd and the suggested STREET hydrogen stations, respectively.

Figure 7 Current connectivity between northern and southern California along Highway 101 provided by the existing Santa Barbara hydrogen station on 150 S La Cumbre Rd.

Figure 8 Future possible connectivity between northern and southern California along Highway 101 provided by suggested STREET hydrogen stations

References

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Appendix

Figure 9 Distribution of BEVs after the application of the Weighted Distribution Method described in Demand Points (Proxy FCEVs) section

Figure 10 Distribution of HEVs+PHEVs after the application of the Weighted Distribution Method described in Demand Points (Proxy FCEVs) section

Figure 11 Distribution of HEVs+PHEVs+BEVs after the application of the Weighted Distribution Method described in Demand Points (Proxy FCEVs) section