IEEE ENERGY CONVERSION CONGRESS & EXPO PHOENIX, ARIZONA, USA OCT. 20-24

VEHICLE-TO-GRID ANALYSIS TO REDUCE ELECTRICAL PEAK LOAD IN THE SAN DIEGO AREA IN 2030

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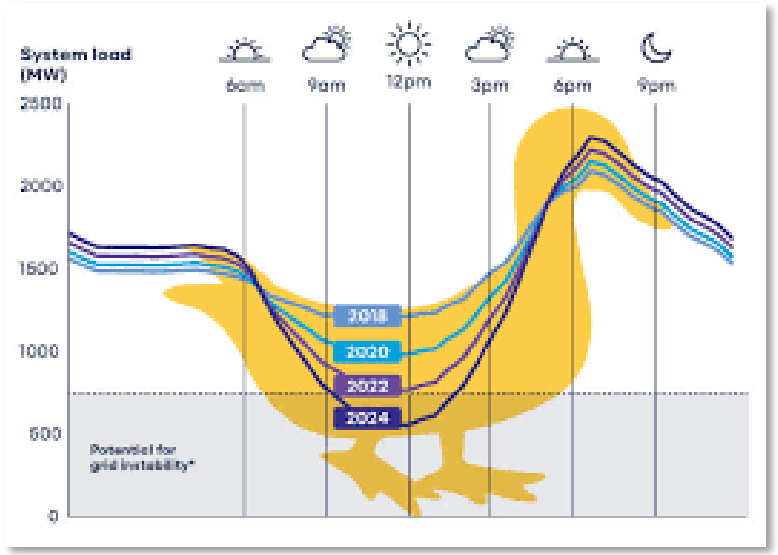
1. INTRODUCTION

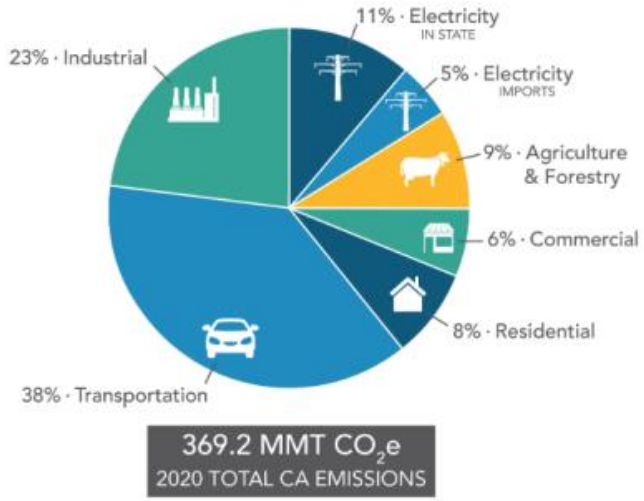
COMPANY APPROACH

CENTER FOR COMMUNITY ENERGY



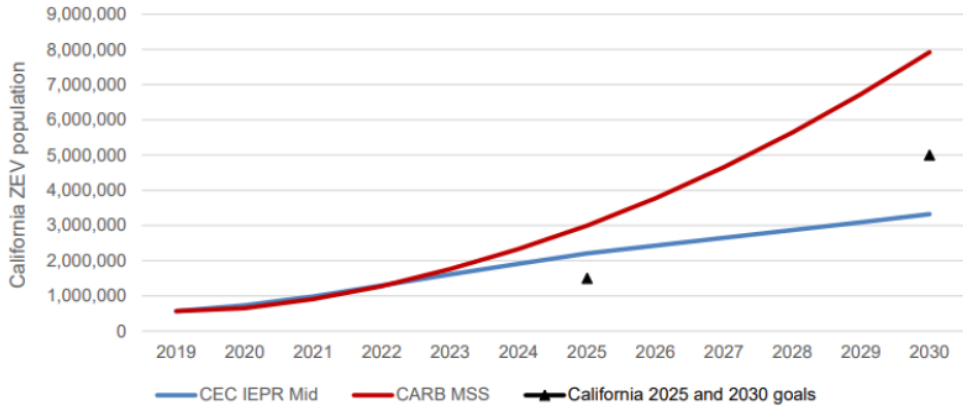
1. INTRODUCTION

SCOPE



- California leading innovator in energy policy
- Transportation resposible for 38% GHG emissions
- Implementing clean transportation policies crucial

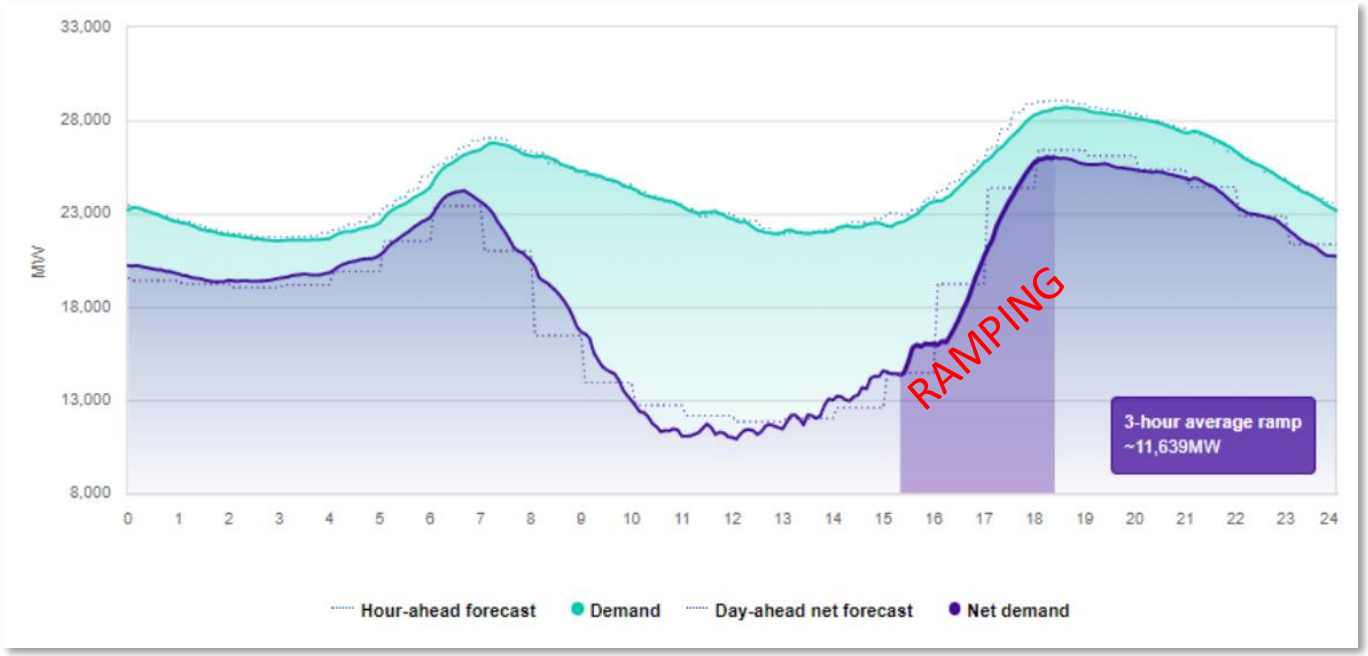
POLICY BACKGROUND

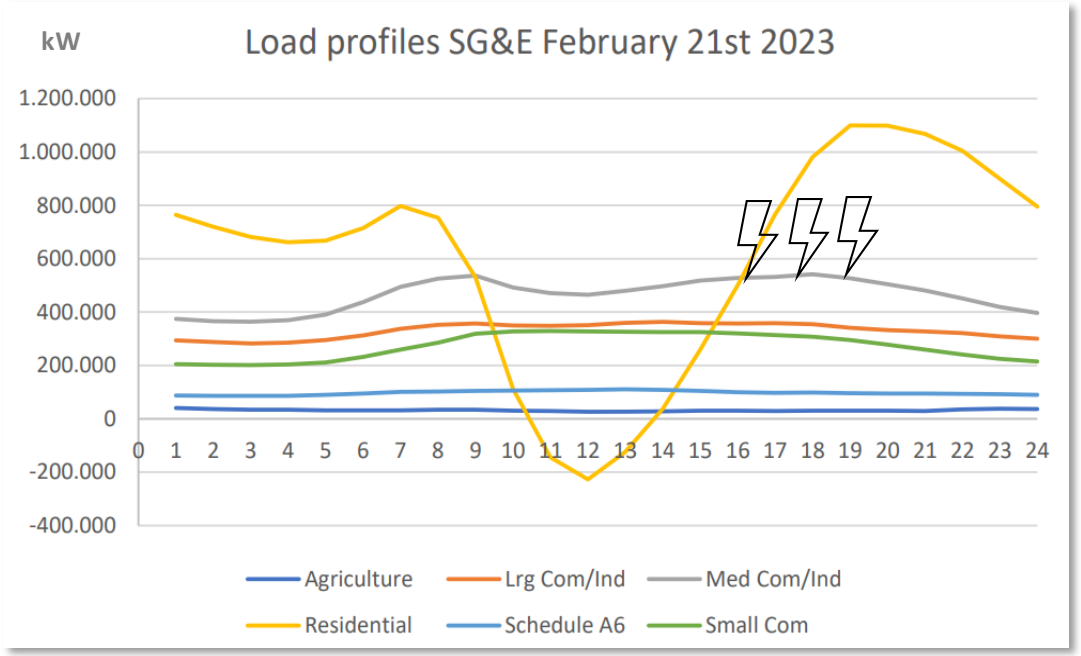


- Executive order B-48-18 Jan 2018
  1.5 million ZEVs on California's roadways by 2025 and 5 million by 2030
- Senate Bill 100 (DeLeon) 2018
  Mandates 60% of Renewable Portfolio Standard by 2030 and 100% by 2045

1. INTRODUCTION

DUCK CURVE





WHY NOT USE BEVs TO REDUCE THE RESIDENTIAL LOAD?

2. CONTRIBUTIONS

MODEL ACCOMPLISHMENT

Circuit capacity	10369 kW
Threshold	0.82
Load increase	0%

nº of household	4260 households
nº of cars	9798 cars
V2G availability	4.5%
BEV V2G 2030	441 BEVs
Power station discharge	7.2 kW
Discharge efficiency	90%
Max power discharge	6.5 kW
Battery size	88 kWh

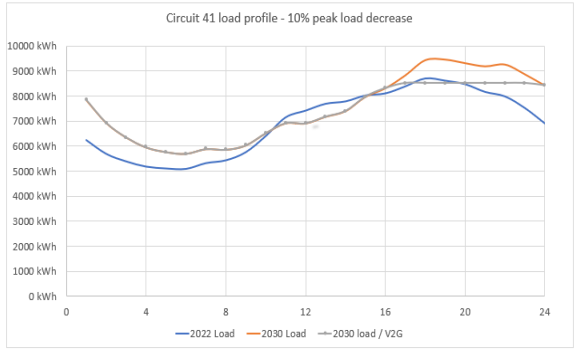
Input parameter

Energy discharged per EV	13.7 kWh
Battery size	88 kWh
% battery withdrawn	16%

Solver parameter	Function	Output
Objetive	10% peak load decre	10%
Changing	Threshold	0.82
Constrains	Discharge rule <1	0.47
	% battery withdrawn	16%

Max peak load decrease	10%

41	2022 Load	Assumed icrease	Fixed increase	2030 Load	% cars home	BEV availables	Energy discharged	Discharge rule	2030 load / V2G	Peak Load decrease	Energy discharged per BEV per hour
1	6241 kWh	26%	26%	7842 kWh	99%	437 BEVs		0.00	7842 kWh		
2	5692 kWh	22%	22%	6930 kWh	98%	438 BEVs		0.00	6930 kWh		
3	5388 kWh	18%	18%	6352 kWh	100%	440 BEVs		0.00	6352 kWh		
4	5180 kWh	15%	15%	5956 kWh	100%	441 BEVs		0.00	5956 kWh		
5	5108 kWh	13%	13%	5768 kWh	99%	437 BEVs		0.00	5768 kWh		
6	5089 kWh	12%	12%	5703 kWh	96%	422 BEVs		0.00	5703 kWh		
7	5319 kWh	11%	11%	5889 kWh	87%	383 BEVs		0.00	5889 kWh		
8	5432 kWh	8%	8%	5862 kWh	68%	300 BEVs		0.00	5862 kWh		
9	5758 kWh	5%	5%	6034 kWh	51%	225 BEVs		0.00	6034 kWh		
10	6402 kWh	2%	2%	6519 kWh	42%	187 BEVs		0.00	6519 kWh		
11	7151 kWh	-3%	-3%	6917 kWh	38%	166 BEVs		0.00	6917 kWh		
12	7420 kWh	-7%	-7%	6910 kWh	35%	154 BEVs		0.00	6910 kWh		
13	7694 kWh	-7%	-7%	7177 kWh	33%	144 BEVs		0.00	7177 kWh		
14	7789 kWh	-5%	-5%	7400 kWh	28%	125 BEVs		0.00	7400 kWh		
15	8027 kWh	-1%	-1%	7971 kWh	28%	122 BEVs		0.00	7971 kWh		
16	8110 kWh	3%	3%	8312 kWh	33%	144 BEVs		0.00	8312 kWh		
17	8391 kWh	5%	5%	8827 kWh	46%	203 BEVs	316 kWh	0.24	8510 kWh	4%	1.6
18	8708 kWh	8%	8%	9432 kWh	68%	302 BEVs	921 kWh	0.47	8510 kWh	10%	3.1
19	8619 kWh	10%	10%	9456 kWh	82%	360 BEVs	946 kWh	0.41	8510 kWh	10%	2.6
20	8477 kWh	10%	10%	9313 kWh	88%	387 BEVs	803 kWh	0.32	8510 kWh	9%	2.1
21	8169 kWh	12%	12%	9187 kWh	91%	402 BEVs	677 kWh	0.26	8510 kWh	7%	1.7
22	7988 kWh	16%	16%	9257 kWh	94%	412 BEVs	747 kWh	0.28	8510 kWh	8%	1.8
23	7521 kWh	18%	18%	8867 kWh	96%	422 BEVs	357 kWh	0.13	8510 kWh	4%	0.8
24	6906 kWh	22%	22%	8420 kWh	98%	432 BEVs		0.00	8420 kWh		



Sensitivity analysis - MAX DISCHARGE RULE

Change in peak load increase

Change in V2G %	0%	5%	10%	15%	20%	25%	30%	35%	40%
0.47									
0.5%	4.24	4.40	4.57	4.74	4.90	5.07	5.24	5.40	5.57
1.5%	1.41	1.47	1.52	1.58	1.63	1.69	1.75	1.80	1.86
2.5%	0.85	0.88	0.91	0.95	0.98	1.01	1.05	1.08	1.11
3.5%	0.61	0.63	0.65	0.68	0.70	0.72	0.75	0.77	0.80
4.5%	0.47	0.49	0.51	0.53	0.54	0.56	0.58	0.60	0.62
5.5%	0.39	0.40	0.42	0.43	0.45	0.46	0.48	0.49	0.51
6.5%	0.33	0.34	0.35	0.36	0.38	0.39	0.40	0.42	0.43
7.5%	0.28	0.29	0.30	0.32	0.33	0.34	0.35	0.36	0.37
8.5%	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33

Over 1

Sensitivity analysis - % Battery withdrawn

Change in peak load increase

	0%	5%	10%	15%	20%	25%	30%	35%	40%
16%	16%	17%	18%	19%	20%	21%	23%	24%	25%

Sensitivity analysis - % Battery withdrawn

Change in V2G %

	0.5%	1.5%	2.5%	3.5%	4.5%	5.5%	6.5%	7.5%	8.5%
16%	140%	47%	28%	20%	16%	13%	11%	9%	8%

Sensitivity analysis - MAX DISCHARGE RULE

Change in power discharge

	4 kW	5 kW	6 kW	7 kW	8 kW	9 kW	10 kW	11 kW	12 kW
0.47									
0.5%	7.63	6.10	5.09	4.36	3.81	3.39	3.05	2.77	2.54

Sensitivity analysis - % Battery withdrawn

Change in peak load increase

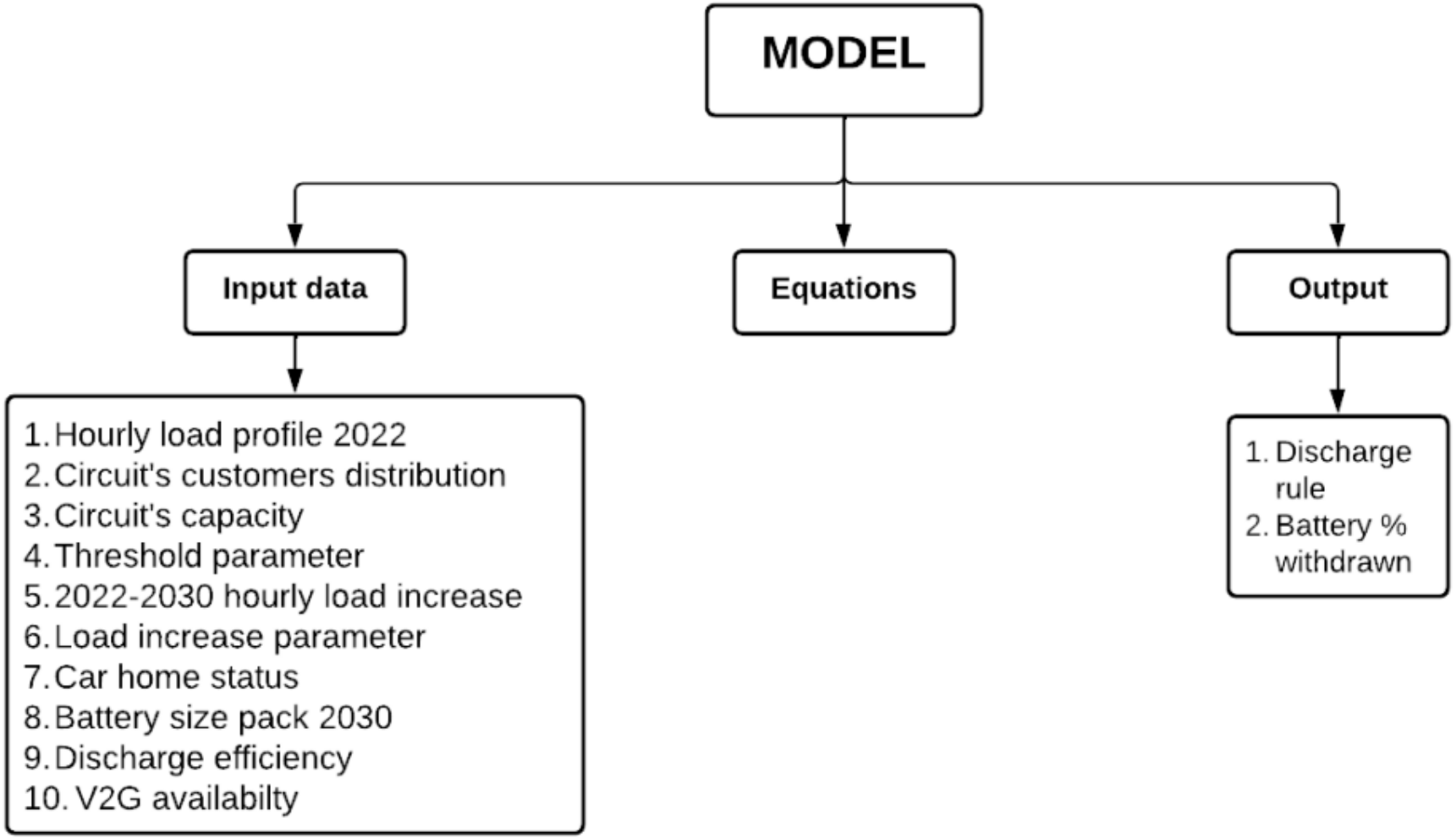
	0%	5%	10%	15%	20%	25%	30%	35%	40%
16%	0%	5%	10%	15%	20%	25%	30%	35%	40%
0.5%	140%	149%	159%	170%	181%	192%	203%	214%	225%

- Functional V2G model for the **evaluation** of the **viability** of V2G scenarios
- Algorithms and profound methodology to provide a **thorough analysis**

OUTPUTS

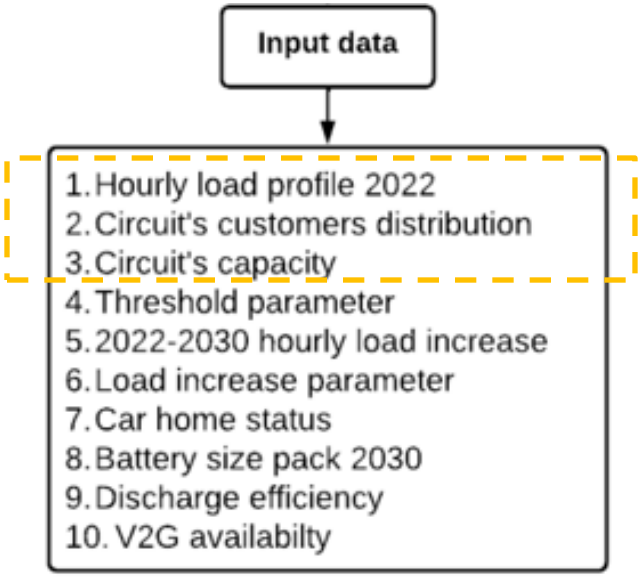
- % Battery withdrawn
- Discharge rule

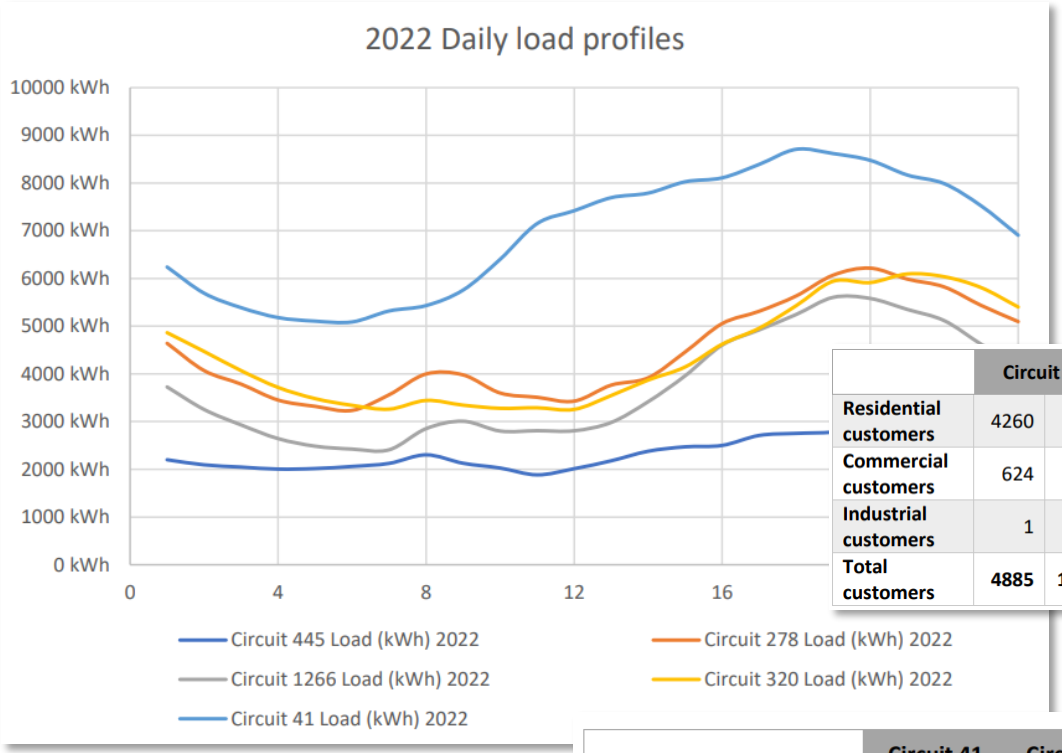
3. METHODOLOGY



3. METHODOLOGY

INPUT DATA





	Circuit 41		Circuit 445		Circuit 278		Circuit 1266		Circuit 320	
Residential customers	4260	87%	787	83%	3772	97%	1879	96%	3199	98%
Commercial customers	624	13%	165	17%	80	2%	81	4%	67	2%
Industrial customers	1	0%	1	0%	25	1%	5	0%	7	0%
Total customers	**4885**	**100%**	**953**	**100%**	**3877**	**100%**	**1965**	**100%**	**3273**	**100%**

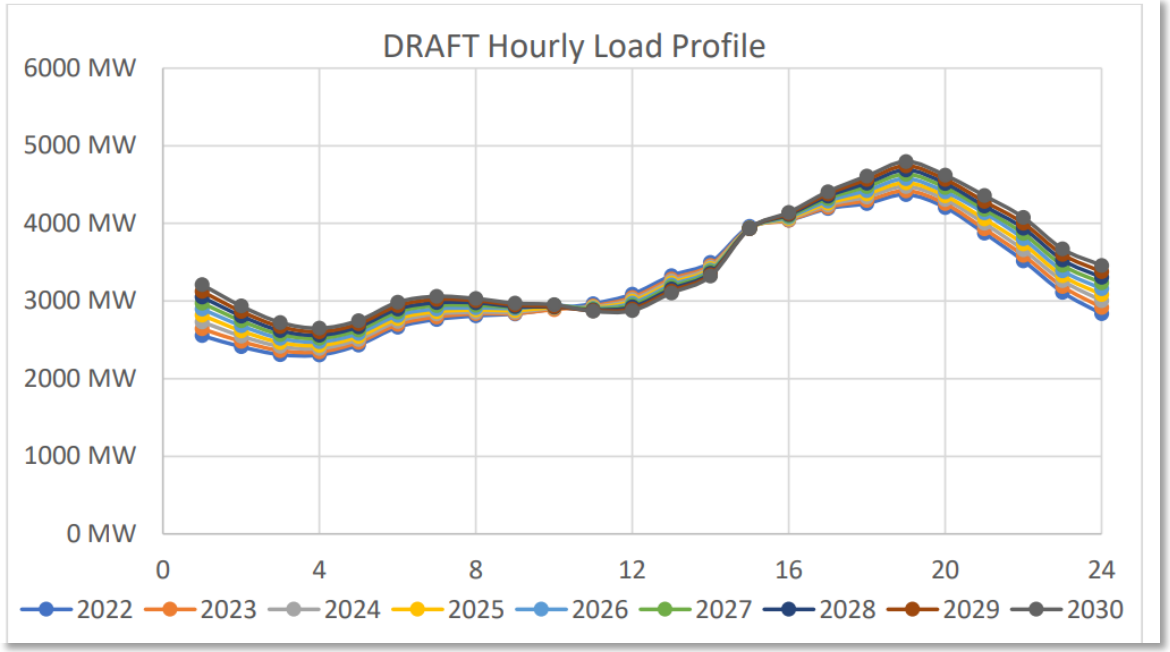
	Circuit 41	Circuit 445	Circuit 278	Circuit 1266	Circuit 320
Forecast demand	8708 kW	2890 kWh	6217 kWh	5604 kWh	6095 kWh
Facility loading	84%	26%	50%	45%	49%
Circuit capacity	10369 kW	11115 kW	12434 kW	12454 kW	12439 kW

3. METHODOLOGY

INPUT DATA

Input data

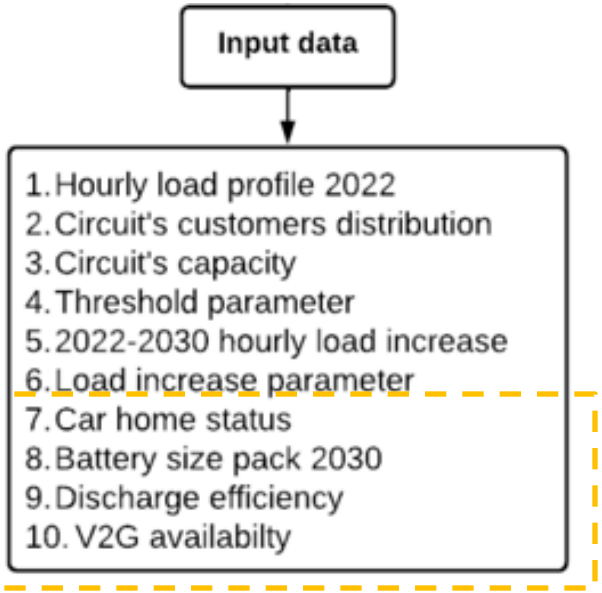
1. Hourly load profile 2022
2. Circuit's customers distribution
3. Circuit's capacity
4. Threshold parameter
5. 2022-2030 hourly load increase
6. Load increase parameter
7. Car home status
8. Battery size pack 2030
9. Discharge efficiency
10. V2G availabilty

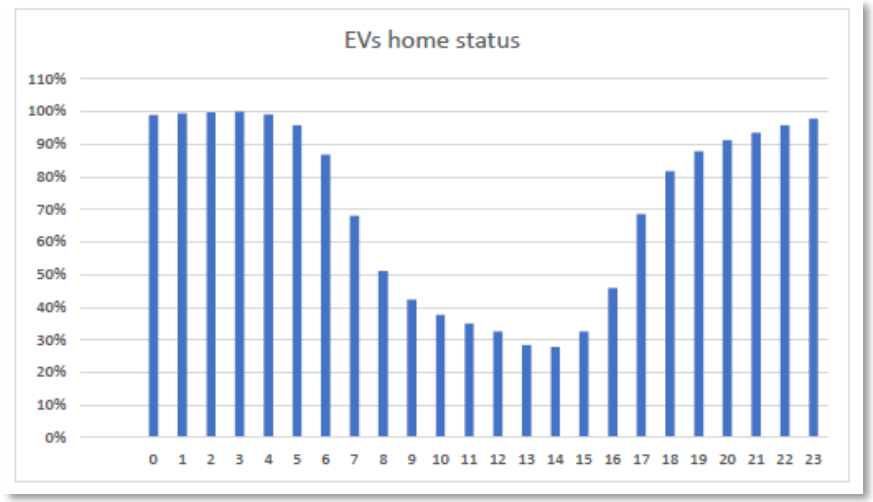


Hour	2022-2030 increase %
1	25.66%
2	21.76%
3	17.88%
4	14.98%
5	12.97%
6	12.06%
7	10.72%
8	7.91%
9	4.81%
10	1.83%
11	-3.27%
12	-6.87%
13	-6.71%
14	-5.00%
15	-0.70%
16	2.50%
17	5.19%
18	8.31%
19	9.72%
20	9.87%
21	12.46%
22	15.89%
23	17.89%
24	21.92%

3. METHODOLOGY

INPUT DATA





- Provided by the US Federal Highway Administration

- 2030 CEC EVs estimations
- 2030 V2G chargers assumption

Number of households in circuit 41	Average number of cars per household in California	Number of cars in circuit 41 2030	Percentage of BEVs in California 2030	Number of Evs in circuit 41 2030
4260	2.3	9798 cars	14.9%	1460 BEVs

Number of BEVs in circuit 41 2030	V2G availability 2030	Number of BEVs with V2G capabilities 2030	% V2G 2030
1460 BEVs	30%	441 BEVs	4.5%

Sensitivity analysis - % Battery withdrawn (0% Load increase)								
Change in V2G %								
0.5%	1.5%	2.5%	3.5%	4.5%	5.5%	6.5%	7.5%	8.5%
140%	47%	28%	20%	16%	13%	11%	9%	8%

3. METHODOLOGY

EQUATIONS

$$Fixed\ increase_t = Assumed\ increase_t * (1 + Load\ increase)$$

$$2030\ Load_t = 2022\ Load_t * (1 + Fixed\ increase)$$

$$BEV\ available_t = BEV\ V2G\ 2030 * \%\ cars\ home\ status_t$$

$$2030\ load\ V2G_t = 2030\ load_t \qquad if\ 2030\ load_t < Circuit\ capacity * Threshold$$

$$2030\ load\ V2G_t = Circuit\ capacity * Threshold \qquad if\ 2030\ load_t > Circuit\ capacity * Threshold$$

$$Energy\ discharged_t = 2030\ Load_t - 2030\ Load\ V2G_t$$

$$Peak\ load\ decrease_t = \frac{2030\ Load_t - 2030\ Load\ V2G_t}{2030\ Load_t}$$

OUTPUTS

$$Discharge\ rule_t = \frac{Energy\ discharged_t}{BEV\ availables_t * Max\ power\ discharge}$$

V2G charger load factor

Avg % discharged

$$\%\ battery\ withdrawn = \frac{\sum_{t=1}^{24} Energy\ discharged\ per\ BEV\ per\ hour}{Battery\ size}$$

3. METHODOLOGY

Circuit 41	2022 Load	Assumed increase	Fixed increase	2030 Load	% cars home	BEV available	Energy discharged	Discharge rule	2030 load / V2G	Peak Load decrease	Energy discharged per BEV per hour
1	6241 kWh	26%	26%	7842 kWh	99%	437 BEVs		0.00	7842 kWh		
2	5692 kWh	22%	22%	6930 kWh	99%	438 BEVs		0.00	6930 kWh		
3	5388 kWh	18%	18%	6352 kWh	100%	440 BEVs		0.00	6352 kWh		
4	5180 kWh	15%	15%	5956 kWh	100%	441 BEVs		0.00	5956 kWh		
5	5106 kWh	13%	13%	5768 kWh	99%	437 BEVs		0.00	5768 kWh		
6	5089 kWh	12%	12%	5702 kWh	96%	422 BEVs		0.00	5703 kWh		
7	5319 kWh	11%	11%	5890 kWh	87%	383 BEVs		0.00	5889 kWh		
8	5432 kWh	8%	8%	5862 kWh	68%	300 BEVs		0.00	5862 kWh		
9	5758 kWh	5%	5%	6034 kWh	51%	225 BEVs		0.00	6034 kWh		
10	6402 kWh	2%	2%	6519 kWh	42%	187 BEVs		0.00	6519 kWh		
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13	7694 kWh	-7%	-7%	7177 kWh	33%	144 BEVs		0.00	7177 kWh		
14	7789 kWh	-5%	-5%	7400 kWh	28%	125 BEVs		0.00	7400 kWh		
15	8027 kWh	-1%	-1%	7971 kWh	28%	122 BEVs		0.00	7971 kWh		
16	8110 kWh	3%	3%	8313 kWh	33%	144 BEVs		0.00	8312 kWh		
17	8391 kWh	5%	5%	8827 kWh	46%	203 BEVs	316 kWh	0.24	8510 kWh	4%	1.6 kWh
18	8708 kWh	8%	8%	9432 kWh	68%	302 BEVs	921 kWh	0.47	8510 kWh	10%	3.1 kWh
19	8619 kWh	10%	10%	9456 kWh	82%	360 BEVs	946 kWh	0.41	8510 kWh	10%	2.6 kWh
20	8477 kWh	10%	10%	9313 kWh	88%	387 BEVs	803 kWh	0.32	8510 kWh	9%	2.1 kWh
21	8169 kWh	12%	12%	9187 kWh	91%	402 BEVs	677 kWh	0.26	8510 kWh	7%	1.7 kWh
22	7988 kWh	16%	16%	9257 kWh	94%	412 BEVs	747 kWh	0.28	8510 kWh	8%	1.8 kWh
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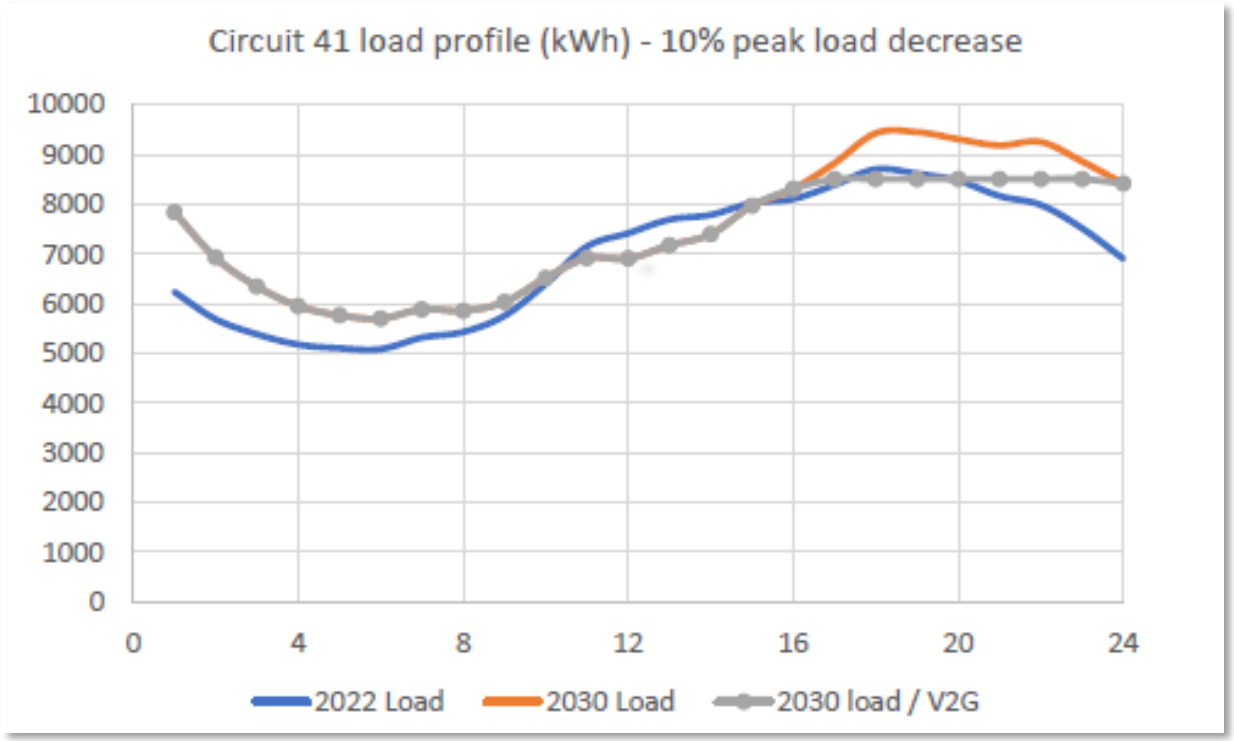
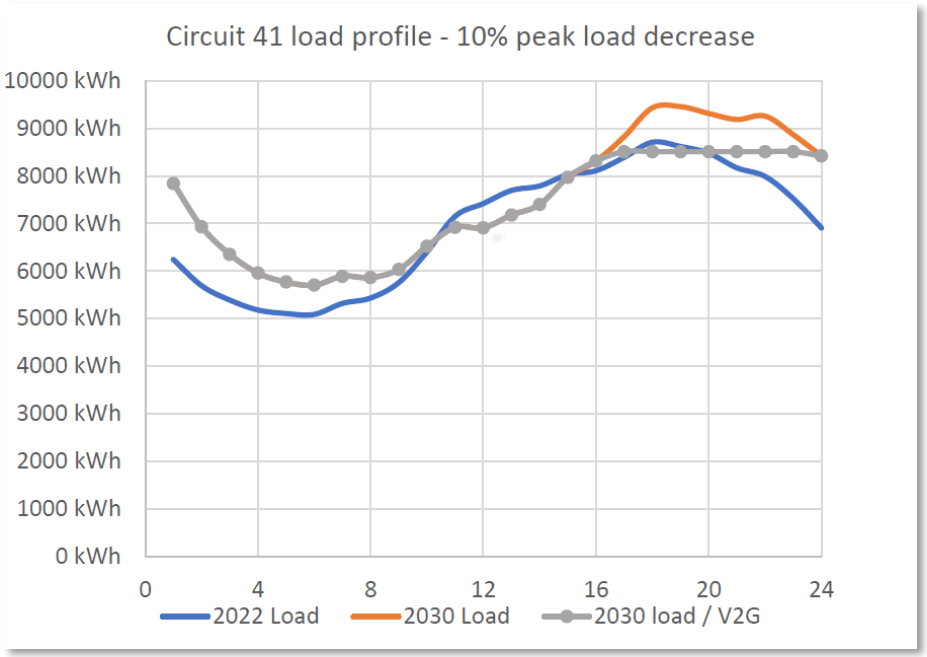
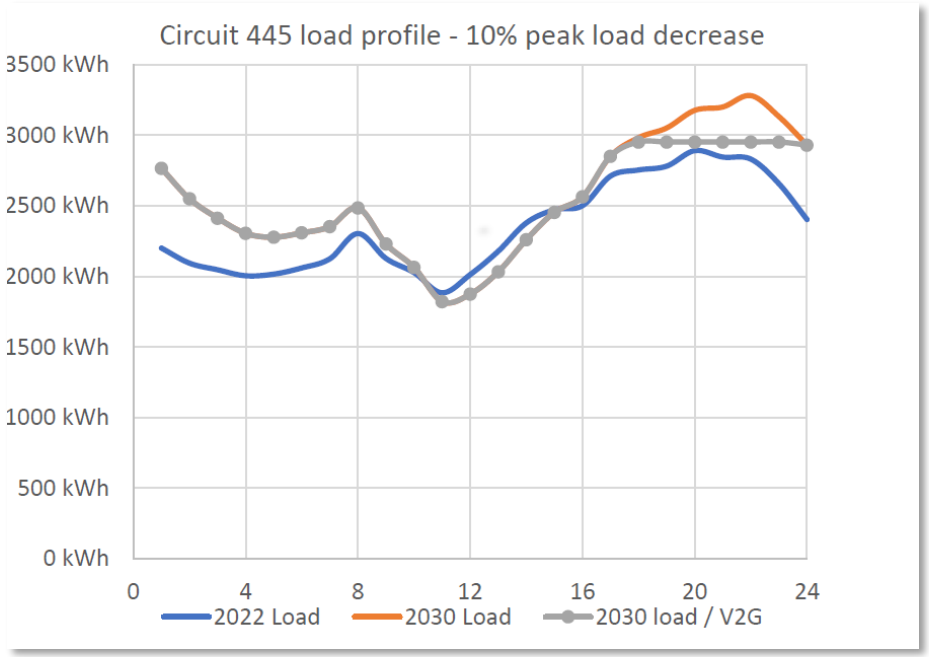


4. CASES OF STUDY & RESULTS

CASE 1: 10% PEAK LOAD DECREASE

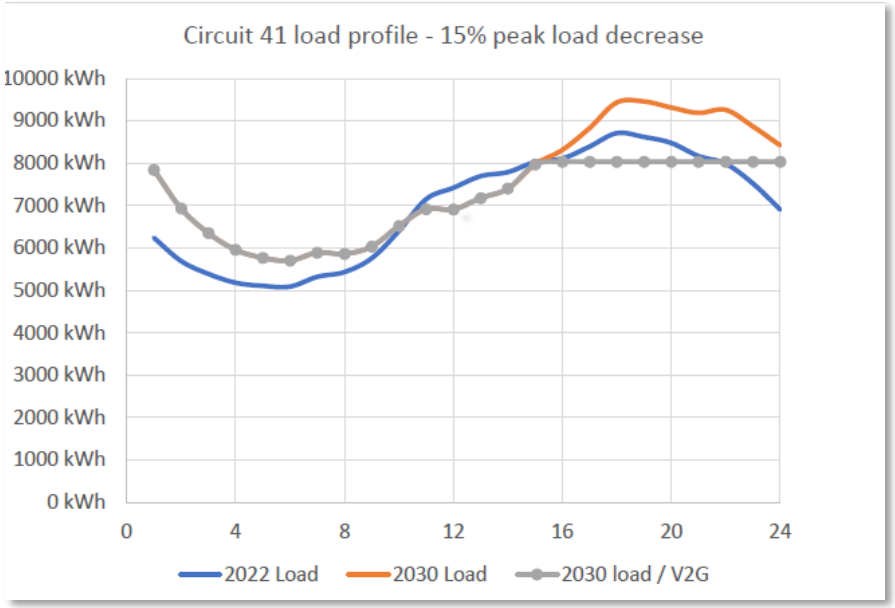




Any peak load decrease value can be chosen.

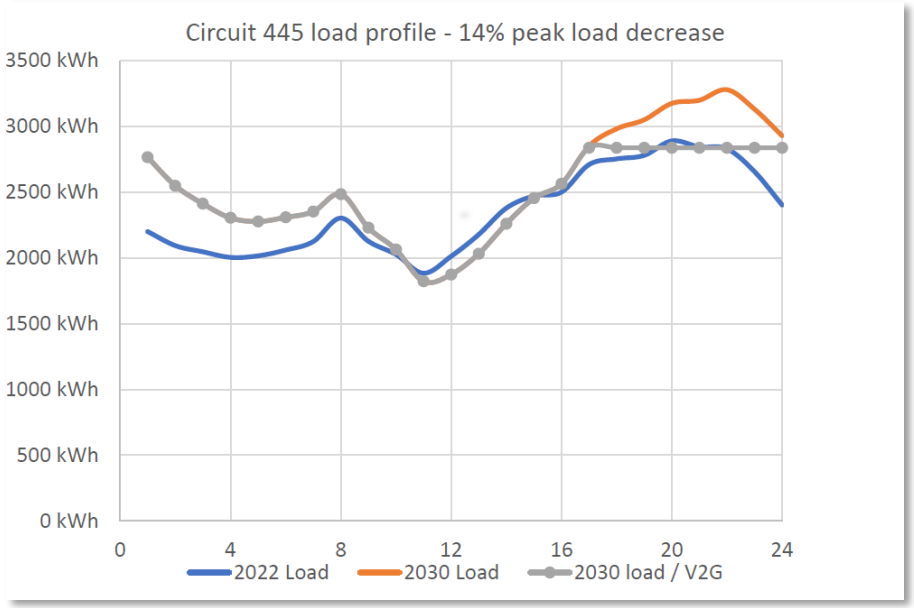
	Circuit 41	Circuit 445	Circuit 278	Circuit 1266	Circuit 320
Residential consumers	4260	787	3772	1879	3199
Comercial consumers	624	165	80	81	67
Industrial consumers	1	1	25	5	7
% residential	87%	83%	97%	96%	98%
Facility loading	84%	25%	50%	45%	49%
Max load/consumer	2.0 kWh	3.7 kWh	1.6 kWh	3.0 kWh	1.9 kWh
Max peak load decrease	10%	10%	10%	10%	10%
Thershold required	0.82	0.27	0.49	0.44	0.51
Max discharge rule	0.47	0.66	0.31	0.60	0.35
Battery % discharged	16%	17%	9%	15%	9%

4. CASES OF STUDY & RESULTS



	Circuit 41	Circuit 445	Circuit 278	Circuit 1266	Circuit 320
Residential consumers	4260	787	3772	1879	3199
Comercial consumer	624	165	80	81	67
Industrial consumer	1	1	25	5	7
% residential	87%	83%	97%	96%	98%
Facility loading 2022	84%	25%	50%	45%	49%
Max load/consumer	2.0 kWh	3.7 kWh	1.6 kWh	3.0 kWh	1.9 kWh
Power discharge	7.2 kW	7.2 kW	7.2 kW	7.2 kW	7.2 kW
Max peak load decrease	15%	14%	22%	16%	21%
Thershold required	0.77	0.26	0.43	0.41	0.45
Max discharge rule	0.71	0.89	0.66	0.96	0.72
Battery % discharged	30%	30%	30%	30%	30%

CASE 2: PEAK LOAD DECREASE MAXIMIZED



Battery withdrawn < 30%
Discharge rule < 1

Determine the limits of the technology

4. CASES OF STUDY & RESULTS

CASE 1: 10% PEAK LOAD DECREASE

	Circuit 41	Circuit 445	Circuit 278	Circuit 1266	Circuit 320
Residential consumers	4260	787	3772	1879	3199
Comercial consumers	624	165	80	81	67
Industrial consumers	1	1	25	5	7
% residential	87%	83%	97%	96%	98%
Facility loading	84%	25%	50%	45%	49%
Max load/consumer	2.0 kWh	3.7 kWh	1.6 kWh	3.0 kWh	1.9 kWh
Max peak load decrease	10%	10%	10%	10%	10%
Thershold required	0.82	0.27	0.49	0.44	0.51
Max discharge rule	0.47	0.66	0.31	0.60	0.35
Battery % discharged	16%	17%	9%	15%	9%

- Residential distribution %
- Circuits 278 & 320 Circuits 41 & 445
- Circuits 41 & 445 similar residential % and battery depletion
- Highest discharge rule for Circuit 445

CASE 2: PEAK LOAD DECREASE MAXIMIZED

	Circuit 41	Circuit 445	Circuit 278	Circuit 1266	Circuit 320
Residential consumers	4260	787	3772	1879	3199
Comercial consumer	624	165	80	81	67
Industrial consumer	1	1	25	5	7
% residential	87%	83%	97%	96%	98%
Facility loading 2022	84%	25%	50%	45%	49%
Max load/consumer	2.0 kWh	3.7 kWh	1.6 kWh	3.0 kWh	1.9 kWh
Power discharge	7.2 kW	7.2 kW	7.2 kW	7.2 kW	7.2 kW
Max peak load decrease	15%	14%	22%	16%	21%
Thershold required	0.77	0.26	0.43	0.41	0.45
Max discharge rule	0.71	0.89	0.66	0.96	0.72
Battery % discharged	30%	30%	30%	30%	30%

- Peak load decrease values varying from 14-22%.
- % Battery withdrawn constrain reached
- Peak load decrease in 445 minimum: V2G challenge

4. CASES OF STUDY & RESULTS

CASE 1: 10% PEAK LOAD DECREASE

	Initial	Sensitivity analysis - Max discharge rule								
		Change in power discharge								
	0.47	4 kW	5 kW	6 kW	7 kW	8 kW	9 kW	10 kW	11 kW	12 kW
Change in V2G %	0.5%	7.63	6.10	5.09	4.36	3.81	3.39	3.05	2.77	2.54
	1.5%	2.54	2.03	1.70	1.45	1.27	1.13	1.02	0.92	0.85
	2.5%	1.53	1.22	1.02	0.87	0.76	0.68	0.61	0.55	0.51
	3.5%	1.09	0.87	0.73	0.62	0.54	0.48	0.44	0.40	0.36
	4.5%	0.85	0.68	0.57	0.47	0.42	0.38	0.34	0.31	0.28
	5.5%	0.69	0.55	0.46	0.40	0.35	0.31	0.28	0.25	0.23
	6.5%	0.59	0.47	0.39	0.34	0.29	0.26	0.23	0.21	0.20
	7.5%	0.51	0.41	0.34	0.29	0.25	0.23	0.20	0.18	0.17
	8.5%	0.45	0.36	0.30	0.26	0.22	0.20	0.18	0.16	0.15

	Initial	Sensitivity analysis - % Battery withdrawn								
		Change in load increase								
	16%	0%	5%	10%	15%	20%	25%	30%	35%	40%
Change in V2G %	0.5%	140%	149%	159%	170%	181%	192%	203%	214%	225%
	1.5%	47%	50%	53%	57%	60%	64%	68%	71%	75%
	2.5%	28%	30%	32%	34%	36%	38%	41%	43%	45%
	3.5%	20%	21%	23%	24%	26%	27%	29%	31%	32%
	4.5%	16%	17%	18%	19%	20%	21%	23%	24%	25%
	5.5%	13%	14%	14%	15%	16%	17%	18%	19%	20%
	6.5%	11%	11%	12%	13%	14%	15%	16%	16%	17%
	7.5%	9%	10%	11%	11%	12%	13%	14%	14%	15%
	8.5%	8%	9%	9%	10%	11%	11%	12%	13%	13%

Sensitivity analysis - % Battery withdrawn (0% Load increase)								
Change in V2G %								
0.5%	1.5%	2.5%	3.5%	4.5%	5.5%	6.5%	7.5%	8.5%
140%	47%	28%	20%	16%	13%	11%	9%	8%

CASE 2: PEAK LOAD DECREASE MAXIMIZED

	Initial	Sensitivity analysis - Max discharge rule								
		Change in power discharge								
	0.71	4 kW	5 kW	6 kW	7 kW	8 kW	9 kW	10 kW	11 kW	12 kW
Change in V2G %	0.5%	11.56	9.25	7.71	6.61	5.78	5.14	4.63	4.21	3.85
	1.5%	3.85	3.08	2.57	2.20	1.93	1.71	1.54	1.40	1.28
	2.5%	2.31	1.85	1.54	1.32	1.16	1.03	0.93	0.84	0.77
	3.5%	1.65	1.32	1.10	0.94	0.83	0.73	0.66	0.60	0.55
	4.5%	1.28	1.03	0.86	0.71	0.64	0.57	0.51	0.47	0.43
	5.5%	1.05	0.84	0.70	0.60	0.53	0.47	0.42	0.38	0.35
	6.5%	0.89	0.71	0.59	0.51	0.44	0.40	0.36	0.32	0.30
	7.5%	0.77	0.62	0.51	0.44	0.39	0.34	0.31	0.28	0.26
	8.5%	0.68	0.54	0.45	0.39	0.34	0.30	0.27	0.25	0.23

	Initial	Sensitivity analysis - % Battery withdrawn								
		Change in load increase								
	30%	0%	5%	10%	15%	20%	25%	30%	35%	40%
Change in V2G %	0.5%	270%	282%	293%	306%	320%	333%	347%	360%	374%
	1.5%	90%	94%	98%	102%	107%	111%	116%	120%	125%
	2.5%	54%	56%	59%	61%	64%	67%	69%	72%	75%
	3.5%	39%	40%	42%	44%	46%	48%	50%	51%	53%
	4.5%	30%	31%	33%	34%	36%	37%	39%	40%	42%
	5.5%	25%	26%	27%	28%	29%	30%	32%	33%	34%
	6.5%	21%	22%	23%	24%	25%	26%	27%	28%	29%
	7.5%	18%	19%	20%	20%	21%	22%	23%	24%	25%
	8.5%	16%	17%	17%	18%	19%	20%	20%	21%	22%

Sensitivity analysis - % Battery withdrawn (0% load increase)								
Change in V2G %								
0.5%	1.5%	2.5%	3.5%	4.5%	5.5%	6.5%	7.5%	8.5%
270%	90%	54%	39%	30%	25%	21%	18%	16%

5. CONCLUSION

- **Proved** that Bidirectional EVs can substitute grid upgrades
- Significant contribution to the **field of sustainable energy and transportation**
- Versatile **model** that empowers users to study and evaluate the viability of V2G scenarios
- Study how the characteristic of distribution lines affect the V2G simulation
- Analyze the **implications on EVs and V2G chargers** while discharging energy to the grid

IEEE ENERGY CONVERSION CONGRESS & EXPO PHOENIX, ARIZONA, USA OCT. 20-24

VEHICLE-TO-GRID ANALYSIS TO REDUCE ELECTRICAL PEAK LOAD IN THE SAN DIEGO AREA IN 2030

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