UCDAVIS

SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

An Institute of Transportation Studies Program

Electricity and Plug-in Vehicles in CA

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IEPR Electricity System Needs in 2030

August 19, 2013

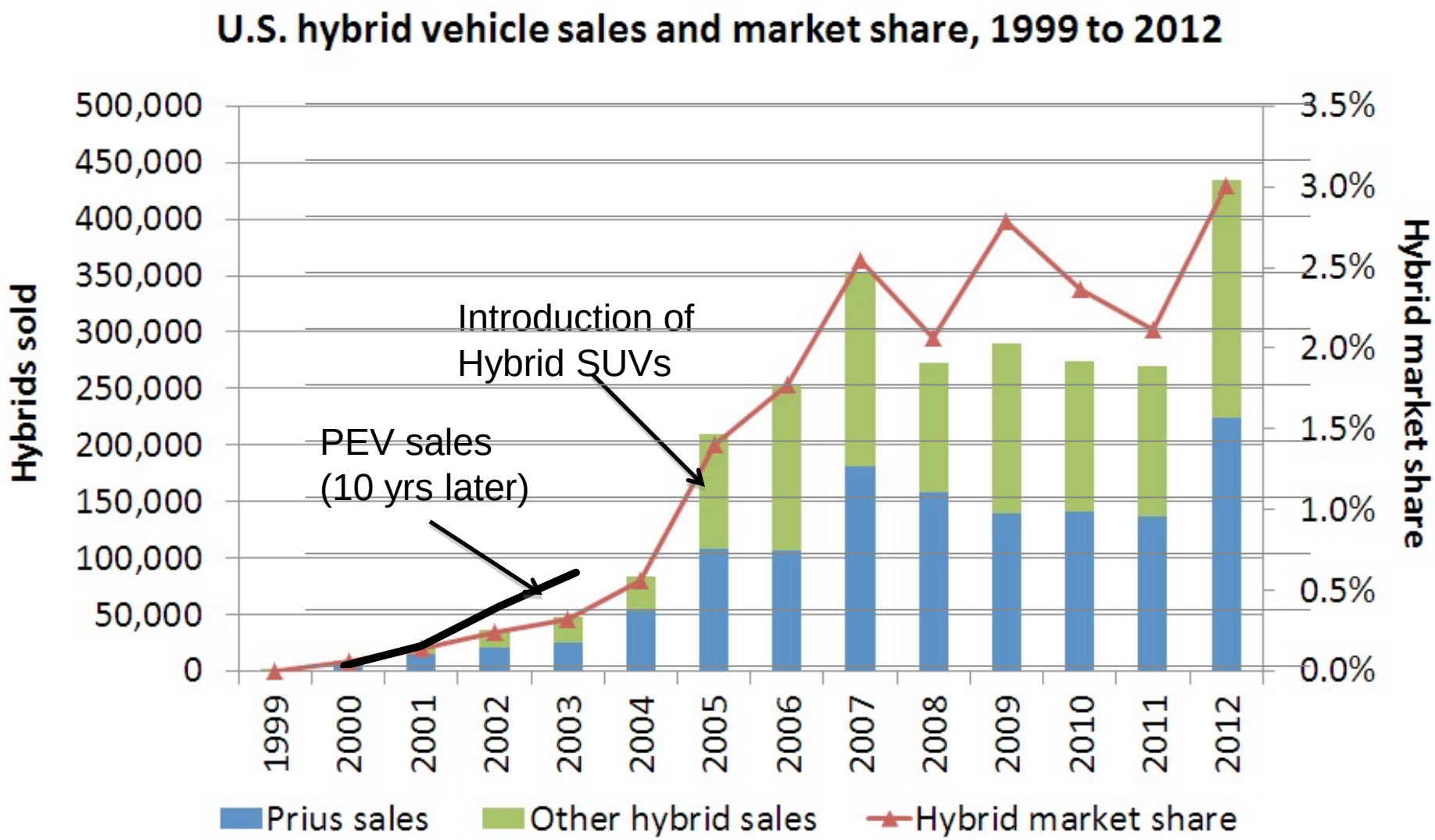
NextSTEPS research program

- Research consortium focusing on analysis of alternative fuels and vehicles, scenarios and transitions

	Hydrogen Fuel Cell Vehicles	**Biofuels** Bio-ICE Vehicles 2nd Gen Biofuels	**Electricity** Battery-electric Plug-in hybrids	**Fossil Fuels** BAU ***Natural Gas*** Low-carbon fuels (incl. ***CCS***)
Transition Dynamics		- Consumer Demand & Behavior - Innovation & Business Strategy		
Models & Analyses		- Infrastructure System Analysis - Env./Energy/Econ. Cost Analyses - Vehicle Technology Evaluation - Mobility, VMT, Travel Behavior		
Policy Analysis		- Market instruments - Fuel requirements - Sustainability standards		

Integrative Scenarios & Transition Strategies

Current Context: HEV and PEV sales



mnordan.com | Sources: DOE Alternative Fuels Data Center, HybridCars.com.

Plug-in Electric Vehicle (PEV) Adoption

- Initial adoption rates have been pretty good
  - Exceeds hybrid adoption rate in 2000s for first 3 years
- Hybrids saw a big jump in the 2004-2005 timeframe
  - Introduction of Gen2 Prius and SUVs (Escape, RX400h, Highlander)
  - Can PEVs keep up their momentum?
    - Model diversity is important and PEVs have many more models than hybrids (but trucks/SUVs will be an issue)

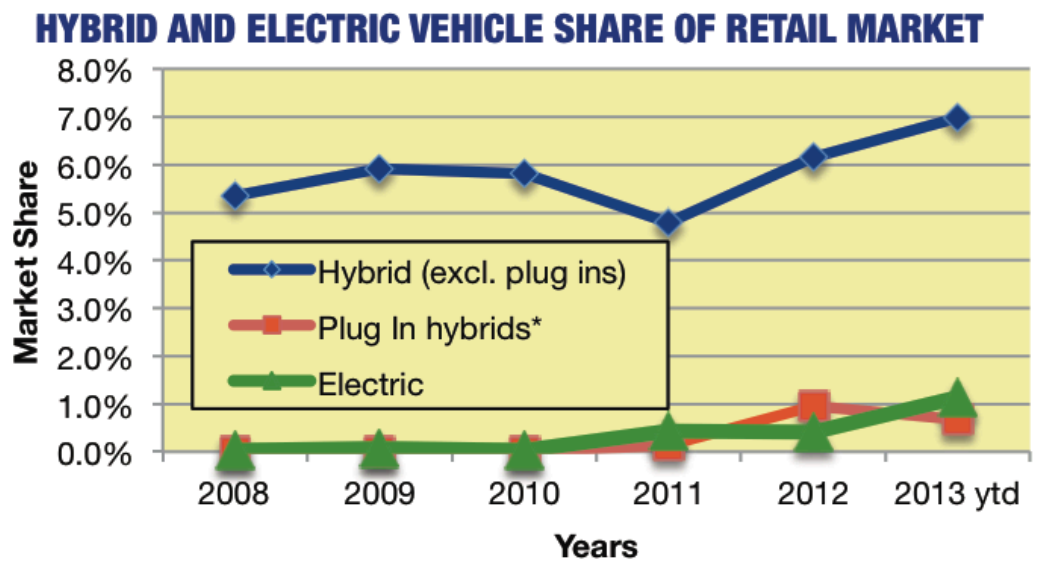
Hybrids	Cars	Truck/SUV
2000	2	0
2005	4	4
2010	16	13
2012	27	13

PEVs	Cars	Truck/SUV
2011	2	0
2012	8	1
2013	13	1

- Home-based charging infrastructure is a challenge
  - 50% of Californians have convenient access to charging at home
  - In cities, the number can be significantly lower (SF ~16%)

PEVs in California

- ~39% of US PEV and ~23% of US HEV sales are in CA with 11% of population
  - 45K sold through June 2013



HYBRID AND ELECTRIC VEHICLE RETAIL REGISTRATIONS AND MARKET SHARE					
	2009	2010	2011	2012	YTD '13 thru June
Hybrid regs. (excl. plug ins)	61292	64211	58563	94238	59330
Hybrid share (excl. plug ins)	5.9%	5.8%	4.8%	6.2%	7.0%
Plug in hybrid regs.*	0	97	1662	14536	5736
Plug in hybrid share	0.0%	0.0%	0.1%	1.0%	0.7%
Electric regs.	772	300	5302	6197	9708
Electric share	0.1%	0.0%	0.4%	0.4%	1.1%

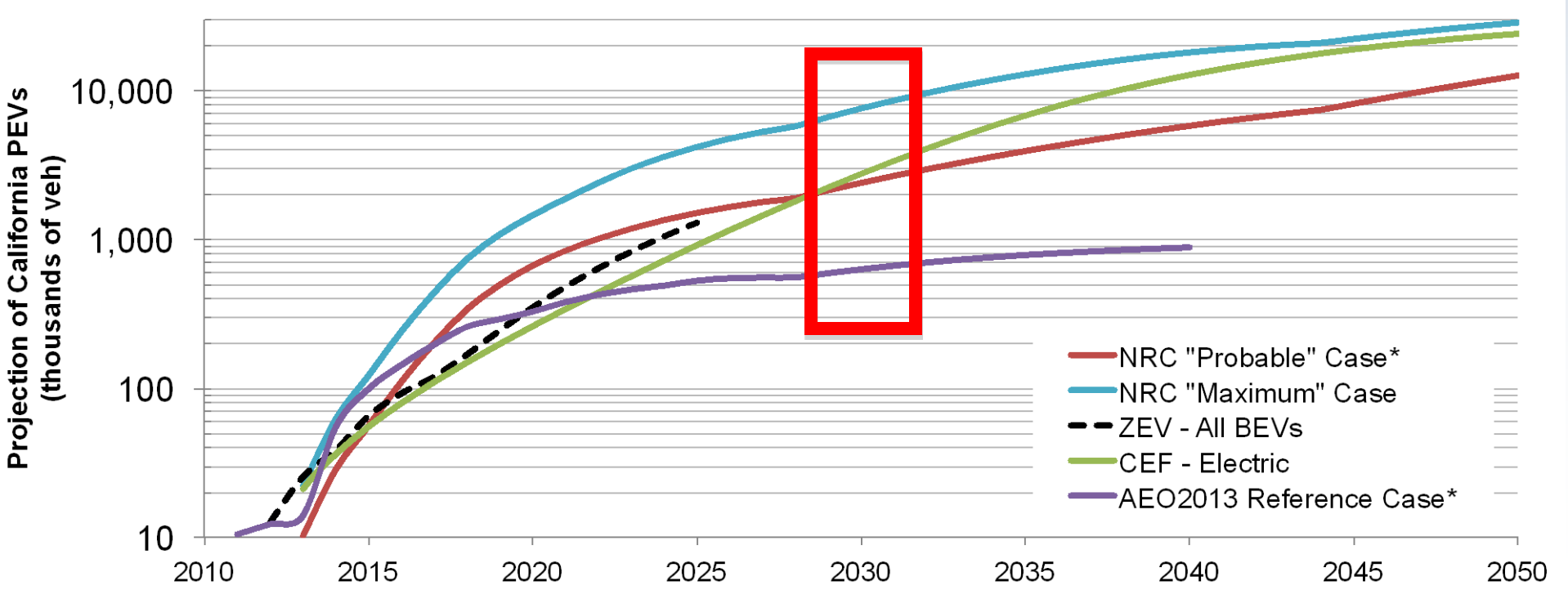
Plug in vehicle charging impacts

- Electricity system and emissions impact
  - How many vehicles will there be?
  - Depends on timing of charging, magnitude of charging demand and resources on the grid
- Electricity demand
  - 1 million BEVs (12,000 mi, 0.35 kWh/mi) would add ~1% to 2030 CA electricity demand
  - PHEVs use less energy based upon utility factor (function of battery size, driving patterns, charging availability)
- Charging demand
  - PEVs can be a flexible, supply following demand.
  - Vehicles are parked 95% of the time
  - Public charging infrastructure
  - Dumb vs smart charging
  - Utility incentives

Future Projections of PEVs

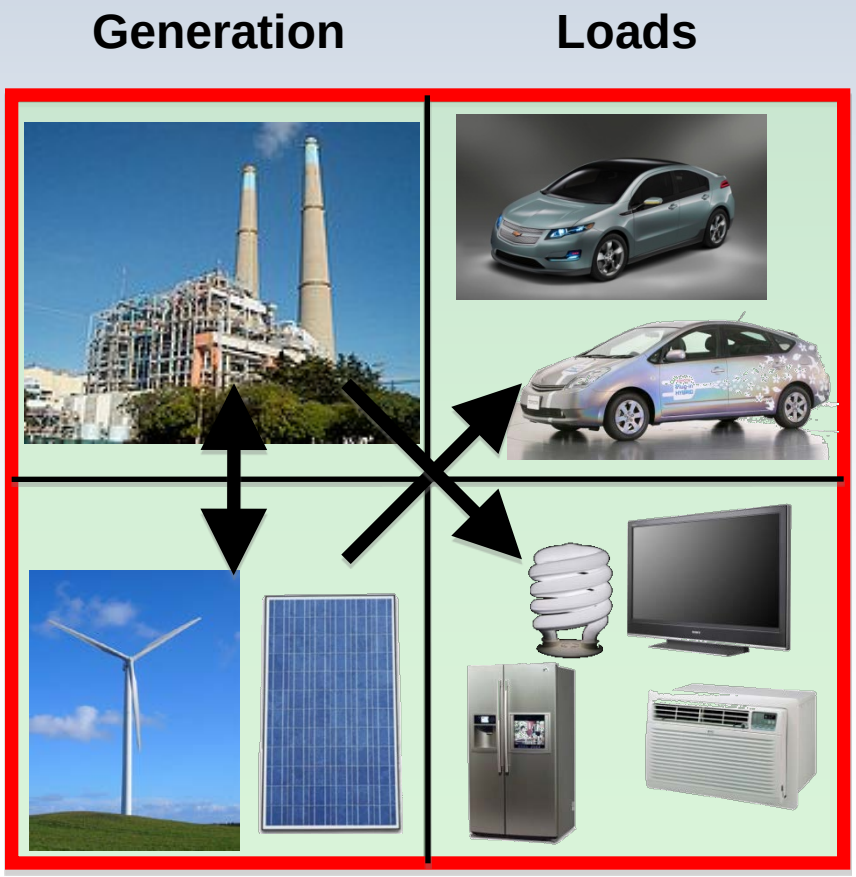
		All BEVs	PHEV/BEV Mix
• NRC (2011) – Maximum case in **2030**:	7.6M	35TWh (10%)	24TWh (7%)
• CEF (2011) – High electrification	2.8M	13TWh (4%)	9TWh (3%)
• NRC (2011) – Probable case	2.4M	11TWh (3%)	8TWh (2%)
• ZEV mandate (2025)	1.3M	6TWh (2%)	4TWh (1%)
• AEO (2013) – Reference case	0.6M	3TWh (1%)	2TWh (<1%)

- CEC's California Energy Demand (2012-22) estimated 2-7 TWh in 2022, *extrapolated to 5 – 13 TWh in 2030*.

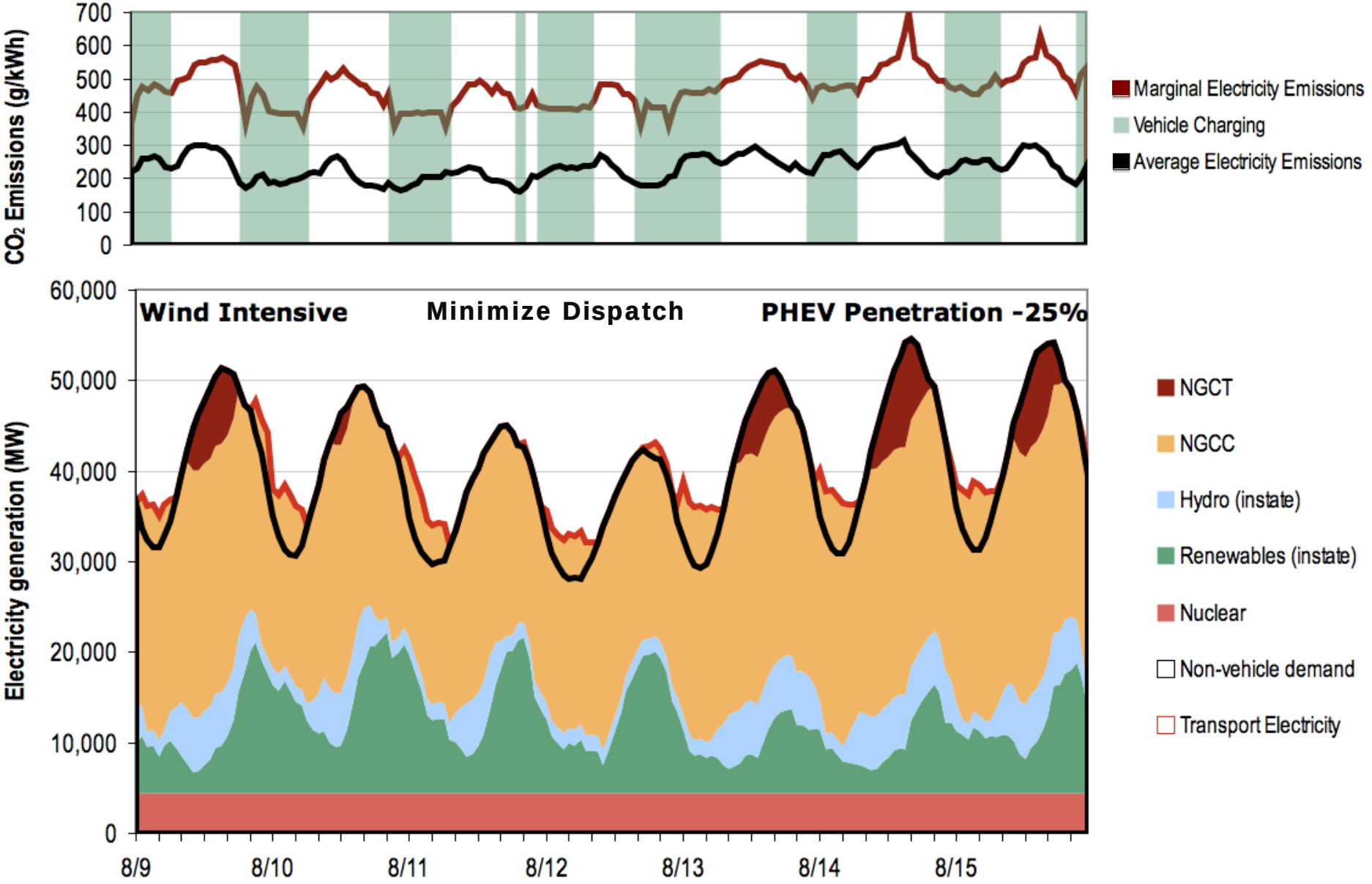


Vehicle Charging – Timing

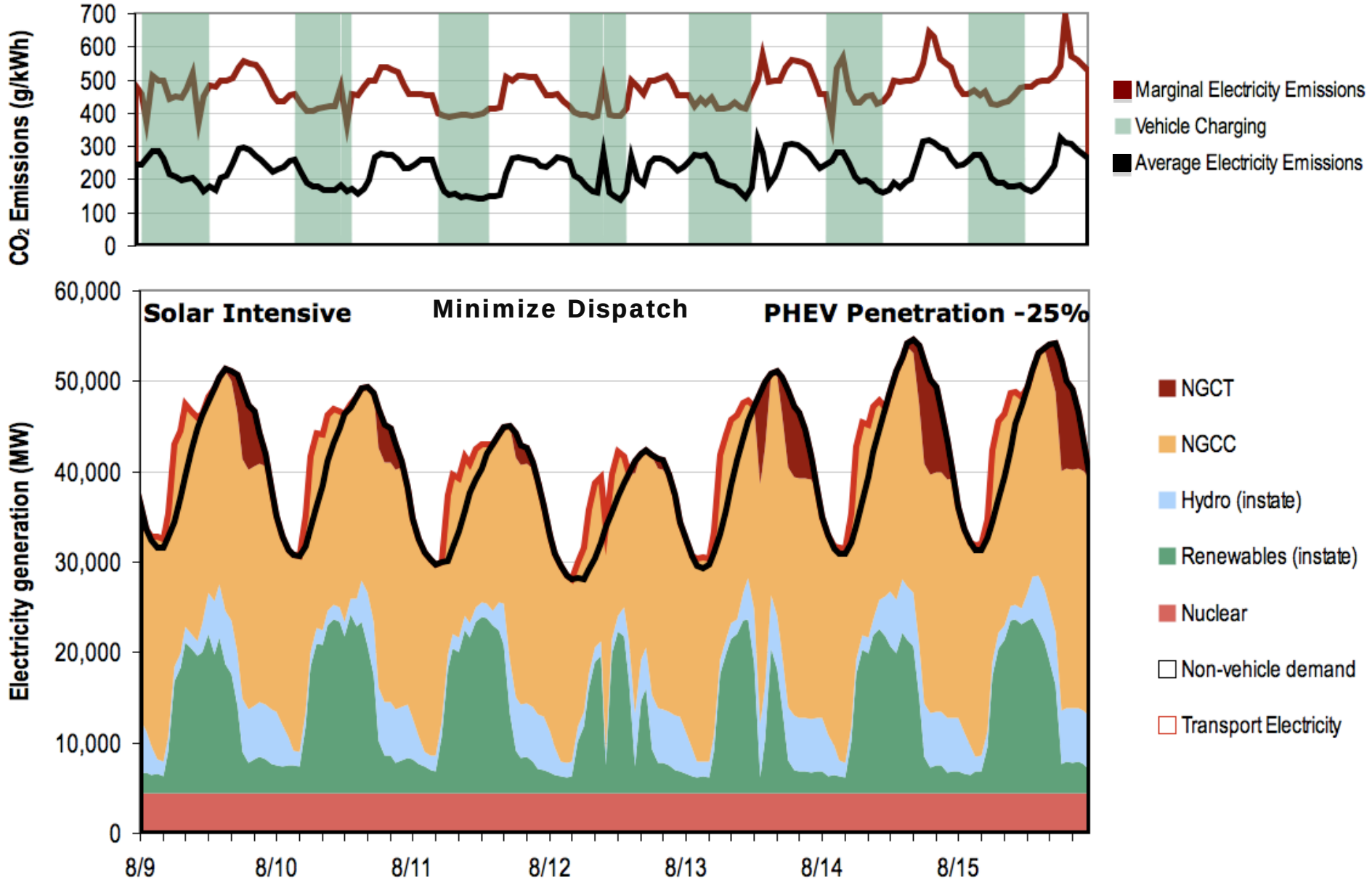
- Grid elements can be defined as *Active* or *Passive*
- Current system: active generation serving passive loads
- Growth of passive generation
  - Wind
  - Solar photovoltaic
  - Solar thermal
- Active ("smart") loads
  - Flexible PEV charging
  - Grid storage
- Grid simulation using LEDGE-CA
  - 2030 grid
  - 25% PEV penetration
  - 20,000 GWh annual
  - ~6% of total elec. demand
  - Smart charging



Results – Wind Intensive



Results – Solar Intensive



Charging Profile (MW)

Min Dispatch – Wind Intensive - 25% PHEVs

MD - Wind - 25%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
0	3775	3183	3249	3303	1901	2942	3982	3799	3147	3416	3239	2795	3229
1	4870	4571	4481	4707	3483	4984	5416	5243	4509	4842	4272	4242	4636
2	5415	5189	5166	5377	4904	5755	6178	5869	5253	5489	5129	5348	5425
3	5311	5575	5584	5196	5878	5861	6126	5949	5586	6070	5605	5796	5714
4	4799	4929	4634	4352	5570	5207	5444	5240	5218	5798	4645	5079	5080
5	3248	3384	3146	3169	6101	4803	4480	3931	4081	3985	3300	3557	3938
6	695	1178	1753	1713	4394	2299	2076	2451	2472	2060	1437	1588	2017
7	665	509	556	624	2231	915	758	614	1757	1128	657	1287	979
8	382	287	304	272	751	300	111	220	1015	501	429	413	415
9	171	151	87	127	137	69	1	0	273	194	198	147	129
10	90	59	117	111	78	0	0	0	7	105	151	96	68
11	68	51	73	105	208	0	0	0	3	11	108	148	65
12	43	89	4	159	109	0	0	0	4	12	169	216	67
13	142	199	27	227	110	0	0	0	0	107	208	494	126
14	481	173	173	183	57	0	0	0	0	167	370	881	208
15	764	372	447	278	106	14	0	0	0	105	434	1248	315
16	397	165	839	556	130	8	0	0	0	34	185	598	244
17	105	63	642	476	102	46	0	9	0	38	109	144	145
18	55	51	241	441	29	112	0	29	0	34	170	123	107
19	0	0	384	538	39	181	0	55	43	54	107	179	132
20	100	5	334	540	22	170	14	122	65	28	252	242	158
21	121	101	641	339	0	291	208	407	99	126	502	220	255
22	500	395	1178	948	15	635	496	994	500	319	947	375	609
23	1728	1792	2242	2105	407	1596	1844	2461	1305	1808	2077	1395	1729
Daily Avg	1414	1353	1513	1494	1532	1508	1547	1558	1472	1518	1446	1525	1491

Min Dispatch – Solar Intensive - 25% PHEVs

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
360	706	348	216	0	0	24	0	128	421	153	63	198
699	1373	692	332	60	23	129	104	279	774	397	339	428
919	1659	919	477	283	190	407	471	534	1138	683	673	691
990	1820	1041	525	410	280	618	758	713	1344	796	807	837
693	1509	857	366	355	197	536	663	518	1148	528	516	653
285	783	489	782	4209	5088	4379	2439	304	506	116	127	1633
40	328	2135	3599	6607	7518	6801	7049	5277	1579	192	7	3445
991	1347	3782	5052	7252	7238	7172	7563	7015	4726	3138	1484	4748
3449	2288	4303	4632	5783	5836	5911	6876	6491	5246	4239	3233	4874
4031	2983	3824	4145	3888	3932	4574	5372	5314	4903	4942	3949	4329
4239	3781	3583	3290	2885	2307	2848	3012	3585	4389	4840	4521	3606
3692	3364	3242	3173	1762	1157	1677	1893	2521	3733	4281	4919	2949
4830	2865	2439	2652	1203	881	1008	791	1326	2698	4090	5144	2493
3627	2924	3298	2741	802	490	530	404	886	2230	3170	5004	2173
2798	2173	2539	2219	669	267	308	0	378	1188	2243	3843	1550
2222	1954	2014	1447	438	320	155	0	60	279	894	1983	976
0	447	709	196	156	250	54	0	0	0	0	0	149
0	0	0	0	0	199	0	0	0	0	0	0	16
0	0	0	0	0	14	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
61	168	87	0	0	0	0	0	5	127	0	0	37
1414	1353	1513	1494	1532	1508	1547	1558	1472	1518	1446	1525	1491

Marginal Vehicle Emissions (gCO2/kWh)

Min Dispatch – Wind Intensive - 25% PHEVs

Wind - Min Dispatch - 25%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
0	454	436	392	371	377	378	389	425	464	451	417	425	414
1	448	433	390	368	372	371	385	425	457	437	406	418	409
2	444	427	391	368	374	369	382	424	454	434	407	412	406
3	444	426	391	370	371	368	383	423	451	432	406	412	406
4	448	429	395	370	371	369	384	426	453	433	408	415	408
5	453	441	394	374	369	369	386	430	461	447	416	420	408
6	462	437	391	375	374	377	388	425	467	465	417	431	404
7	477	454	400	376	382	384	398	428	468	456	424	445	398
8	484	467	417	392	397	405	420	456	479	483	446	448	403
9	491	476	433	412	412	430	446	472	485	482	456	464	410
10	491	479	441	422	416	447	466	489	492	490	462	462	394
11	490	474	446	424	436	461	484	505	496	493	465	467	393
12	481	472	444	426	443	468	495	515	503	498	463	461	389
13	474	469	434	423	449	470	501	526	511	503	459	453	401
14	474	472	428	418	451	470	501	535	513	508	452	447	413
15	473	473	423	415	448	468	495	547	513	514	447	441	412
16	478	472	421	404	448	466	484	547	512	516	452	443	404
17	493	483	421	397	450	458	469	529	515	519	460	458	394
18	503	490	419	394	439	441	444	513	520	520	464	465	399
19	508	490	422	397	437	426	424	482	515	514	459	473	408
20	509	488	429	393	440	420	417	461	507	511	458	471	411
21	498	478	417	392	435	410	409	460	499	499	447	463	411
22	476	465	407	391	416	395	405	445	490	467	435	449	411
23	457	450	400	380	391	385	395	436	468	462	422	443	418
Daily Avg	446	431	392	368	371	369	384	425	454	438	407	416	408

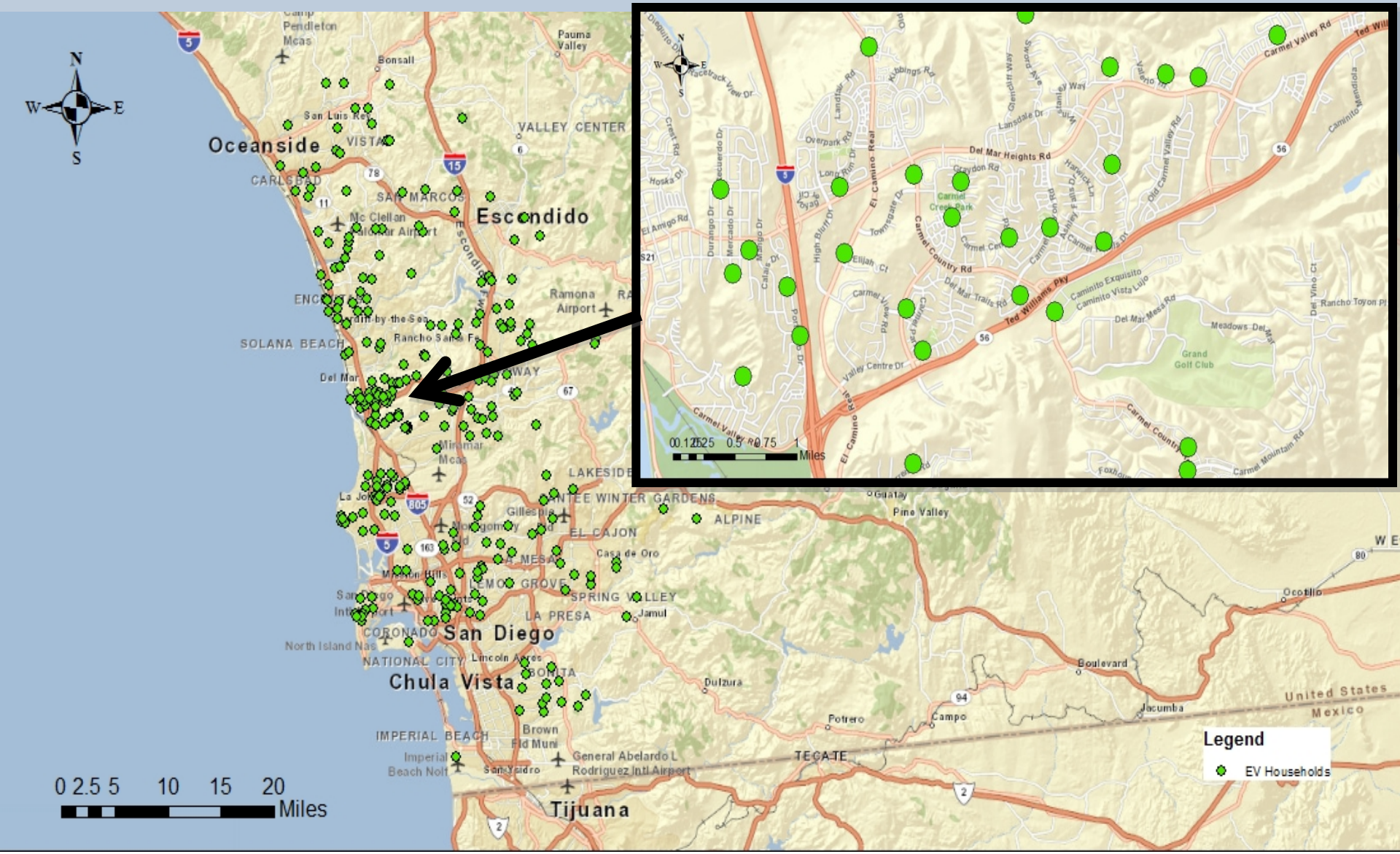
Min Dispatch – Solar Intensive - 25% PHEVs

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
467	454	422	401	415	428	431	463	464	469	452	467	459
443	445	419	395	394	404	410	442	456	450	432	443	448
438	439	431	393	390	395	404	443	460	435	420	433	442
439	435	420	399	390	392	405	443	458	427	415	431	441
439	445	423	399	396	399	408	458	459	427	421	428	444
466	453	443	400	389	388	398	437	453	442	444	453	409
487	462	407	385	380	380	392	416	424	431	435	474	399
430	427	407	381	379	382	394	414	419	419	421	430	398
424	427	409	384	383	385	396	419	413	418	415	423	399
420	431	414	389	387	390	399	425	424	420	403	422	401
423	429	402	392	388	394	404	430	424	424	405	417	402
424	426	409	394	392	388	413	421	437	428	408	412	402
415	434	418	394	391	399	407	442	437	425	402	414	401
423	437	412	394	403	396	424	449	442	435	416	413	402
433	440	415	394	401	412	428	465	453	445	413	420	402
431	449	405	382	408	418	433	470	451	460	414	424	405
491	446	400	385	421	435	448	487	477	501	487	488	401
505	502	448	447	453	457	474	507	499	521	501	504	395
521	509	488	461	487	483	498	545	533	542	515	517	352
523	512	494	469	500	505	512	576	540	543	517	522	518
527	516	496	469	507	518	526	557	537	537	516	525	519
521	510	481	468	507	514	522	540	528	532	506	523	513
508	501	450	446	492	501	503	523	508	517	497	511	496
484	476	422	417	451	466	469	491	476	492	475	492	469
416	419	400	383	382	384	395	420	422	417	406	410	404

PEVs and Electric Grid

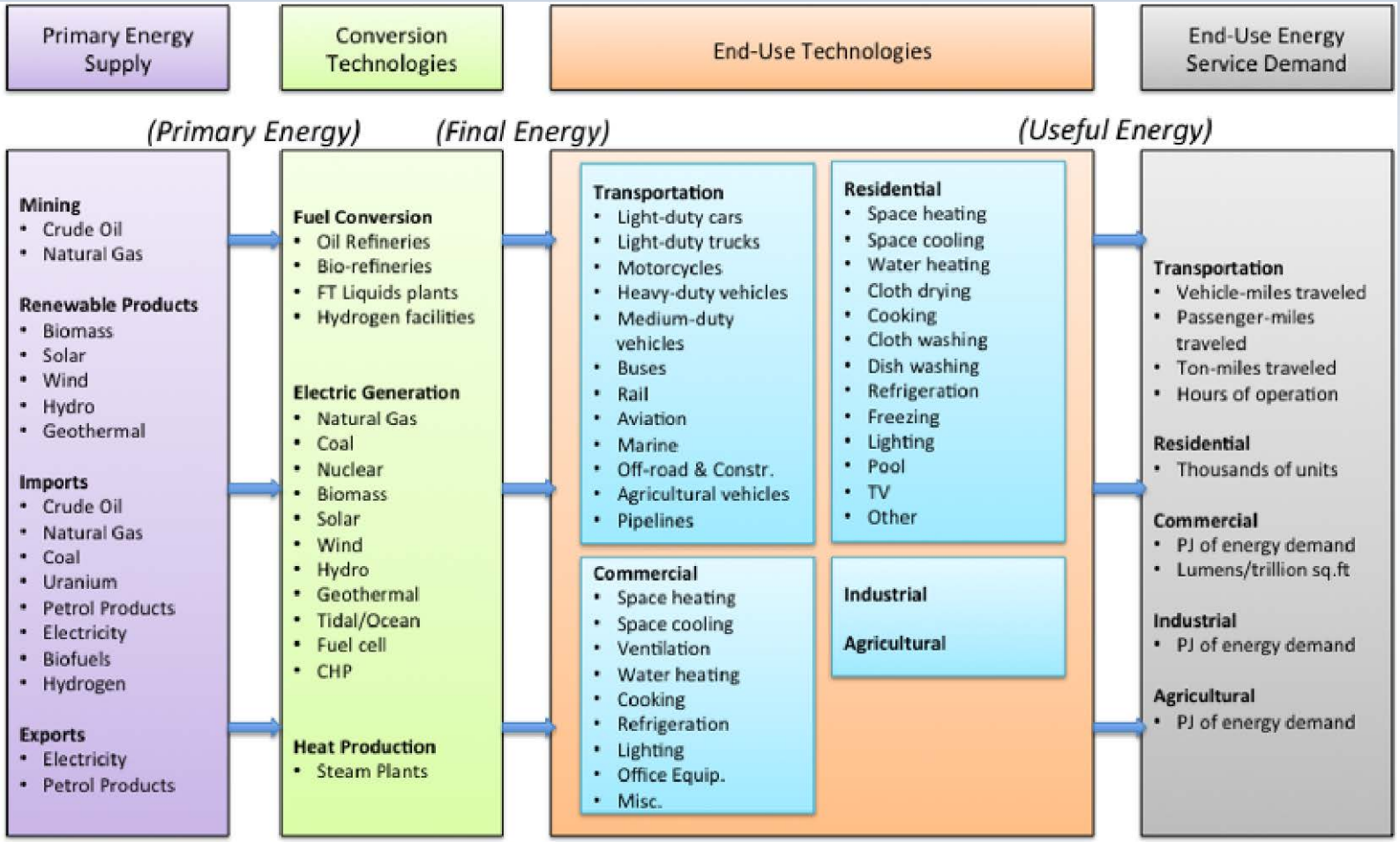
- V1G – (one way) flexible charging
- V2G – (two way) using PEV batteries as grid storage
  - Total capacity of 1M PEV batteries ~10-20 GWh
- 2nd use of batteries
  - 100,000 used PEV batteries can provide about 1-2 GWh of grid storage after retirement from car
- Distribution level effects
  - Regionalization of sales
  - HEV and PEV purchases tend to be clustered in certain neighborhoods and ZIP codes
  - A Nissan Leaf uses ~4000 kWh/yr similar to an average CA home
  - Impact on substations and pole transformers

Clustered Sales



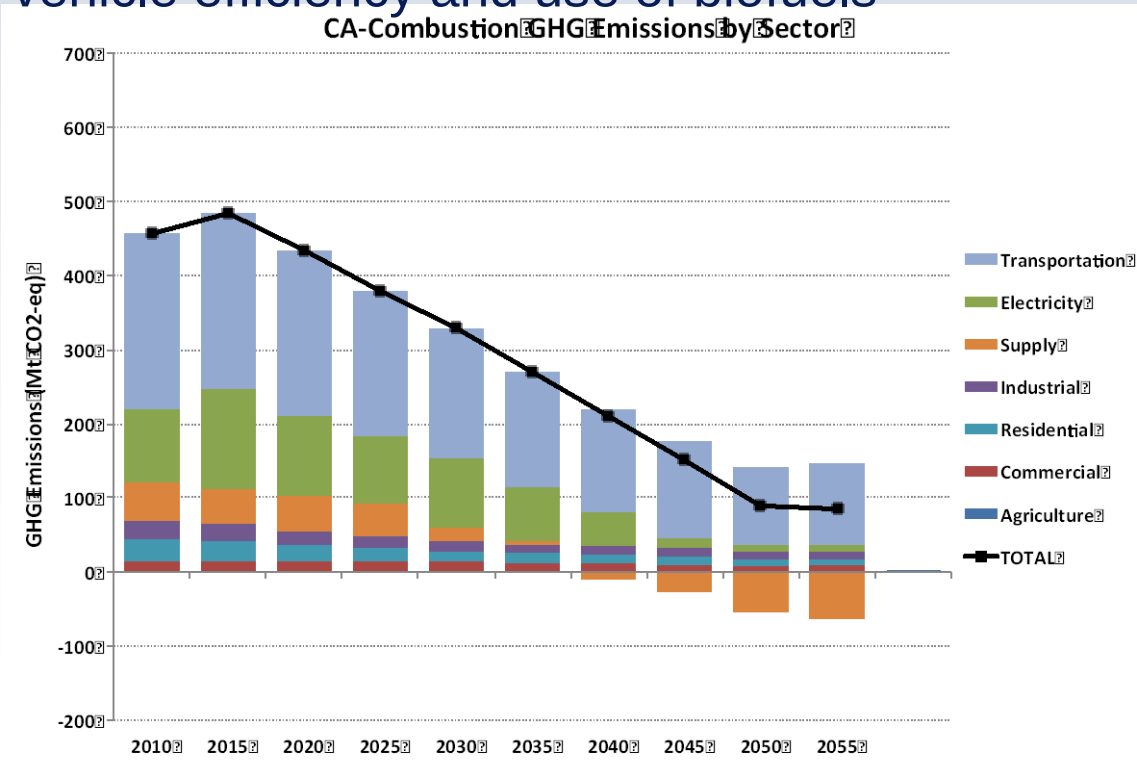
Energy System Modeling: CA-TIMES

- Optimization model of California energy system at ITS
  - Understand technology options for GHG reductions to 2050
  - Primary focus on transportation, fuels and electricity sectors



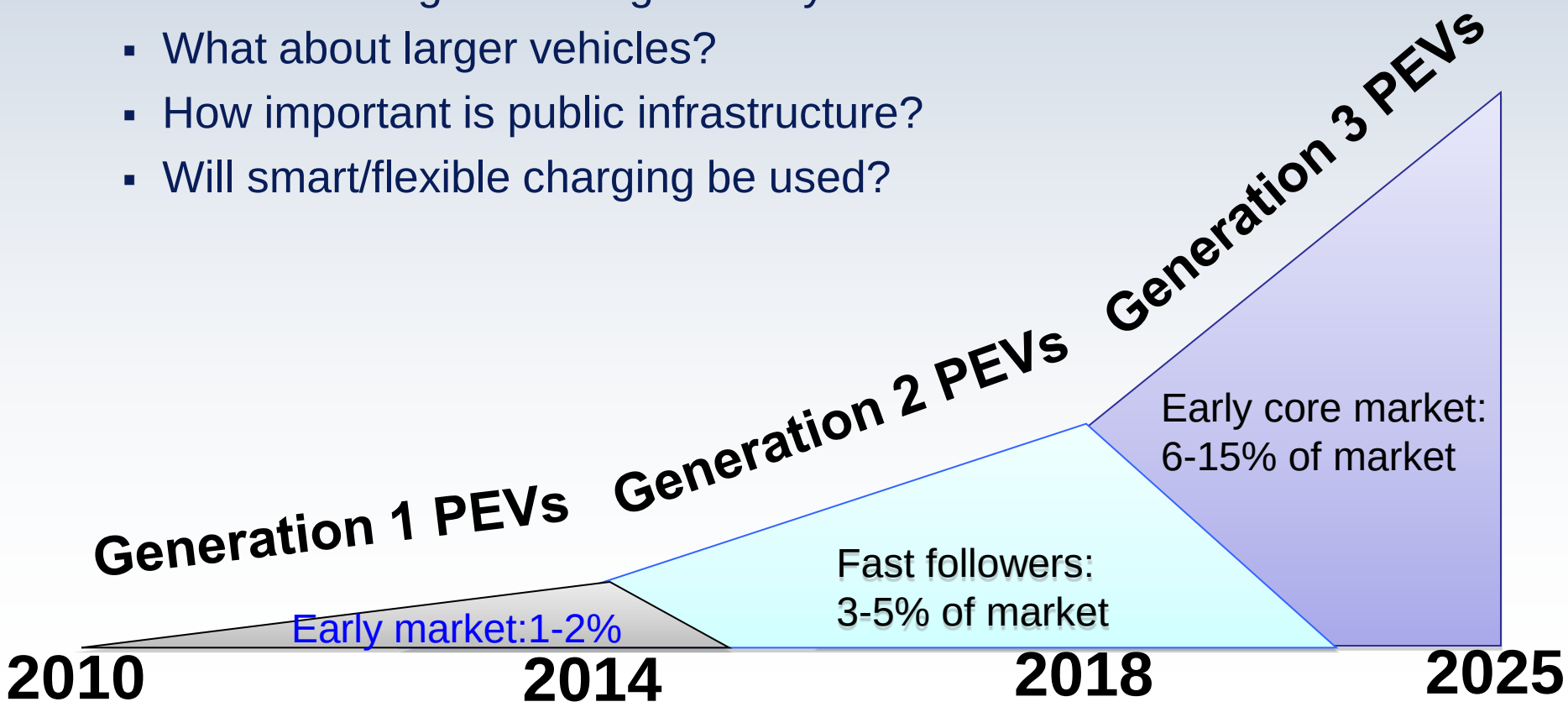
CA-TIMES Results

- Modeling results for meeting an 80% reduction in energy system GHG emissions:
  - Electricity is almost fully decarbonized (nuclear, significant renewables, some fossil with CCS)
  - Transportation reduces emissions less than other sectors
  - Significant increases in vehicle efficiency and use of biofuels
  - Biofuels are made with CCS, resulting in net negative emissions which offset some continued petroleum usage



PEVs: Lots of questions remain

- PEVs are in infancy in commercialization process
  - Can PEVs continue to exceed hybrid sales and reach early mass market consumers?
  - Which technologies are likely to succeed (BEVs, PHEVs)?
  - Who are the gen 2 and gen 3 buyers?
  - What about larger vehicles?
  - How important is public infrastructure?
  - Will smart/flexible charging be used?



Conclusions

- PEVs are doing well by many measures in the very early market
  - Uncertainty about the pace of growth in next decade
  - Range of estimates for 2030 PEVs in CA is quite large
- PEVs grid impacts
  - Demand isn’t expected to be very large relative to expected electricity demands:
    - 1 to 10% of CA electricity is possible but ~2-4% seems more likely
  - Flexible charging and V2G can improve grid function
    - Balance renewables
    - Depends on incentives

Thank you!