

# Medium- and Heavy-Duty Electric Vehicle Charging Infrastructure Cost Analysis for California's CALGreen Building Code

## Addendum #1 Manufacturing and Office Building Cost Analysis

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**Acronyms**

3ph Three Phase Power Distribution

<b>A</b>	Amperes (Amps)
<b>CALGreen</b>	California Green Building Code Title 24, Part 11
<b>EV</b>	Electric Vehicle
<b>kVA</b>	kilo Volt-Ampere (Apparent Power)
<b>MHD</b>	Medium-/Heavy-Duty Vehicle
<b>RSMeans</b>	Robert Snow Means (Construction cost data now offered by Gordian)
<b>V</b>	Voltage (Volts)

# 1. Prior Report

This addendum adds additional building types to the cost model created for the prior report published in September 2021<sup>1</sup>. As with the first report, Arup’s electrical engineers utilized industry-standard power density averages to select representative power transformer, switchgear, and distribution equipment. Arup’s construction cost estimators then utilized industry-standard methods (RSMMeans and supplier quotes) to inform the development of a MHD EV charging infrastructure cost impact model.

# 2. Findings for New Building Types

Table 1 shows the findings for Manufacturing Facilities and Office Buildings. As with the prior building types, the benefits increase as building size increases and as building load increases. Relatedly, adding 200 kVA of electrical capacity to a small building is more cost-effective than adding 400 kVA. As in the prior report, these scenarios varied the size of the building and the number of charging spaces.

**Table 1. Cost Analysis**

Building Type	Sq. ft	Charging Spaces	Charging Capacity power ~ current (at 480V 3ph)	Initial Amps → Final Amps	Retrofit Cost / First Cost Ratio	First Cost / Total Cost Ratio (range)
Manufacturing Facilities	20,000	1	200kVA ~ 300A+/-	600A → 1200A	230%	0.8% - 1.2%
	20,000	2	400kVA ~ 600A+/-	600A → 1200A	224%	1.0% - 1.5%
	60,000	2	400kVA ~ 600A+/-	2000A → 2500A	228%	0.3% - 0.4%
Office Buildings	20,000	1	200kVA ~ 300A+/-	400A → 600A	231%	0.7% - 1.1%
	20,000	2	400kVA ~ 600A+/-	400A → 800A	218%	1.0% - 1.5%
	60,000	2	400kVA ~ 600A+/-	800A → 1200A	222%	0.3% - 0.5%

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<sup>1</sup> California Statewide Utility Codes and Standards Team. 2021. "[Medium- and Heavy-Duty Electric Vehicle Charging Infrastructure Cost Analysis for Title 24, Part 11 \(CALGreen\).](#)"

### 3. Retrofit Cost versus Additional First Cost

There are overall cost savings associated with a “build now” requirement as it takes advantage of the economy of scale of a whole-building construction project. The disruption due to a retrofit project and other higher “soft costs” are not included; thus, the results are conservative.

Figure 1 shows the cost comparison of the “Build EV Charging Capacity Now” versus “Current Code First Code + Later Cost of Retrofit” for the new Manufacturing and Office Building scenarios. The general pattern is clear that “Build EV Charging Capacity Now” is less expensive in total than “Retrofit Later.” The savings from “build now using proposed code” are greatest for scenarios that require a new transformer and/or new switchgear during the upgrade. These estimates exclude most soft costs.

Please see the [original report](#) for the full discussion on this topic.

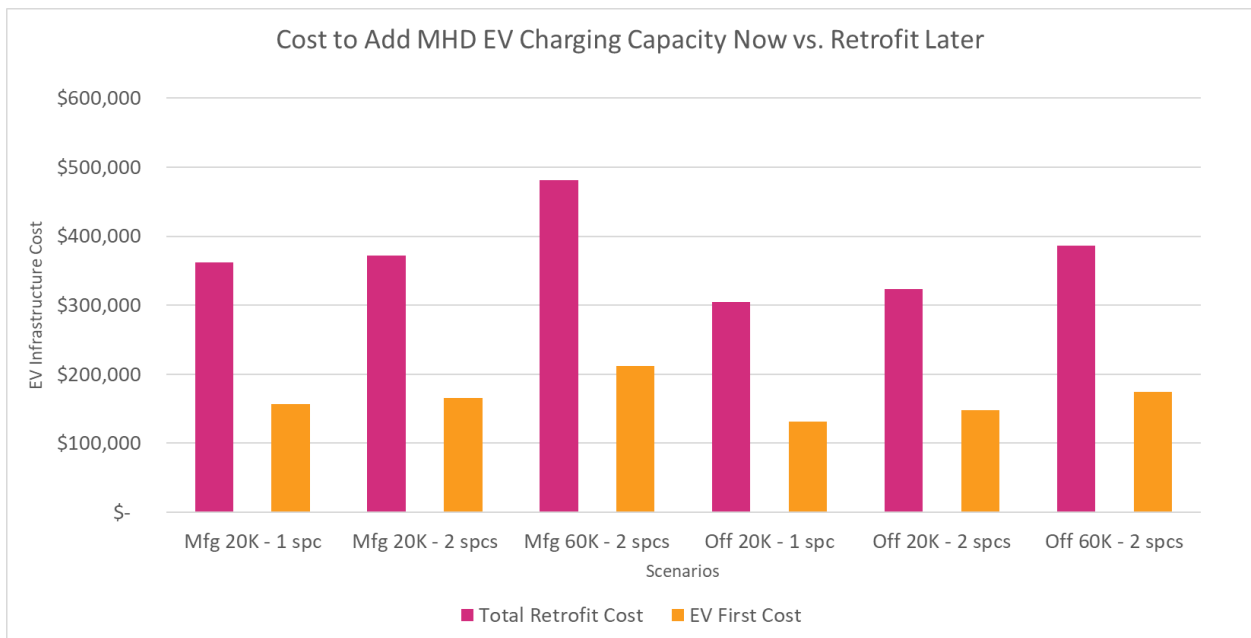
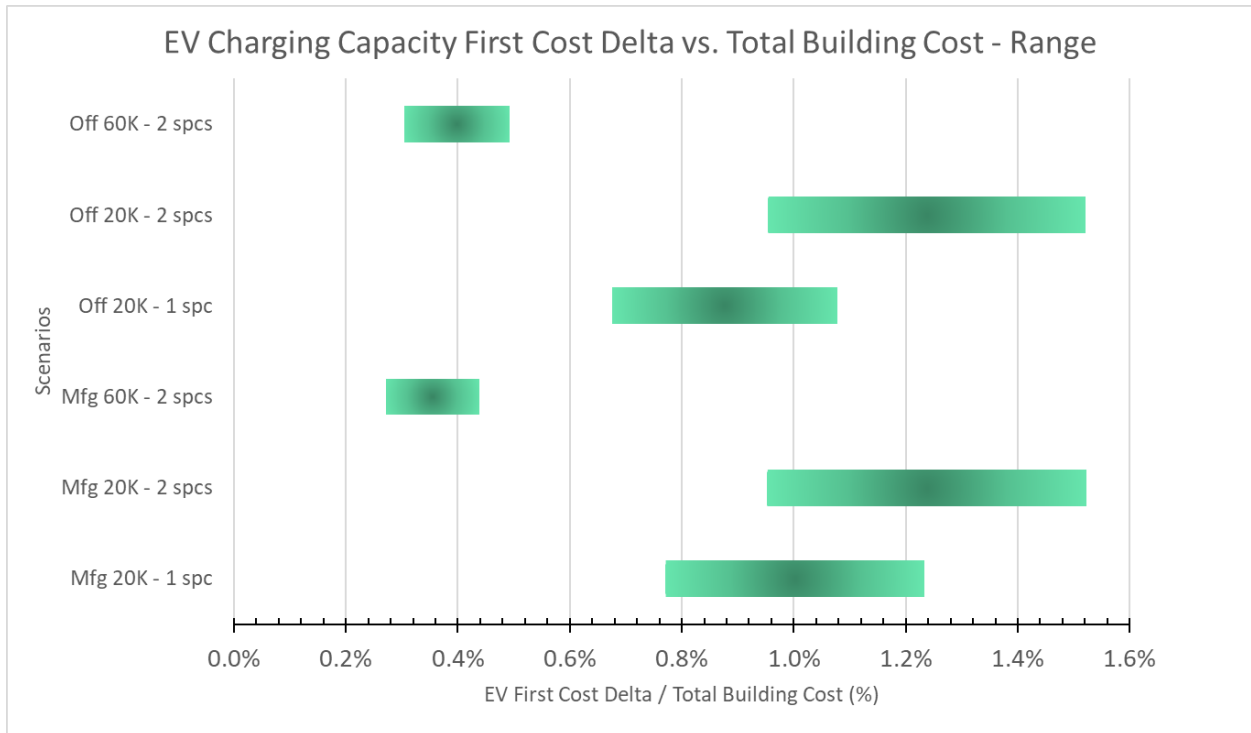


Figure 1. Cost to Add EV Charging Capacity (Building Now vs. Retrofit Later)

## 4. Additional First Cost vs. Overall Construction Costs

The larger and more complex the building, the higher the overall construction costs. Figure 2 shows a range of cost impacts depending on building use case and size (as a percentage of total building costs). As illustrated below, the extra cost to include EV charging capacity impacts larger buildings less than smaller buildings.

The [original report](#) shows similar results for building types: grocery, retail, and warehouse.



**Figure 2. EV Charging Capacity First Cost vs. Total Building Cost - Range**

## 5. References

- California Statewide Utility Codes and Standards Team. 2021. “Medium- and Heavy-Duty Electric Vehicle Charging Infrastructure Cost Analysis for Title 24, Part 11 (CALGreen).” September 21, 2021. <https://title24stakeholders.com/measures/2022-calgreen/medium-and-heavy-duty-ev-charging-infrastructure-cost-analysis/>
- CA BSC. 2022. “Draft Express Terms for Proposed Building Standards of the California Building Standards Commission Regarding the 2022 California Green Building Standards Code, California Code of Regulations, Title 24, Part 11 (CALGreen)”. Agenda Items 5b for CALGreen EV (Intervening Cycle) Workshop August 18, 2022. Accessed November 10, 2022. <https://www.dgs.ca.gov/-/media/Divisions/BSC/03-Rulemaking/2022-Intervening-Cycle/Pre-Cycle/CEVW-20220818/Draft-Item-5b-Section-510654MHDV.pdf>

## 6. Appendix: Input, Calculation and Output Tables

### 6.1 Unit Costs for 2022

The estimates for each scenario utilize a library of materials and their costs. Retrofit projects were estimated to have 15% higher unit costs to reflect the lack of purchasing in bulk. We started with data from RSMeans for materials and labor. For equipment not listed, we used data gathered from outreach to major electrical contractors and/or cost experience on previous engineering and design projects. Figure 3. below provides inflation-adjusted costs with increases between 6% and 23% for 2022.

Description	Unit	Aug-22					Assumption/Source	2021 vs 2022 Costs
		Material Cost	Labor Cost	Unit Cost		Unit Cost Factor		
				Within Building Construction	Separate Construction			
Remove existing transformer	EA	\$ -	\$ 2,122	\$ 2,122	15%	\$ 2,440		6%
Remove existing switchgear	EA	\$ -	\$ 9,846	\$ 9,846	15%	\$ 11,323	Assuming \$145/hr for 2 workers in 4 days. No crane assur	6%
Demolish wall to accommodate bigger equipment	LF	\$ -	\$ 48	\$ 48	15%	\$ 55		6%
Concrete Wall	SF			\$ 59	15%	\$ 68		18%
Concrete Pad	CY			\$ 1,766	15%	\$ 2,030	LBNF	18%
Finishes	SF			\$ 18	15%	\$ 20		18%
Conduits, 4" diam.	LF			\$ 12	15%	\$ 14	Assumed additional 20% for supports	23%
Conduits, 4" diam. - 2 sets (includes trench and duct ba	LF			\$ 60	15%	\$ 69		23%
Conduits, 4" diam. - 4 sets (includes trench and duct ba	LF			\$ 135	15%	\$ 155		23%
75 kVA Transformer	EA	\$ 21,225	\$ 5,475	\$ 26,700	15%	\$ 27,521		19%
150 kVA Transformer	EA	\$ 35,909	\$ 9,263	\$ 45,172	15%	\$ 46,561		19%
225 kVA Transformer	EA	\$ 44,424	\$ 11,459	\$ 55,883	15%	\$ 57,602		19%
300 kVA Transformer	EA	\$ 50,471	\$ 13,018	\$ 63,489	15%	\$ 65,442		19%
500 kVA Transformer	EA	\$ 61,206	\$ 15,788	\$ 76,994	15%	\$ 79,362		19%
750 kVA Transformer	EA	\$ 69,721	\$ 17,984	\$ 87,705	15%	\$ 90,403		19%
1000 kVA Transformer	EA	\$ 75,768	\$ 19,544	\$ 95,311	15%	\$ 98,243		19%
1500 kVA Transformer	EA	\$ 84,282	\$ 21,740	\$ 106,022	15%	\$ 109,283		19%
2000 kVA Transformer	EA	\$ 90,329	\$ 23,300	\$ 113,628	15%	\$ 117,123		19%
2500 kVA Transformer	EA	\$ 95,018	\$ 24,509	\$ 119,527	15%	\$ 123,203		19%
100A Panelboard	EA	\$ 2,347	\$ 4,923	\$ 7,270	15%	\$ 8,009	Assuming \$145/hr for 2 workers in 2 days. No crane assur	11%
150A Panelboard	EA	\$ 2,816	\$ 4,923	\$ 7,740	15%	\$ 8,478	Assuming \$145/hr for 2 workers in 2 days. No crane assur	11%
225A Panelboard	EA	\$ 5,289	\$ 4,923	\$ 10,212	15%	\$ 10,950	Assuming \$145/hr for 2 workers in 2 days. No crane assur	14%
400A Main Switchboard	EA	\$ 17,770	\$ 7,385	\$ 25,154	15%	\$ 26,262	Assuming \$145/hr for 2 workers in 3 days. No crane assur	17%
600A Main Switchboard	EA	\$ 21,533	\$ 7,385	\$ 28,918	15%	\$ 30,026	Assuming \$145/hr for 2 workers in 3 days. No crane assur	18%
800A Main Switchboard	EA	\$ 25,297	\$ 7,385	\$ 32,682	15%	\$ 33,789	Assuming \$145/hr for 2 workers in 3 days. No crane assur	19%
1200 Main Switchboard	EA	\$ 33,195	\$ 7,385	\$ 40,579	15%	\$ 41,687	Assuming \$145/hr for 2 workers in 3 days. No crane assur	19%
1600A Main Switchboard	EA	\$ 34,675	\$ 7,385	\$ 42,060	15%	\$ 43,168	Assuming \$145/hr for 2 workers in 3 days. No crane assur	20%
2000A Main Switchboard	EA	\$ 39,982	\$ 9,846	\$ 49,828	15%	\$ 51,305	Assuming \$145/hr for 2 workers in 4 days. No crane assur	19%
2500A Main Switchboard	EA	\$ 45,288	\$ 9,846	\$ 55,134	15%	\$ 56,611	Assuming \$145/hr for 2 workers in 4 days. No crane assur	20%
3000A Main Switchboard	EA	\$ 101,558	\$ 9,846	\$ 111,404	15%	\$ 112,881	Assuming \$145/hr for 2 workers in 4 days. No crane assur	21%
4000A Main Switchboard	EA	\$ 107,975	\$ 9,846	\$ 117,821	15%	\$ 119,298	Assuming \$145/hr for 2 workers in 4 days. No crane assur	22%

Figure 3. Updated Unit Costs



## 6.2 Detailed Results

The scenarios add capacity for either one charger at 200kW or two chargers at 400kW, resulting in ~300A or ~600A+/- of additional panel capacity required. The capacity increase for switchgear is rounded up to the next common size available as seen in the rightmost column of Table 2.

**Table 2. Capacity Sizing for Each Scenario**

Type of Facility	W/Sqft	Sqft	Charger Capacity Added	Initial Amps-> Final Amps	Calculated Amps - Initial	Amps	Calculated Amps - Final	Final Amps
Manufacturing	19.5	20,000	1	600A -> 1200A	587	600	828	1,200
			2				1,069	1,200
		60,000	2	2000A -> 2500A	1,761	2,000	2,243	2,500
Office Building	7.6	20,000	1	400A -> 600A	229	400	470	600
			2	400A -> 800A			711	800
		60,000	2	800A -> 1200A	686	800	1,168	1200

Shown in Table 3. below, the total building costs cover a range for each building type that corresponds to the range of low and high per-square-foot construction costs taken from RSMMeans.

**Table 3. Total Building Cost Estimates for Each Building Type**

Type of Facility	Sqft	Total bldg. cost \$/Sqft – low	Total bldg. cost \$/Sqft – high	Total bldg. cost \$ – low	Total bldg. cost \$ – high
Manufacturing	20,000	146	237	3,000,000	4,800,000
	60,000	130	212	7,900,000	12,800,000
Office Building	20,000	181	294	3,700,000	5,900,000
	60,000	168	273	10,100,000	16,400,000

It is always less expensive to add capacity during initial construction compared to retrofits. Table 4. shows how the extra first cost for this capacity adds only ~0.4% to ~1.2% to the overall cost to a project for these building types.

**Table 4. First Cost vs. Retrofit Cost Comparison**

Type of Facility	Initial -> Final Amps	Current Code (\$)		Proposed Code (\$)	First cost/ total cost: median	Retrofit cost/ first cost
		First Cost of building Initial Amps	Cost of later Demolition and building Final Amps	First Cost of building Final Amps		
Manufacturing	600A -> 1200A	120,200	241,500	157,200	~1.0%	230%
			251,400	165,900	~1.2%	224%
	2000A -> 2500A	176,900	304,500	211,600	~0.4%	228%
Office Building	400A -> 600A	92,000	213,000	131,900	~0.9%	231%
	400A -> 800A		231,600	148,300	~1.2%	218%
	800A -> 1200A	124,500	262,100	174,300	~0.4%	222%

## 6.3 Example Cost Estimate Calculation

Each scenario requires specific equipment to deliver the required capacity. In Figure 4. the increased capacity for the 20,000 sq ft Manufacturing Facility rounds up to 600A (1200A total). This increase primary impacts the transformer and switchboard.

Manufacturing	Bldg Area 20,000	Option MF 20K 1 sp: 600A -> 1200A										
		Build w/ current code & then retrofit				Build more infrastructure now				Delta		
		Unit	Unit Cost	Qty	Total Construction Cost	Unit Cost	Qty	Total Construction Cost	\$	% savings		
<b>Base Building</b>				\$	361,700			\$	157,200	\$	(204,500)	57%
<b>Equipment &amp; Feeders</b>				\$	120,200							
500 kVA Transformer	EA	\$ 76,994	1	\$	76,994			does not apply to "build more now" cases				
600A Main Switchboard	EA	\$ 28,918	1	\$	28,918			does not apply to "build more now" cases				
<b>General Conditions</b>				\$	14,298							
Indirects (Supervision, QA, Documentation)	LS	14%		\$	14,298			does not apply to "build more now" cases				
<b>EV Infrastructure</b>				\$	241,500			\$	157,200			
<b>Civil</b>				\$	48,561			\$	-			
Remove Existing Transformer	EA	\$ 2,440	1	\$	2,440			does not apply to "build more now" cases				
Remove Existing Switchgear	EA	\$ 11,323	1	\$	11,323							
Demolish wall to accommodate bigger equipment	LF	\$ 55	25	\$	1,373							
Concrete Wall	SF	\$ 68	350	\$	23,687							
Concrete Pad	CY	\$ 2,030	1.3	\$	2,632							
Finishes	SF	\$ 20	350	\$	7,106							
<b>Equipment &amp; Feeders</b>				\$	143,885			\$	138,541	\$	37,000	
750 kVA Transformer	EA	\$ 90,403	1	\$	90,403	\$	87,705	1	\$	87,705		
1200 Main Switchboard	EA	\$ 41,687	1	\$	41,687	\$	40,579	1	\$	40,579		
Conduits, 4" diam.	LF	\$ 14	142	\$	1,935	\$	12	142	\$	1,682		
Conduits, 4" diam. - 2 sets (includes trench and duct bank)	LF	\$ 69	142	\$	9,861	\$	60	142	\$	8,575		
<b>General Conditions</b>				\$	49,074			\$	18,703			
Indirects (Supervision, QA, Documentation)	LS	26%		\$	49,074	14%		\$	18,703			

**Figure 4. Cost Estimate Example**