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City of Carlsbad Electric Vehicle Ordinance Cost Analysis

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Submitted To:

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Executive Summary

The City of Carlsbad requested a cost analysis be completed to implement an electric vehicle (EV) charging infrastructure ordinance. The proposed EV ordinance would require that nonresidential new construction, residential new construction, and residential major alterations prepare for and in some cases install electric vehicle charging supply equipment (EVSE). The proposed ordinance requires a set of EVSE Capable, EVSE Ready and/or EVSE Installed parking spaces and defines the number of EV spaces as either a fraction of total parking spaces or an absolute minimum number.

The EV ordinance originates from Carlsbad's Climate Action Plan (CAP) consistency checklist and the requirements developed by Center for Sustainable Energy (CSE) in communication with City of Carlsbad.[1] TRC reviewed the ordinance requirements and defined six scenarios based on building and parking type. TRC reviewed past studies and other literature along with interviews to collect information on specifications and cost of electrical components, installation process of EV charger and other underlying construction requirements from retailers, contractors, manufacturers, industry experts and RSMeans.

In new construction scenarios, TRC compared the costs for installing proposed EV infrastructure with the mandatory 2016 CALGreen requirements. That incremental cost was then compared to the incremental cost of retrofitting a building that is 2016 CALGreen compliant during an untriggered retrofit to find the avoided retrofit costs.

In major alteration scenarios, the cost of installing the proposed EV infrastructure in existing residential buildings was compared with an untriggered EV retrofit scenario. The added costs of installing EV in an untriggered retrofit represent the cost savings benefits of integrating EV charging infrastructure during major alterations.

Figure 1 through Figure 3 provide TRC's estimates for avoided retrofit costs for each scenario. The avoided retrofit costs percentage range from 8 to 46 depending on building type and defined EV parking scenarios. The difference in avoided retrofit cost percentage between the surface and enclosed parking type is larger in major alterations because of the added demolition costs.

Figure 1. Cost results for single-family building

	Single-family New construction		Single-family Major Alterations	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Measure type	EVSE Ready	EVSE Ready	EVSE Ready	EVSE Ready
Parking type	Surface	Enclosed	Surface	Enclosed
Cost savings	$175	$175	$758	$758
% Cost savings	36%	38%	27%	46%

[1] City of Carlsbad Climate Action Plan (Sept 2015). Dyett & Bhatia Urban and Regional Planners. Available at: http://www.carlsbadca.gov/civicax/filebank/blobdload.aspx?BlobID=29361

Figure 2. Cost results for multifamily building

	Multifamily New construction		Multifamily Major Alterations	
	Scenario 3	Scenario 4	Scenario 3	Scenario 4
Measure type	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed
Parking type	Surface	Enclosed	Surface	Enclosed
Cost savings	$1,603	$538	$413	$433
% Cost savings	31%	17%	8%	13%

Figure 3. Cost results for nonresidential building

	Nonresidential New construction	
	Scenario 5	Scenario 6
Measure type	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed
Parking type	Surface	Enclosed
Cost savings	$1,869	$904
% Cost savings	37%	23%

1 Introduction

The City of Carlsbad engaged TRC to research and analyze the costs of an electric vehicle charging infrastructure ordinance as a part of City's Climate Action Plan (CAP) goals. The intent is to mandate electric vehicle readiness for residential new construction and major alterations, as well as nonresidential new construction buildings.

TRC analyzed the following conditions, described in more detail throughout this report:

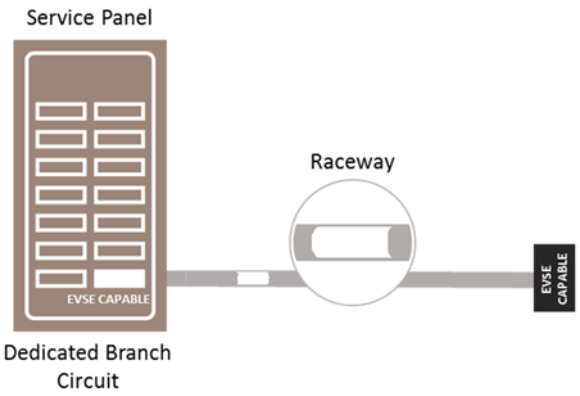
- **Measure Types:** EVSE Capable, EVSE Ready, or EVSE Installed (described further in *Section 1.1 Measure Types*)
- **Ordinance Requirements**: A mixture of Measure Types for each building type dependent on the number of parking spaces (described further in *Section 1.2 Ordinance Requirements*)
- **Construction Types**: New construction, major alteration, untriggered retrofit (discussed further in *Sections 1.2 Ordinance Requirements* and *1.3 Analysis Scope*)
- **Scenarios**: Enclosed or Surface (described further in *Section 2.2 Scenarios*)
- **Measure Components**: Materials and labor associated with EV Measure Types (described further in *Section 3 Measure Component Descriptions and Costs)*

1.1 Measure Types

The proposed ordinance for the electric vehicle measure is aligned with current 2016 CALGreen Voluntary Tiers as well as 2019 CALGreen[2] requirements for Electric Vehicle (EV) ready infrastructure, provided by the City of Carlsbad and Center for Sustainable Energy (CSE). The EV ordinance requirements have three types of measures:

- **EVSE Capable:** Installation of "raceway" (the enclosed conduit that forms the physical pathway for electrical wiring to protect it from damage), and adequate panel capacity to accommodate future installation of a dedicated branch circuit and charging station(s).

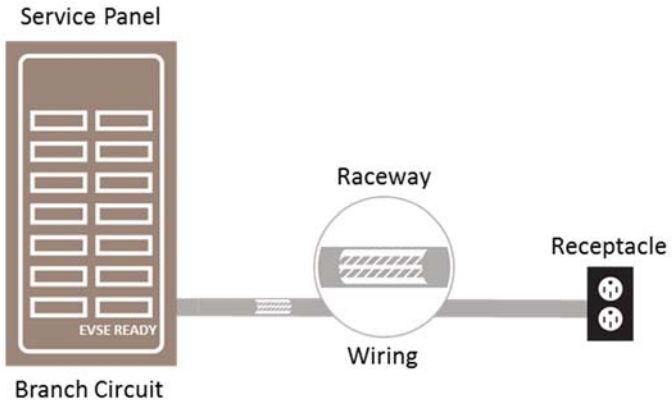
Figure 4. EVSE Capable Schematic



- **EVSE Ready:** Installation of dedicated branch circuit(s), circuit breakers, and other electrical components, including a receptacle or blank cover needed to support future installation of one or more charging stations.

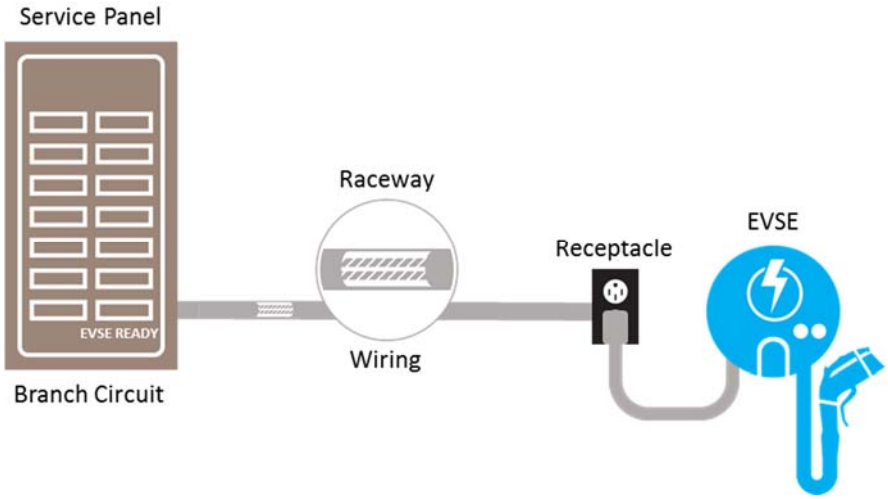
[2] For 2016 requirements visit: https://codes.iccsafe.org/content/document/658?site_type=public
For 2019 requirements visit: https://www.energy.ca.gov/title24/2019standards/rulemaking/documents/calgreen-code/index.php.

Figure 5. EVSE Ready Schematic



- **EVSE Installed:** An EV space with dedicated branch circuit(s), circuit breakers, and other electrical components, including a receptacle. The receptacle shall be equipped with electric vehicle supply equipment (EVSE).

Figure 6. EVSE Installed Schematic



1.2 Ordinance Requirements

The ordinance requirements for EV parking spaces are explained below and summarized in Figure 7 at the end of this section.

1.2.1 Nonresidential New Construction

The proposed EV ordinance would mirror the current 2016 CALGreen Voluntary Tier 2 provisions that all new nonresidential construction have 10% of parking spaces, or a minimum of 1 space, be **EVSE Capable**. The proposed ordinance would further require that 50% of the EVSE Capable spaces, or a minimum of 1 space, must be an **EVSE Installed** space.

There are no nonresidential alterations requirements proposed.

1.2.2 Residential New Construction

The proposed EV ordinance would require all new residential construction to meet the following requirements:

- One- and two-family dwellings and townhouses with attached private garages must have 1 parking space per dwelling unit be **EVSE Ready**, which is consistent with current CALGreen Voluntary Tier 1 and Tier 2 provisions.
- Consistent with proposed 2019 CALGreen mandatory requirements, multi-family projects (3 or more dwelling units) must have 10% of parking spaces, or a minimum of 1 space, be **EVSE Capable**. The proposed ordinance would further require that 50% of the EVSE Capable spaces, or a minimum of 1 space, must be an **EVSE Installed** space. Where common or visitor use parking is provided, at least one EV parking space equipped with EVSE shall be in the common or visitor parking area and shall be available for use by all residents.

1.2.3 Residential Major Alterations

All residential additions and alterations that meet one of the following thresholds must meet the residential new construction requirements.

- One- and two-family dwellings and townhouses
  - Project includes an electrical service panel upgrade, or
  - Project has a permit valuation ≥ $60,000.
- Multi-family project (3 or more dwelling units) is a major alteration as defined by CALGreen and has a permit valuation ≥ $200,000.[3]

1.2.4 Potential Exemptions

On a case-by-case basis, Carlsbad may choose to determine that EV charging and infrastructure are not feasible based upon one or more of the following conditions drawing from CALGreen and the City of San Francisco requirements:

1. Where there is no commercial power supply.
2. Where there is evidence substantiating that meeting the requirements will alter the local utility infrastructure design requirements on the utility side of the meter to increase the utility side cost to the homeowner or the developer by more than $400 per parking space. In such cases, buildings subject to CALGreen Section 4.106.4 shall maximize the number of EV Charging Spaces, up to a utility side cost of a maximum of $400 per space. Cost shall be determined by dividing the increase in local utility infrastructure cost attributable to compliance with this section by the sum of parking spaces and EV Charging Spaces.

[3] Major Alterations: Alterations and additions where interior finishes are removed and significant site work and upgrades to structural and mechanical, electrical, and/or plumbing systems are proposed. Significant site work as used herein means site alterations that: require a grading permit pursuant to CMC Chapter 15.16; rehabilitate or install 2,500 square feet or more of landscaping; or repave, replace or add 2,500 square feet or more of vehicle parking and drive area.

3. In major alterations, where there is evidence substantiating that meeting the requirements of this section presents an unreasonable hardship or is technically infeasible, the project sponsor may appeal to reduce the number of EV Charging Spaces required or provide for EV charging elsewhere.

Figure 7. Ordinance requirements for number of EV parking spaces

	EVSE Capable	EVSE Ready	EVSE Installed
One- and two-family dwellings and townhouses with attached private garages		1 space per dwelling unit	
Multi-family Projects (3 or more dwelling units)	10% or a minimum of 1 space		50% of EVSE Capable spaces or a minimum of 1 space; minimum of 1 space in common parking
Nonresidential projects	10% or a minimum of 1 space		50% of EVSE Capable spaces or a minimum of 1 space

1.3 Analysis Scope

TRC assessed the costs of installing charging infrastructure for EVs, for both residential new construction and alterations and nonresidential new construction. TRC used single family, low-rise multifamily and nonresidential office prototype buildings to evaluate the scenarios outlined in Figure 7 above. Surface parking or garage specifications are dependent on prototype building floor areas and Carlsbad's parking requirements. A major alteration scenario is analyzed only for residential buildings according to the proposed ordinance parameters and is like the new construction scenario except for added demolition costs specific to EV construction.

TRC determined the total cost of the EVSE Capable, EVSE Ready, and EVSE Installed options for new construction and major alterations, compared them to the relevant baseline, and then compared the incremental cost to an untriggered retrofit scenario:

1. **New Construction: EV space requirements already required in 2016 CALGreen.** Costs for adhering to Carlsbad's proposed ordinance will be compared to the costs to adhere to the 2016 CALGreen mandatory requirements. The incremental cost difference is compared to the cost of retrofitting a building that has met the 2016 CALGreen standards to determine the avoided retrofit costs.
2. **Major Alterations: a similar untriggered retrofit for EV infrastructure without any other major site work.** The untriggered retrofit scenario assumes that an EV retrofit is happening in isolation, and thus has higher costs associated with infrastructure upgrades and permitting.[4] This cost analysis is intended to illustrate that the proposed ordinances will reduce costs for EV upgrades associated with major alterations in comparison to no EV ordinance, assuming that EV retrofits would need to take place eventually in order to meet California's greenhouse gas emissions goals.[5] This report only covers construction costs and does not include benefits or costs associated with operating electric vehicles, such as reduced greenhouse gas emissions or increased electric utility rates.

1.4 Assumptions

This study has the following assumptions:

- **Location.** All cost analysis is intended to be relevant to Carlsbad region.

[4] 2016 CALGreen is not the baseline for major alterations, because CALGreen does not require major alterations to install EV spaces.

[5] Executive Order B-55-18 to Achieve Carbon Neutrality. Available at: https://www.gov.ca.gov/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf

- **Building Prototypes.** TRC used standard California Energy Commission-defined prototypes for the basis of developing parking area geometry and associated infrastructure geometry, such as electrical panel locations and conduit lengths. Findings are intended to be pertinent to, but not representative of, the variety of geometries present in many building types. Prototypes are the same as those analyzed for Carlsbad energy efficiency ordinances.
- **Sensitivity.** The study assumes one set of design conditions at one specific point in time.

2 Methodology

TRC estimated the avoided retrofit costs of the proposed EV ordinances by comparing the costs of new construction against their untriggered retrofit scenario assuming CALGreen-required EV infrastructure was already in place. Major alterations were compared against an untriggered EV charging retrofit, assuming no existing EV infrastructure was in place. TRC evaluated both surface (outdoor) parking and enclosed (indoor) parking scenarios for each building type.

2.1 Prototypes

TRC used the following building types to determine the parking area parameters per Carlsbad municipal code and ultimately the costs associated with EV infrastructure:

- 2,700 ft^2 two-story home. Parking space is either on an exterior driveway or an attached garage.
- 6,960 ft^2 low-rise multifamily residential building, with two stories and eight dwelling units. Parking is either on an adjacent parking lot or an enclosed garage.
- 5,502 ft^2 one-story small office building. Parking is either on an adjacent parking lot or an enclosed garage.

2.2 Scenarios

TRC analyzed Carlsbad's proposed requirements for each of the three building types with both surface and enclosed parking, resulting in a total of six scenarios. The number of parking spaces for every scenario is defined as per the proposed ordinance and Carlsbad municipal code parking requirements.[6]

- Regardless of the number of parking spaces required by the municipal code, single family buildings will be required to have one 'EVSE ready' parking space.
- For the multifamily building, municipal code requires 1.5 and 2 spaces per one- and two-bedroom dwelling units, respectively, plus .3 visitor spaces per unit. The multifamily prototype has 4 one-bedroom and 4 two-bedroom units, amounting to a total of 14 resident and three visitor parking spaces. Per the proposed ordinance requirements in *Section 1.2* Ordinance Requirements, this multifamily building would be required to have two EVSE Capable parking spaces with one being an EVSE Installed space.
- For the office building, the Carlsbad municipal code requires 1 space per 250 ft^2 of gross floor area. The small office prototype has 5,502 ft^2 of floor area and will have 22 parking spaces. Per the proposed ordinance requirements in *Section 1.2 Ordinance Requirements*, this office building would require two EV parking spaces, one EVSE Capable and one EVSE Installed.

The six proposed scenarios have the same number of required parking spaces for both surface and enclosed parking as well as new construction and major alterations.

As described in Section 1.3, TRC compared Carlsbad's proposed ordinance costs for new construction scenarios to a 2016 CALGreen mandatory EV charging baseline and then to an untriggered retrofit scenario to identify avoided retrofit costs. Proposed ordinance costs for major alterations are compared to an untriggered retrofit scenario. The untriggered retrofit scenario assumes that an EV retrofit is happening in isolation, and thus has higher costs associated with infrastructure upgrades and permitting.

[6] Carlsbad Municipal Code - Section 21.44.020 Off-street parking spaces required. http://www.qcode.us/codes/carlsbad/

Figure 8 summarizes the EV scenarios per Carlsbad's proposed ordinance for the prototypes described in Section 2.1, which are the same for new construction and major alterations.

Figure 8. Carlsbad proposed ordinance - Parking spaces in new construction and major alterations

	Single-family		Multifamily		Nonresidential (new construction only)	
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Parking type	Surface	Enclosed	Surface	Enclosed	Surface	Enclosed
Total EV parking spaces	**1**	**1**	**2**	**2**	**2**	**2**
- ***EVSE Capable***	*0*	*0*	*1*	*1*	*1*	*1*
- ***EVSE Ready***	*1*	*1*	*0*	*0*	*0*	*0*
- ***EVSE Installed***	*0*	*0*	*1*	*1*	*1*	*1*

2016 CALGreen is the baseline for new construction, shown in Figure 9. The eight-dwelling unit multifamily prototype would not trigger the 2016 CALGreen mandatory requirements, which requires EV spaces for multifamily buildings of 17 dwelling units or more.

Figure 9. 2016 CALGreen mandatory requirements – Parking spaces in new construction

	Single-family		Multifamily		Nonresidential	
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Parking type	Surface	Enclosed	Surface	Enclosed	Surface	Enclosed
Total EV parking spaces	**1**	**1**	**0**	**0**	**1**	**1**
- ***EVSE Capable***	*1*	*1*	*0*	*0*	*1*	*1*
- ***EVSE Ready***	*0*	*0*	*0*	*0*	*0*	*0*
- ***EVSE Installed***	*0*	*0*	*0*	*0*	*0*	*0*

2.3 Cost Determination

TRC determined the total cost of the EVSE Capable, EVSE Ready, and EVSE Installed measure types for new construction and major alterations per the ordinance requirements and compared them to their respective baseline to find the incremental cost of the proposed ordinance requirements. To summarize:

- **Baseline Costs:** 2016 CALGreen Mandatory requirements for new construction. Existing residential buildings are assumed to not being prepared for EV charging infrastructure, so no baseline was considered for existing residential.
- **Proposed Ordinance Costs:** The cost of installing EV charging infrastructure to meet the requirements of the proposed ordinance as part of residential or nonresidential new construction or as a retrofit in existing residential major alterations.
- **Incremental Costs:** The cost difference between the proposed ordinance costs and the respective baseline costs.

Incremental costs were compared to a similar untriggered EV charging infrastructure retrofit that installed EV infrastructure without any other major site work. The untriggered retrofit scenario assumes that an EV retrofit is

happening in isolation, and thus has higher costs associated with infrastructure upgrades and permitting. For new construction, the untriggered retrofit scenario assumes 2016 CALGreen Mandatory measures have already been installed. For existing construction, the untriggered retrofit scenario assumes the building has not been prepared for EV infrastructure.

- **Untriggered Retrofit Costs:** The cost of retrofitting a baseline building with EV charging infrastructure to meet the proposed ordinance requirements as an isolated retrofit.

The results are demonstrated in terms of avoided retrofit costs or *cost savings* value and percentage.

Cost savings value is defined as:

(Retrofitted Costs – Incremental Costs) = Avoided Retrofit Costs

and cost savings percentage is defined as

(Retrofitted Costs – Incremental Costs) / Retrofit Costs = Avoided Retrofit Cost Percentage

TRC performed a literature review, interviewed electrical contractors and engineers and EV experts, and used online cost databases to determine components costs associated with EV charging infrastructure. [7] TRC identified the components for each measure type based on the proposed ordinance language, EVSE installation guidelines and typical electrical engineering design assumptions.[8,9,10] Components primarily include electrical panel upgrades, dedicated raceway installation, subterranean trenching, permitting, and EVSE.

[7] The online cost database was RS Means: https://www.rsmeansonline.com/
[8] https://www.chargepoint.com/files/home/home-install-guide.pdf
[9] https://www.chargepoint.com/files/CT4000_Install_Guide.pdf
[10] https://energycenter.org/sites/default/files/docs/nav/transportation/plug-in_sd/Plug-in%20SD%20Installation%20Best%20Practices%20Report.pdf

3 Measure Component Descriptions and Costs

TRC investigated the proposed ordinance requirements as per the parameters defined by the Center for Sustainable Energy and the City of Carlsbad described in *Section 1.2 Ordinance Requirements*. This section describes in detail each component of EV infrastructure, the cost estimate for each component, and the source of those costs.

Per guidance from the City of Carlsbad, TRC assumed that the City would require infrastructure compatible with Level 2 EV chargers. Please see *Section 3.6 Electric Vehicle Supply Equipment* for further detail on the types of chargers.

3.1 Electrical Panel

The first step toward EVSE Readiness is to ensure that the electrical panel has enough capacity to integrate EV charging infrastructure. TRC estimated the baseline panel size (i.e., the panel that would have served the parking area without any additional EV infrastructure requirements) as well as the upgraded panel to meet the proposed ordinance requirements as shown in Figure 10. Panel sizes were determined using the following assumptions:

- Surface parking areas require a panel for providing outdoor lighting.
- Enclosed parking areas require a panel for providing indoor lighting and exhaust ventilation.
- A Level 2 EV charger requires 40 Amps (40A) of panel capacity.

TRC oversized both baseline panel cases so that neither are at full capacity. In other words, electrical panel capacity increases may not be directly proportional to the number of EV spaces multiplied by 40A.[11]

Single Family: Newly-constructed single family dwellings and panel upgrades to existing dwellings are typically done with a 200A panel. With exceptions for very large homes, a 200A panel typically has sufficient capacity for an EV charging circuit in addition to the rest of the home's electrical needs and does not require any further upgrade. Thus, the baseline panel size and proposed panel sizes are equivalent.

Multifamily: The prototype has eight dwelling units and is not subject to 2016 CALGreen requirements. TRC assumes that baseline panel size for the open surface parking area is a separate 100A panel for lighting, and for the enclosed parking area is 150A to serve lighting as well as exhaust fans. TRC assumes that the EV infrastructure would necessitate an upgrade to 200A panel in both surface and enclosed scenario to serve the additional load of two EV parking spaces.

Office Building: 2016 CALGreen code requires only one EV parking space. TRC assumes a separate panel for parking areas with a baseline size of 150A and 200A for all surface and enclosed scenarios respectively. These panels are upgraded to 200A and 250A for surface and enclosed scenarios to account for two proposed EV parking spaces in Scenarios 5 and 6.

In the new construction and major residential alterations scenarios a panel update would trigger EVSE requirements, and the increase in panel capacity is the only incremental cost. Untriggered retrofit costs include a new panel installation because TRC assumes that in the absence of an ordinance a panel upgrade would be necessary for the EV infrastructure. TRC assumed the same panel sizes for major alterations and untriggered retrofits except a lower baseline panel size of 150A for single family existing buildings in the untriggered retrofit

[11] https://energycenter.org/sites/default/files/docs/nav/programs/pev-planning/san-diego/fact-sheets/ResComm%20EVSE%20Permit%20Guidelines%20v3_Final_attach.pdf

scenario. The 150A size is based on electrical contractor interviews and assumes that a panel upgrade is only being performed for EV infrastructure upgrade.

The associated materials and labor costs for panel upgrades are calculated from RSMeans as summarized in Figure 10 below. 'Panel Upgrade Cost' represents the incremental cost between the Base Panel to the EVSE-Readiness Panel.

Figure 10. Base and EV-ready panel size and associated upgrade costs

		Single-family		Multifamily		Nonresidential	
Construction Type		**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**
New Construction	Baseline (2016 CALGreen) panel (Amp)	200	200	100	150	150	200
	Proposed panel (Amp)	200	200	200	200	200	250
	Incremental Panel Upgrade Cost	**$0**	**$0**	**$1,099**	**$325**	**$325**	**$131**
New Construction *– Untriggered Retrofit*	Baseline (2016 CALGreen) panel (Amp)	200	200	100	150	150	200
	Proposed panel (Amp)	200	200	200	200	200	250
	Retrofitted Panel Upgrade Cost	**$0**	**$0**	**$1,337**	**$583**	**$563**	**$650**
Major Alteration **(Res Only)**	Baseline panel (Amp)	150	150	100	150	-	-
	Proposed panel (Amp)	200	200	200	200	-	-
	Incremental Panel Upgrade Cost	**$0**	**$0**	**$1,099**	**$325**	**-**	**-**
Major Alteration *– Untriggered Retrofit*	Baseline panel (Amp)	150	150	100	150	-	-
	Proposed panel (Amp)	200	200	200	200	-	-
	Retrofitted Panel Upgrade Cost	**$583**	**$583**	**$1,337**	**$583**	**-**	**-**

3.2 Electrical Branch Circuit

Each EV parking space requires a dedicated 240V 40A branch circuit. TRC assumes this branch circuit would not exist if no EV parking space was installed.

The number of branch circuits required to be installed are directly proportional to the total number of EVSE ready or EVSE Installed spaces, however several 40A circuits can share a single conduit from the panel to the location of the EV parking spaces. EVSE Capable spaces do not require installation of a full electrical circuit for compliance, just empty conduits terminating in outlet boxes. The cost of circuit breakers is not added separately as breakers are already included with the upgraded panel and must only be reserved for future EV use. Full circuit installation includes conduit, electrical wiring and outlet.

Conduit

TRC estimated the length of polyvinyl chloride (PVC) conduits for each building type based on assumptions for distance between the electrical panel serving the parking area and the EV parking spaces. The thickness and diameter of the conduit aligns with installation guides provided by the manufacturers and electrical contractors,

and depends on the number of wires running through the conduits.[12] For scenarios with multiple EV parking spaces, there can be multiple wires running through the conduits that would be branched closer to the parking spaces. TRC assumed a 2" diameter to allow enough room for wires for multiple circuits.

TRC assumed the following conduit lengths:

- For the single-family building, 55 ft. for surface parking and 50 ft. for enclosed parking.
- For multifamily building, 80 ft. for both surface and enclosed parking. In surface parking, conduit would travel in a straight line from the panel to the nearest parking space. In enclosed parking, conduit would have to travel up and down walls and across ceilings to the nearest parking space.
- For the small office, 100 ft. of shared conduit plus 20 ft. of conduit branching off to the two EV spaces. TRC assumes that EV charger mounts are installed with dual outlets.

Electrical Wiring

TRC assumed 600 volt #10 wires including three THW (thermoplastic, high heat and water resistant) copper wires and a ground to estimate the costs, typically used when installing outdoors. The length of wiring is equivalent to the length of conduit and number of EVSE ready or EVSE Installed spaces.

Outlet

The term 'outlet' here collectively includes cost for outlet box, cover, and receptacle (if applicable). TRC assumed that 4" pressed steel outlet boxes are installed for each of the three EV configurations and that receptacles are installed for EVSE Ready and EVSE parking spaces only with an additional $89 cost per receptacle.

Figure 11 summarizes the specification and materials and labor costs of branch circuit components commonly applied to EV spaces.

[12] https://energycenter.org/sites/default/files/docs/nav/programs/pev-planning/san-diego/fact-sheets/ResComm%20EVSE%20Permit%20Guidelines%20v3_Final_attach.pdf

Figure 11. Electrical branch circuit costs

		Single-family		Multifamily		Nonresidential	
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Measure Type		EVSE Ready	EVSE Ready	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed
Parking Type		Surface	Enclosed	Surface	Enclosed	Surface	Enclosed
Total EV Parking Spaces		1	1	2	2	2	2
2" PVC Conduits							
	Baseline Length (ft.)	55	50	0	0	120	120
	Proposed Length (ft.)	55	50	80	80	120	120
	Baseline (2016 CALGreen) Cost	$547	$497	$0	$0	$1,193	$1,193
	Proposed Cost	$547	$497	$795	$795	$1,193	$1,193
	Incremental Cost	***$0***	***$0***	***$795***	***$795***	***$0***	***$0***
600V, #10 wires							
	Baseline Length (ft.)	0	0	0	0	0	0
	Proposed Length (ft.)	55	50	80	80	120	120
	Baseline Cost	$0	$0	$0	$0	*$0*	*$0*
	Proposed Cost	$198	$180	$289	$289	*$433*	*$433*
	Incremental Cost	***$198***	***$180***	***$289***	***$289***	***$433***	***$433***
Outlets							
	Baseline (2016 CALGreen) Count	1	1	0	0	1	1
	Proposed Count	1	1	2	2	2	2
	Baseline Cost	$51	$51	$0	$0	$51	$51
	Proposed Cost	$140	$140	$190	$190	$190	$190
	Incremental Cost	***$89***	***$89***	***$190***	***$190***	***$139***	***$139***
New Construction	Total Branch Circuit Baseline (2016 CALGreen) Cost	$598	$548	$0	$0	$1,244	$1,244
	Total Branch Circuit Proposed Cost	$885	$817	$1,274	$1,274	$1,816	$1,816
	Total Branch Circuit Incremental/Retrofitted Cost	**$287**	**$269**	**$1,274**	**$1,274**	**$662**	**$662**
Major Alterations	Total Branch Circuit Baseline Cost	$0	$0	$0	$0	$0	$0
	Total Branch Circuit Proposed Cost	$885	$817	$1,274	$1,274	$1,816	$1,816
	Total Branch Circuit Incremental/Retrofitted Cost	**$885**	**$817**	**$1,274**	**$1,274**	**$1,816**	**$1,816**

3.3 Construction and Demolition

Surface parking scenarios require trenching and backfilling work for subterranean electrical conduits connecting the panel to the charging heads. Costs are proportional to the distance between the charging units and service panels. TRC included costs associated with equipment rental for a backhoe and asphalt spreader in major alterations and untriggered retrofit scenarios but excluded them for new construction as they would already be used for the new parking. The major alteration and untriggered retrofit scenario involves additional demolition costs to run the conduits through existing concrete walls. Figure 12 summarizes the construction related costs.

Figure 12. Construction and demolition costs

	Single-family		Multifamily		Nonresidential	
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Trenching						
Length (ft.)	55	N/A	80	N/A	120	N/A
Cost	*$93*	N/A	*$135*	N/A	*$202*	N/A
Demolition/paving						
Length (ft.)	55	N/A	80	N/A	120	N/A
Cost	*$342*	*$28*	*$498*	*$98*	*$746*	*$197*
Equipment Rental						
Duration (day)	1	N/A	1	N/A	1	N/A
Cost	*$614*	N/A	*$614*	N/A	*$614*	N/A
TOTAL						
New Construction – Baseline	**$0**	**0**	**$1,247**	**$98**	**$1,361**	**$197**
New Construction – Proposed	**$0**	**0**	**$135**	**0**	**$0**	**0**
Major Alterations – Baseline	**$1,049**	**$28**	**$1,247**	**$98**	**-**	**-**
Major Alterations – Proposed	**$1,049**	**$28**	**$1,247**	**$98**	**-**	**-**

3.4 Construction Management

TRC increased materials and labor costs by seven (7) percent to account for construction management overhead (i.e., planning and coordination).[13] This includes both electrical and construction work defined in sections above. Figure 13 below summarizes the total construction management costs for all scenarios.

Figure 13. Construction management costs

	Single-family		Multifamily		Nonresidential	
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
New Construction – Baseline	$20	$19	$176	$96	$135	$54
New Construction – Proposed	$20	$19	$99	$89	$40	$40
Major Alterations – Baseline	$135	$59	$176	$96	-	-
Major Alterations – Proposed	$94	$21	$176	$96	-	-

3.5 Permitting

Electrical panel upgrades and electrical wiring must be in conformance with the current edition of the California Electrical Code.[14] To verify compliance, TRC estimated electrical and building permit costs as per the City of

[13] The percentage is assumed based on literature review and electrical contractor interviews.
[14] https://energycenter.org/sites/default/files/docs/nav/programs/pev-planning/san-diego/fact-sheets/ResComm%20EVSE%20Permit%20Guidelines%20v3_Final_attach.pdf

Carlsbad master fee schedule.[15] TRC assumed that for new construction and major alterations the inspection fees for electrical and building construction would be included in the overall inspection fees, and not be additive specifically for the EV requirement. For the baseline untriggered retrofit scenarios, TRC has added permit costs for building construction and electrical inspections because the work scope is solely EV charging infrastructure upgrades. This measure will trigger a Cogen permit with a work class of EVC and a fee of $175.

Figure 14. Permitting and inspection fees

	Single-family		Multifamily		Nonresidential	
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
New Construction – Baseline	$175	$175	$175	$175	$175	$175
New Construction – Proposed	$0	$0	$0	$0	$0	$0
Major Alterations – Baseline	$175	$175	$175	$175	-	-
Major Alterations – Proposed	$0	$0	$0	$0	-	-

3.6 Electric Vehicle Supply Equipment

The third proposed EV configuration is EVSE Installed, which includes the installation of the EV charging equipment. The Carlsbad region has access to many trained electrical contractors and EVSE suppliers such as ChargePoint, ClipperCreek, Greenlots and Siemens.

EVSE is characterized by amperage and voltage that directly correlates to the speed of charging. There are three levels of EVSE:[16,17]

- **Level 1 - 120V**: Uses the charger included with the electric vehicle and plugs directly into the designated power outlet. It takes between 7-15 hours for full charge depending on the battery size.
- **Level 2 - 240V**: External chargers installed to be fitted with most cars. The amperages can range from 20-50A with requiring a 240 volt outlet. It takes between 3-5 hours for full charge.
- **DC Fast Charger (DCFC) - 480V**: Provides DC power to cars at a high charging speed of about 30 minutes.

Per direction from Carlsbad, TRC used Level 2 chargers capability to estimate EVSE costs. Level 2 charger provides an optimum balance between charging times and cost. Level 2 chargers are most suitable for office or residential buildings that have well-defined users that use the EVCS for a longer duration. One DCFC can replace five Level 2 chargers and would make most sense in a retail type building, where users park their cars for relatively short span of time. However, Level 2 chargers are more suitable for office or residential buildings that have well-defined users and that use the facility EVCS for a longer duration.

Most Level 2 chargers have a universal connector (SAE J1772) that is compatible with all major EV vehicles. TRC researched different Level 2 charger options available in the market for both residential and nonresidential building types. Residential chargers for single family units by ChargePoint, ClipperCreek, and other manufacturers are available from online vendors, and hardware costs range from $450 to $700. These are installed in attached private garages and do not necessarily require an access control to restrict its use for non-intended users. The hardware cost for multifamily and nonresidential chargers has a larger range depending on the manufacturer and added features.

[15] http://www.carlsbadca.gov/civicax/filebank/blobdload.aspx?BlobID=36324
[16] https://chargehub.com/en/electric-car-charging-guide.html
[17] https://www.sdge.com/residential/electric-vehicles/ev-charging

The EV chargers referenced in the analysis are summarized in Figure 15. These costs are applicable for all new construction, major alteration and untriggered retrofit scenarios with 40A service. TRC included both high and low range products from two popular manufacturers and used the average costs in final estimates.

Figure 15. Hardware costs for electric vehicle charger

	Manufacturer	Model	Source	Cost	Average Cost
Single Family	ChargePoint	Residential	www.amazon.com	$559	**$599**
	ClipperCreek	HCS-50	www.amazon.com	$639	
Multifamily	ChargePoint	CPF25	Smartchargeamerica.com	$1,500	**$1,033**
	ClipperCreek	HCS-40	www.clippercreek.com	$565	
Nonresidential	ChargePoint	CT4013	Smartchargeamerica.com	$3,990	**$2,278**
	ClipperCreek	HCS-40	www.clippercreek.com	$565	

In addition to hardware and installation costs, software costs may be added depending on the amount of access control required. EVSE manufacturers provide subscription options for a software interface, service and maintenance throughout the lifetime. However, software features and associated costs vary by manufacturers and are not included in this study because they vary widely, and are assumed to be equally applied in new construction, major alteration, or untriggered retrofit scenarios and thus do not represent an incremental cost.

Manufacturers such as ChargePoint offer a sophisticated software interface resulting in higher service and maintenance costs. These software capabilities are applicable to multifamily or office building type scenarios, where the owner would like to restrict access to the charging stations and charge them along with monthly amenity fees or through pay-as-you-go mobile apps. Less expensive access control options include a key card system or number code system provided either by the manufacturer or a third-party service.

4 Cost Summary

This section presents component and total costs for all scenarios and construction types in single-family, low-rise multifamily and nonresidential office building in Figure 16 through Figure 19 respectively. The proposed ordinance for new construction and residential major alterations results in 8 to 46 percent of cost savings as compared to their respective baseline untriggered retrofit scenario. Untriggered EV upgrade retrofits include higher stand-alone costs for panel upgrades, demolition, and permitting because they are not part of larger upgrades.

The absolute costs for 'surface' type parking is always higher than 'enclosed' type due to additional construction related costs. However, the comparison of cost savings between surface and enclosed parking depends on the construction type. The cost savings in surface parking are higher than enclosed parking in new construction and lower in major alterations. This is attributed to the demolition costs included in major alterations but not during new construction, lowering the cost savings percentage by a larger amount.

These costs conservatively assume new electrical panel and branch circuit installation, which may not be the case in many situations. Costs associated with panel upgrades and construction are the largest differences between the baseline and proposed ordinance.

Figure 16. Final cost summary and savings for single-family building – new construction

	Single-family New construction (BASELINE)		Single-family New Construction (PROPOSED)		Single-family New Construction (INCREMENTAL)		Single-family New Construction (RETROFIT)	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Measure type	EVSE Capable	EVSE Capable	EVSE Ready	EVSE Ready	EVSE Ready	EVSE Ready	EVSE Ready	EVSE Ready
Parking type	Surface	Enclosed	Surface	Enclosed	Surface	Enclosed	Surface	Enclosed
Electrical Panel	$0	$0	$0	$0	$0	$0	$0	$0
Electrical Branch Circuit	$598	$548	$885	$817	$288	$270	$288	$270
Construction and Demolition	$93	$0	$93	$0	$0	$0	$0	$0
Construction Management	$48	$38	$68	$57	$20	$19	$20	$19
Permitting	$0	$0	$0	$0	$0	$0	$175	$175
EVSE	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL	**$738**	**$586**	**$1,046**	**$874**	**$308**	**$288**	**$483**	**$463**
			% Cost savings		***36%***	***38%***	***n/a***	***n/a***

Figure 17. Final cost summary and savings for multifamily building – new construction

	Multifamily New Construction (BASELINE)		Multifamily New Construction (PROPOSED)		Multifamily New Construction (INCREMENTAL)		Multifamily New Construction (RETROFIT)	
	Scenario 3	Scenario 4	Scenario 3	Scenario 4	Scenario 3	Scenario 4	Scenario 3	Scenario 4
Measure type	No req't	No req't	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed
Parking type	Surface	Enclosed	Surface	Enclosed	Surface	Enclosed	Surface	Enclosed
Electrical Panel	$0	$0	$1,099	$325	$1,099	$325	$1,337	$583
Electrical Branch Circuit	$0	$0	$1,274	$1,274	$1,274	$1,274	$1,274	$1,274
Construction and Demolition	$0	$0	$135	$0	$135	$0	$1,247	$98
Construction Management	$0	$0	$99	$89	$99	$89	$176	$96
Permitting	$0	$0	$0	$0	$0	$0	$175	$175
EVSE	$0	$0	$1,033	$1,033	$1,033	$1,033	$1,033	$1,033
TOTAL	**$0**	**$0**	**$3,639**	**$2,721**	**$3,639**	**$2,721**	**$5,242**	**$3,259**
				% Cost savings	***31%***	***17%***	***n/a***	***n/a***

Figure 18. Final cost summary and savings for single-family and multifamily building – major renovations

	Single-family Major Renovations (PROPOSED)		Single-family Major Renovations (RETROFIT)		Multifamily Major Renovations (PROPOSED)		Multifamily Major Renovations (RETROFIT)	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 3	Scenario 4
Measure type	EVSE Capable	EVSE Capable	EVSE Ready	EVSE Ready	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed
Parking type	Surface	Enclosed	Surface	Enclosed	Surface	Enclosed	Surface	Enclosed
Electrical Panel	$0	$0	$583	$583	$1,099	$325	$1,337	$583
Electrical Branch Circuit	$885	$817	$885	$817	$1,274	$1,274	$1,274	$1,274
Construction and Demolition	$1,049	$28	$1,049	$28	$1,247	$98	$1,247	$98
Construction Management	$135	$59	$135	$59	$176	$96	$176	$96
Permitting	$0	$0	$175	$175	$0	$0	$175	$175
EVSE	$0	$0	$0	$0	$1,033	$1,033	$1,033	$1,033
TOTAL	**$2,069**	**$904**	**$2,828**	**$1,663**	**$4,829**	**$2,826**	**$5,242**	**$3,259**
% Cost savings	**27%**	**46%**	-	-	**8%**	**13%**	**-**	**-**

Figure 19. Final cost summary and savings for nonresidential office building

	Nonresidential New construction (BASELINE)		Nonresidential New Construction (PROPOSED)		Nonresidential New Construction (INCREMENTAL)		Nonresidential New Construction (RETROFIT)	
	Scenario 5	Scenario 6	Scenario 5	Scenario 6	Scenario 5	Scenario 6	Scenario 5	Scenario 6
Measure type	EVSE Capable	EVSE Capable	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed
Parking type	Surface	Enclosed	Surface	Enclosed	Surface	Enclosed	Surface	Enclosed
Electrical Panel	$774	$0	$1,099	$131	$325	$131	$563	$650
Electrical Branch Circuit	$1,243	$1,244	$1,816	$1,816	$573	$573	$573	$573
Construction and Demolition	$202	$0	$202	$0	$0	$0	$1,361	$197
Construction Management	$101	$87	$141	$127	$40	$40	$135	$54
Permitting	$0	$0	$0	$0	$0	$0	$175	$175
EVSE	0	0	$2,278	$2,278	$2,278	$2,278	$2,278	$2,278
TOTAL	**$2,321**	**$1,330**	**$5,536**	**$4,352**	**$3,216**	**$3,021**	**$5,085**	**$3,926**
				% Cost savings	***37%***	***23%***	***n/a***	***n/a***

5 Conclusions

For all scenarios, TRC confirmed cost savings to install EV readiness infrastructure as compared to its untriggered retrofit baseline. Results support an ordinance proposal for installing charging infrastructure for electric vehicle during new construction in residential and nonresidential building as well as residential major alterations.

For all building types, Figure 20 through Figure 22 show positive cost savings to install EV readiness requirements proposed by Carlsbad as compared to their retrofitted baselines. Carlsbad's proposed EV ordinances should be considered for adoption considering that EV installations would need to proliferate eventually in order to meet California's greenhouse gas emissions goals, and incremental costs for each building type are likely minimal when compared with other new construction costs.[18]

Figure 20. Cost savings results for single-family building

	Single-family New Construction		Single-family Major Alterations	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Measure type	EVSE Ready	EVSE Ready	EVSE Ready	EVSE Ready
Parking type	Surface	Enclosed	Surface	Enclosed
Cost savings	$175	$175	$758	$758
% Cost savings	36%	38%	27%	46%

Figure 21. Cost savings results for multifamily building

	Multifamily New Construction		Multifamily Major Alterations	
	Scenario 3	Scenario 4	Scenario 3	Scenario 4
Measure type	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed
Parking type	Surface	Enclosed	Surface	Enclosed
Cost savings	$1,603	$538	$413	$433
% Cost savings	31%	17%	8%	13%

Figure 22. Cost savings results for nonresidential building

	Nonresidential New Construction	
	Scenario 5	Scenario 6
Measure type	EVSE Capable + EVSE Installed	EVSE Capable + EVSE Installed
Parking type	Surface	Enclosed
Cost savings	$1,869	$904
% Cost savings	37%	23%

The baseline untriggered EV charging retrofit includes additional costs related to demolition, permitting, inspection and possibly longer conduits and construction costs. These costs conservatively assume electrical panel and branch circuit installation, which may not be the case in many situations.

This study is specifically for Level 2, 240V-40A chargers as they provide a reasonable optimization between charging speed and installation cost. Project developers may consider DC fast chargers for non-residential

[18] Executive Order B-55-18 to Achieve Carbon Neutrality. Available at: https://www.gov.ca.gov/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf

projects. The high charging speed of one DCFC can replace five Level 2 chargers. This is more appropriate for retail building type, however offices can still have Level 2 chargers as per the amount of access control desired.

In San Diego territory, the direct-install type incentive programs such as 'Power Your Drive' by SDG&E support installations in multi-unit dwellings and workplaces.[19] Other benefits include the Clean Air EV Rebate, bill credit and tax credits suggested by the SDG&E utility.[20] The customers can also choose to include sub-metering as applicable to facilitate special rate schedules such as EV-TOU for buildings with electric vehicles.[21] SANDAG is developing the Regional Electric Vehicle Charging Infrastructure Program, which will provide incentive funding for public and workplace charging by 2021.[22] These current and potential future incentives haven't been included in the analysis to remain conservative.

[20] https://www.sdge.com/ev-incentives
[21] https://www.sdge.com/residential/pricing-plans/about-our-pricing-plans/electric-vehicle-plans
[22] https://www.sandag.org/index.asp?projectid=560&fuseaction=projects.detail