# Electric Vehicle Charging Infrastructure Costing Study

Electrical Engineering Services

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City of Calgary & City of Edmonton

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# About This Report

The City of Calgary and the City of Edmonton commissioned this *Electric Vehicle Charging Infrastructure Costing Study* to inform local governments, developers, electrical designers, utilities, and other stakeholders, about the costs of making parking in new construction EV Ready, and the design strategies that can help minimize these costs. This report provides background information relating to EV Ready requirements; summarizes 100% EV Ready design options and costing analysis for three residential building archetypes common to the City of Calgary and City of Edmonton; and makes recommendations for EV Ready residential parking for the City of Calgary and City of Edmonton's governments.

This report was prepared by AES Engineering Ltd., an electrical engineering firm that has assisted multiple Canadian local governments in developing EV Ready requirements.

# Summary

Electric vehicle (EV) adoption is growing rapidly, and near total replacement of passenger vehicles with EVs will be required to achieve local and Federal government climate targets. Providing access to “at home” EV charging is a critical factor to ensure that households will choose EVs. Accordingly, local governments are increasingly requiring 100% “EV Ready” residential parking in new developments. EV Ready parking is defined as a parking stall that has an adjacent energized outlet (i.e. an electrical junction box or a receptacle) at which an EV supply equipment (EVSE – i.e. an EV charger) can be installed in the future.

This *Electric Vehicle Charging Infrastructure Costing Study* summarizes design options and costing analysis for three residential development archetypes typical of the Cities of Calgary’s and Edmonton’s new construction to comply with 100% EV Ready residential parking requirements. Table ES-1 summarizes the archetypes.

*Table ES-1: Overview of parking for each archetype.*

| | | | | Parking Stalls | |
|---|---|---|---|---|---|
| # | Archetype | Storeys | Number of Units | Resident | Visitor |
| 1 | High-Rise | 17 | 334 | 204 | 36 |
| 2 | Mid-Rise | 6 | 169 | 169 | 17 |
| 3 | Townhouse | 3 | 16 | 8 | 0 |

For each archetype, a range of different electrical design scenarios were developed.

For each electrical design, cost estimates were made. Figures ES-1 through ES-3 summarize the cost estimates for the various archetypes’ different electrical design scenarios. Costs are broken down into different categories of costs, including metering; communications systems; EV panels and cabling; feeders; and increases to utility service / transformer rating.

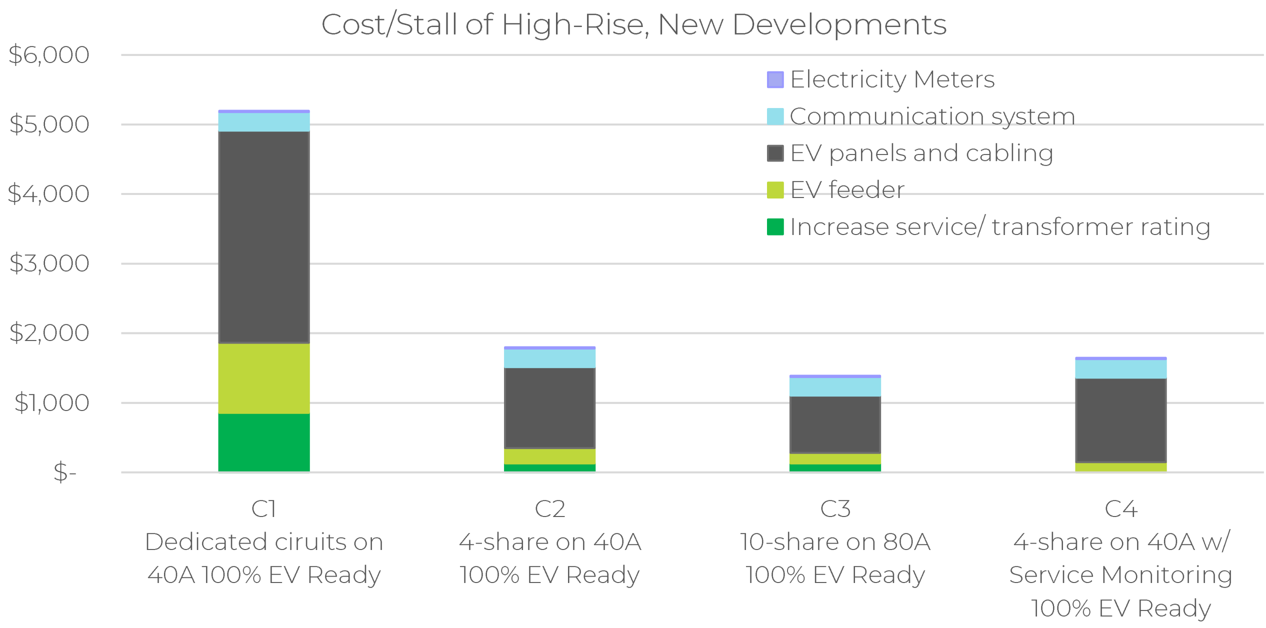



*Figure ES-1: Cost of EV charging infrastructure for the high-rise archetype in Alberta*

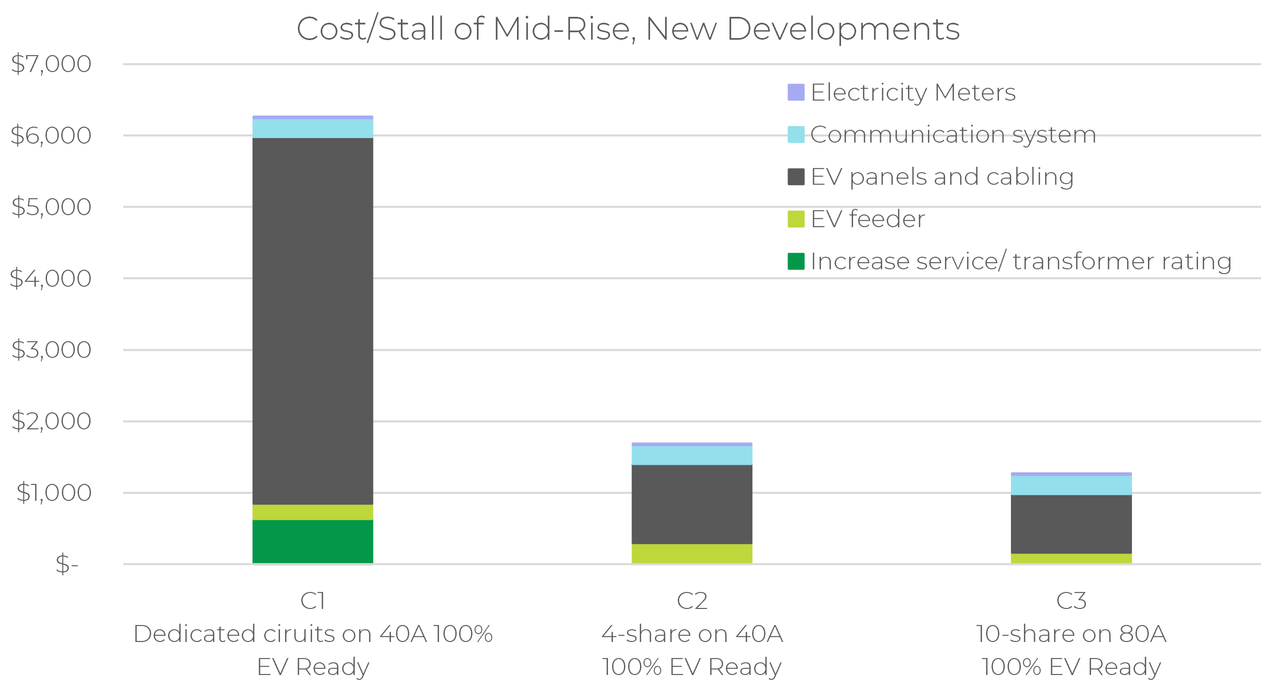



*Figure ES-2: Cost of EV charging infrastructure for the mid-rise archetype in Alberta*

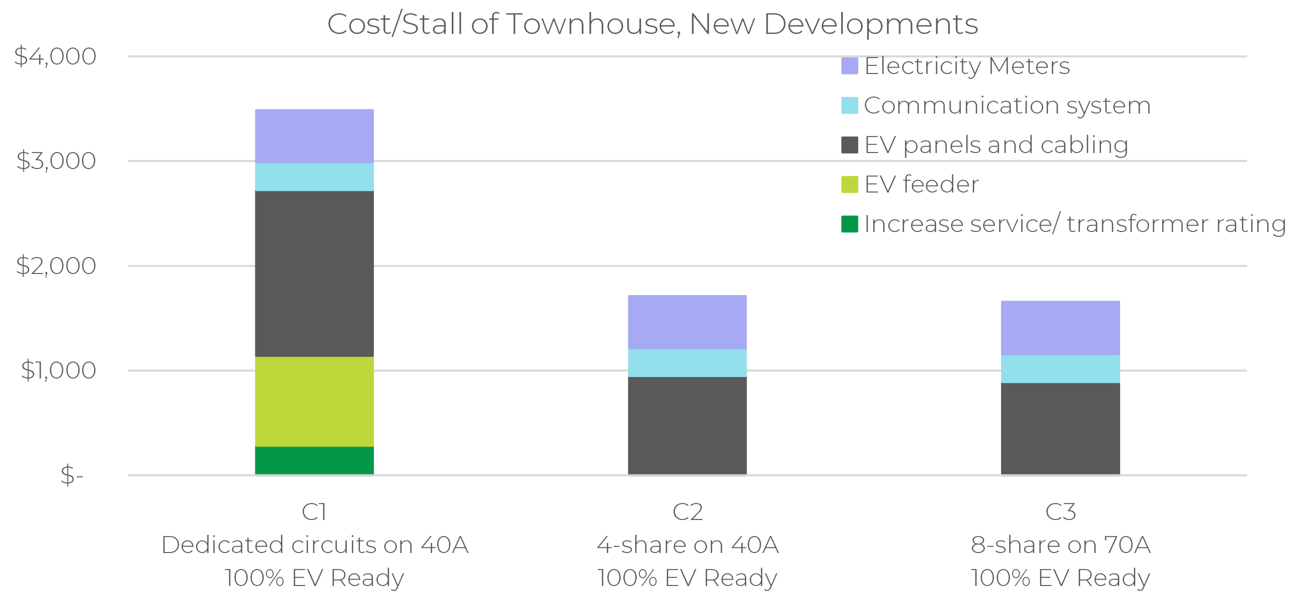



*Figure ES-3: Cost of EV charging infrastructure for the townhouse archetype in Alberta*

This costing analysis suggests that in the high-rise and mid-rise archetypes, it is possible to implement 100% EV Ready parking for approximately $1250 to $1400 per parking space. For the townhouse archetype, parking can be made EV Ready at a cost of approximately $1700 or less per parking space. These costs represent a small fraction of the cost for a new development to provide onsite parking. Moreover, future-proofing buildings with this EV charging infrastructure will realize significant value for drivers, enabling them to adopt EVs and benefit from their associated savings in total cost of vehicle ownership. The costing analysis indicates that EV charging infrastructure retrofits will be much more costly and complicated than futureproofing new construction with 100% EV Ready parking.

It is recommended that municipal governments implement 100% EV Ready requirements for residential parking in new developments.

# 1. Definitions

This section defines terms related to EV charging infrastructure.

- **Electric Vehicle (EV)**: A vehicle that can plug-in to an external source of electricity (e.g. the electrical grid) to charge an onboard battery that powers the vehicle. EVs include pure battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs).
- **Electric Vehicle Supply Equipment (EVSE):** "A complete assembly consisting of cables, connectors, devices, apparatus, and fittings installed for the purpose of power transfer and information exchange between the branch circuit and the electric vehicle" [1]. Commonly referred to as an EV charging station or EV charger.
- **EV Ready Parking Stall:** A parking stall that has an adjacent electrical outlet (i.e. a junction box with a cover plate, or a receptacle) at which an EVSE can be installed in the future, as shown in Figure 1. Drivers will install EVSE at EV Ready parking stalls over time, as they adopt EVs.

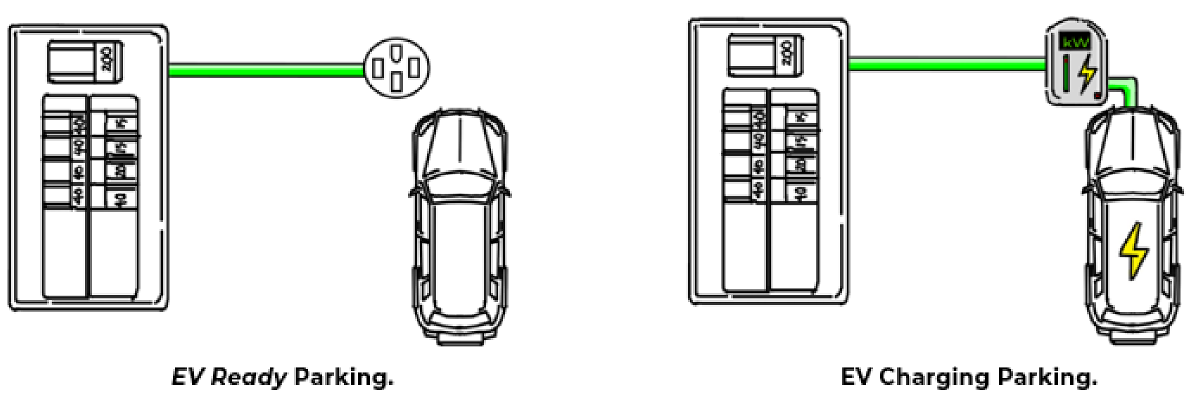



*Figure 1: EV Ready vs EV Charging Parking*

- **Level 1 (L1) EVSE:** An EVSE which supplies alternating current (AC) power, with nominal supply voltage of 120V single-phase power with maximum current of 12A (1.44kW) [2]. The voltage and amperage of L1 EVSE is typical of a regular household outlet. At 1.44kW, a L1 charger can provide approximately 4km to 8km of range per hour, depending on the vehicle.

- **Level 2 (L2) EVSE:** An EVSE which supplies AC power, with nominal supply voltage of 208V to 240V single-phase power, with maximum current of 80A (19.2kW) [2]. At 6.7kW (a common power output), a L2 charger can provide approximately 25km to 40km of range per hour, depending on the vehicle.
- **EV Energy Management System (EVEMS):** A system to "monitor electrical loads and to control [EVSE] loads", often by remote means [1]. This includes systems that allow for load sharing (one circuit shared between multiple EVSE) and service monitoring (monitoring the service and controlling EVSE to avoid overloading the service). Figure 2 helps to visualize how EVEMS compare to unmanaged charging configurations. CSA Group has published a research paper on EVEMS, which summarizes the range of EVEMS technologies, for those wishing to better understand these systems [3].

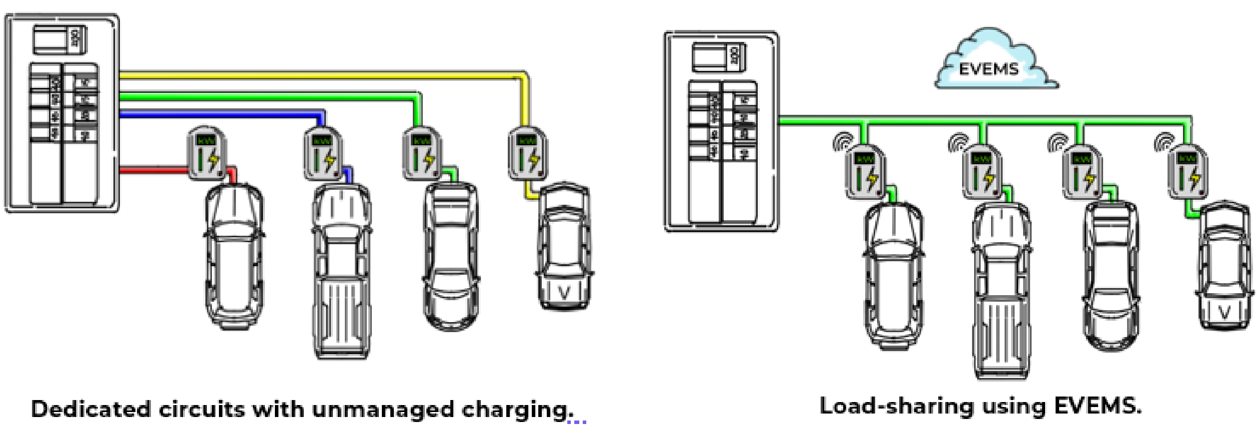



*Figure 2: Electrical configurations for visualizing EV charging options*

- **Dedicated Circuits:** A configuration of EVSE which includes a dedicated branch circuit to each EVSE, without any load sharing, as depicted in Figure 3. EV charging with dedicated circuits can operate without the use of EVEMS.

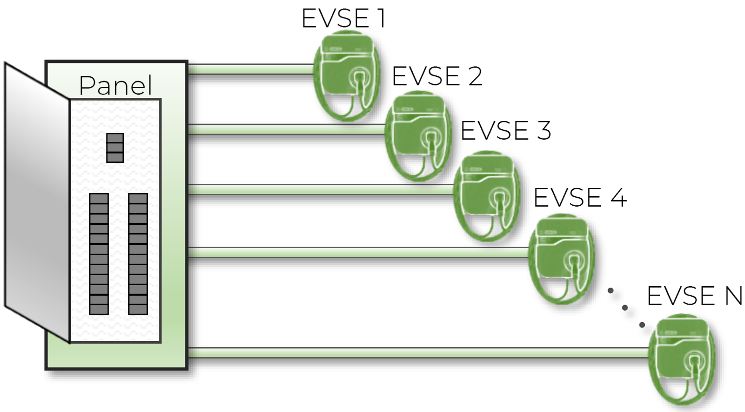



*Figure 3: Dedicated circuit configuration of EVSE.*

- **Load Sharing:** Sharing one branch circuit between multiple EVSE, with an EVEMS that controls each EVSE such that the total circuit or panel capacity is not exceeded, as depicted in Figure 4. Load calculations to size the feeder and service use the "maximum load allowed by the [EVEMS]" (CSA C22.1-18 Rule 8-106(10)) [1]. Many EVEMS systems enable load sharing across a branch circuit.

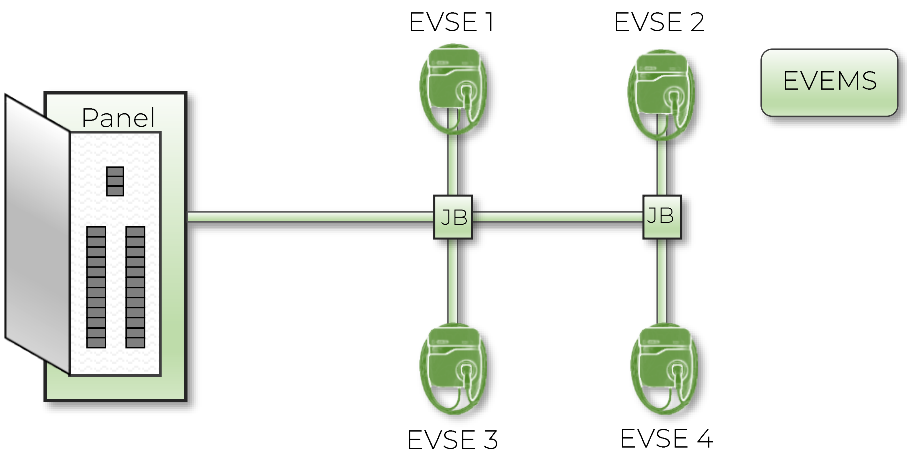



*Figure 4: Load sharing configuration of EVSE with EVEMS.*

- **Service Monitoring:** An EVEMS that monitors the load on the service or feeder supplying the EVSE and other loads. This may also be referred to as Building Demand Load Management. The EVEMS controls the EVSE such that the maximum capacity of the service or feeder is not exceeded, as depicted in Figure 5. With a correctly configured service monitoring EVEMS, the load for the EVSE "shall not be required to be considered in the determination of the calculated load" (CSA C22.1-18 Rule 8-106(11)) to size the service or feeder [1]. EVEMS with Service Monitoring capability are currently less common than those that facilitate load sharing across a branch circuit; nevertheless, a variety of EV charging service vendors provide EVSE and EVEMS that can perform service monitoring, and service monitoring technology may be more common in the future.

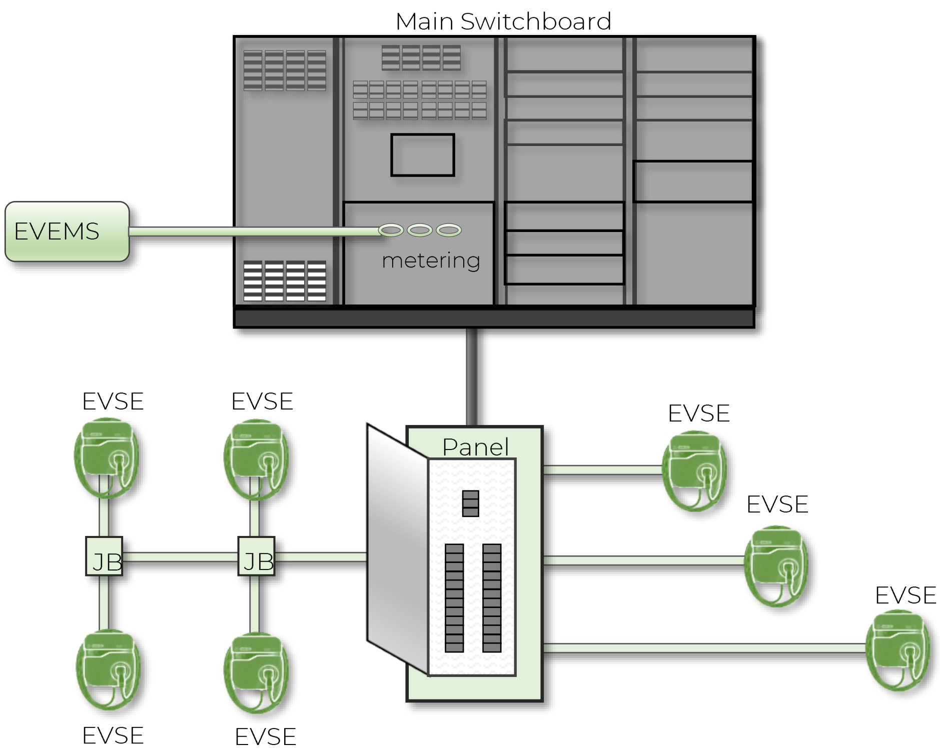



*Figure 5: Service monitoring configuration of EVSE with EVEMS.*

# 2. Background

This section provides background information and rationale for EV Ready requirements for new construction.

## 2.1 EV BENEFITS

EVs realize a variety of benefits for both drivers and broader society, including:

- **Cost savings**. Future EV drivers will save significantly on the life-cycle costs of their vehicles. The fuel cost to charge an EV at home in Alberta is equivalent to roughly $0.35 per litre gasoline [4] (exact costs depend on the timing of EV charging under time-of-use or wholesale pricing utility rates, and other factors relating to utility tariffs and vehicle efficiency). Maintenance costs of EVs are half that of gasoline vehicles [5]. Despite EVs currently typically having higher upfront costs than comparable internal combustion vehicles (ICEVs), on a life cycle cost basis, EVs are already typically competitive with ICEVs [6]. And the purchase and lease costs of EVs are declining, making them more and more advantageous [7].
- **Improved performance.** EVs typically have superior handling. Additionally, EVs are quieter inside, which many drivers report makes for a more enjoyable environment for music and conversation.
- **Reduced GHG emissions, better air quality and improved health**. EVs' lifecycle Green House Gas (GHG) emissions are about 50% less than fossil fuel vehicles when charging on an electric grid with Alberta's GHG intensity, even accounting for raw material production, manufacturing, use and disposal of vehicles [6]. As Alberta's electric grid decarbonizes into the future, EVs will realize greater life cycle emissions reductions. Moreover, EVs have zero tailpipe emissions, improving the health of our communities. The International Council on Clean Transportation and the Climate & Clean Air Coalition estimate that transitioning on-road transportation to EVs in Canada would avoid 900 deaths each year from tailpipe emissions and save $7.8 billion in annual healthcare costs [8].

## 2.2 EV ADOPTION TRENDS

EV adoption is growing exponentially worldwide and is widely forecast to continue to accelerate rapidly over the coming decade and beyond [9] [10]. The cost to produce batteries used in EVs is declining with technology innovation and increased scale of manufacturing. Because of these cost declines, multiple analysts, including the International Council on Clean Transportation and

Bloomberg New Energy Finance, forecast that by the mid-2020s, the cost to produce EVs will be equivalent to internal combustion engine vehicles (ICEVs), and lower cost thereafter [7] [10].

Accordingly, many of the world's largest automakers have announced plans to phase out sales of conventional internal combustion engine vehicles [9] [11]. There is also increasing consumer demand for EVs – A 2021 survey by KPMG suggests that of Canadians planning to purchase an automobile within the next five years, 68% report being likely or very likely to purchase an EV [12].

Public policy is likewise driving EV adoption, with the Government of Canada targeting all sales of passenger vehicles to be zero emissions by 2035 [13]. Achieving local, national, and global climate targets will require the near complete electrification of passenger transportation prior to 2050, 2040 in a best-case scenario.

In summary, despite relatively low levels of adoption of EVs in Alberta in recent years, local governments can confidently expect rapidly growing demand for EVs, and EV charging, in the future. The preponderance of evidence suggests that within 15-20 years, most households will drive an EV, if they have a vehicle.

## 2.3 THE NEED FOR ACCESS TO HOME CHARGING

The US Department of Energy's "charging pyramid" (see Figure 6) provides a conceptual summary of where passenger vehicle EV charging occurs, including:

- **At home.** The large majority (currently about 72% in Canada [14] and over 80% in the USA [15]) of passenger EV charging occurs at drivers' home. Access to home charging is a critical factor determining whether households will adopt an EV.
- **At work.** Approximately 15% of charging occurs at work [14].


*Figure 6: Charging Pyramid. Source: US DOE.*

- **Fleet charging.** For vehicles that are part of corporate fleets, almost all charging usually occurs at fleets' "home-base" or depot.
- **Public charging**. A relatively small proportion of private vehicles' charging occurs at public charging stations. Nevertheless, public charging is important for households without access to home or work charging; to provide "opportunity charging" (i.e. convenient top-up charging when drivers are parked for shopping, recreating, etc.); and to provide for very fast charging on longer trips.

As the upfront costs of EVs continue to decline, access to convenient forms of charging will increasingly become the most important factor determining EV adoption. As home charging is widely recognized as the most convenient form of EV charging, improving access to home charging is particularly important to enabling EV adoption.

## 2.4 THE CHALLENGE OF RETROFITTING EV CHARGING IN MULTIFAMILY BUILDINGS

For single family homes with their own private onsite parking space (e.g. a garage or parking pad), implementing "at home" EV charging is usually relatively simple and low cost. However, retrofitting EV charging into multifamily buildings is much more complicated and costly. Broadly, multifamily buildings that are not constructed with EV Ready infrastructure can pursue one of two strategies to implement EV charging:

1. **Comprehensive EV Ready retrofits**. A building undertakes an electrical renovation to make all parking EV Ready. As drivers adopt EVs, EVSE are installed at their assigned parking space.
2. **Incremental additions of EV chargers**. A building implements a few chargers at a time. Often, EVSE are located in common parking areas (e.g. visitor parking). Over time, as more EVs are adopted by residents, additional EVSE will need to be added.

Table 1 compares these two models for providing EV charging in existing multifamily buildings that have not been future-proofed in new construction for EV charging. Table 1 makes clear that there are significant challenges to retrofitting multifamily buildings to provide EV charging. Comprehensive 100% EV Ready retrofits often provide the greatest value over the life cycle of the building but are complicated and entail greater costs than future-proofing new construction. To avoid perpetuating the challenge of providing EV charging infrastructure in multifamily buildings, Canadian local governments are increasingly adopting 100% EV Ready residential parking requirements for new construction.

*Table 1: Comprehensive EV Ready retrofits vs. incremental EVSE additions*

| | Comprehensive 100% EV Ready retrofits | Incremental additions of EVSE |
|---|---|---|
| **Life-Cycle Cost Per Parking Space** | Less expensive, especially when designed with appropriate levels of load sharing and EVEMS. | Much more expensive over time, assuming that all vehicles in multifamily buildings will ultimately be EVs. |
| **Process** | One-time significant electrical renovation. | Repeated electrical renovations. |
| **Location of charging stations** | In drivers' assigned parking space. | Often initially in commonly accessible parking (e.g. visitor parking). Sometimes in assigned parking. |
| **Process for drivers to install chargers** | Simple (after initial comprehensive electrical renovation). | Typically lengthy and complicated. |
| **Convenience** | Highly convenient for drivers, EV charging in regular assigned parking spot. | Inconvenient for drivers when chargers are located in commonly accessible parking (e.g. visitor parking) |
| **Futureproofing** | With EVEMS, frequently can ensure sufficient electrical capacity for all parking spaces to have EV charging. | Initial installations may not leave room for later expansion; potential for stranded assets. Potential to exhaust limited electrical capacity if design for EVEMS not considered. |
| **Market adoption** | Currently very uncommon, incentives are increasing adoption by offsetting the high upfront cost. | Typical approach to adding EV charging in existing multifamily buildings. |
| **Electrical Permit** | Typically, only a single electrical permit is required. | New electrical permits will be required for each electrical renovation. |

## 2.5 EV READY REQUIREMENTS

Cities and other jurisdictions are increasingly focused on ensuring that their residents have access to convenient forms of EV charging. Table 2 summarizes EV Ready requirements adopted by a selection of Canadian cities. Other Canadian cities are understood to be considering similar requirements.

*Table 2: EV Ready parking requirements in select Canadian jurisdictions (list of jurisdictions is not intended to be comprehensive).*

| Jurisdiction | EV Ready Parking Requirements | |
|---|---|---|
| | Residential | Commercial |
| City of Toronto, ON | 100% | 25% |
| City of Vancouver, BC | 100% | 10% |
| City of Port Moody, BC | 100% | 20% |
| City of Surrey, BC | 100% | 20% |
| City of Victoria, BC | 100% | ~5% (varies by land use) |
| District of Saanich, BC | 100% | ~5% (varies by land use) |
| City of Richmond, BC | 100% | |
| City of Burnaby, BC | 100% | |
| City of New Westminster, BC | 100% | |
| City of North Vancouver, BC | 100% | |
| District of West Vancouver, BC | 100% | |
| District of North Vancouver. BC | 100% | |
| Town of View Royal, BC | 100% | |
| Township of Langley. BC | 1 per dwelling unit | |
| City of Nelson. BC | 1 per dwelling unit | 10% |
| City of Coquitlam, BC | 1 per dwelling unit | |
| City of Laval, QC | 50% in multifamily buildings | |
| Province of Quebec | All single family dwelling parking | |

Local governments with 100% EV Ready requirements have allowed new developments to design for use of EVEMS, reducing the cost of implementing 100% EV Ready parking.

## 2.6 WHY REQUIRE 100% EV READY PARKING

AES typically recommends jurisdictions adopt 100% EV Ready residential parking requirements. Benefits of EV Ready parking requirements include:

- **Consistency with local and national GHG and EV sales targets.** The Government of Canada has adopted targets for 100% of passenger vehicle sales to be zero emissions by 2035. This is well within the lifetime of new residential buildings that would be subject to EV Ready requirements.
- **Equity between residents.** Requirements for 100% "EV Ready" parking stalls provide all residences with equitable access to an outlet that provides adequate electrical capacity for EV charging, and avoids challenges associated with trading parking spaces or renovating for EV access.

  If instead, only a portion of parking spaces are made "EV Ready", households without access to such an "EV Ready" space would either need to 1) renovate electrical systems to provide access to EV charging, or 2) trade parking spaces with households that have an EV Ready space.

  Trading parking spaces is typically challenging or not possible in condominiums. Different forms of parking tenure in condominiums have different implications for trading parking stalls; however, all present major difficulties for residents of condominiums to trade parking stalls. This is widely recognized by those in the EV charging industry as an impediment to EV adoption.

  As noted in section 2.4, retrofitting parking to provide EV charging is costly and complicated. In practice, the challenges associated with trading and/or renovating stalls typically prevent EV uptake in Multi-Unit Residential Buildings (MURBs).
- **Simple enforcement.** Compared to other ways that jurisdictions have structured EV charging infrastructure requirements for new developments, 100% EV Ready requirements are relatively simple for local governments to enforce.

  Some jurisdictions (e.g. California) have required that new developments provide sufficient electrical capacity on electric panels to provide for future EV charging, but do not require wiring an electrical outlet. However, local building officials, transportation, and/or development approvals staff typically do not possess the requisite experience or qualifications to review electrical plans and calculations. EV Ready requirements necessitates checking for the provision of an electrical outlet, a much simpler task for personnel without electrical background.

- **Reasonable cost**. As explored below, 100% EV Ready parking can be implemented in new construction at reasonable costs.

# 3. EV Charging Performance Requirements

To ensure that drivers can receive sufficient charge from EV charging systems, cities' EV Ready requirements typically reference minimum "charging performance requirements". These charging performance requirements limit the amount of load sharing allowed between EVs. This is intended to ensure that EVs receive an adequate amount of energy to meet drivers' needs.

Appropriate charging performance requirements vary between different geographic areas, based on factors including:

- Daily driving distance. Average vehicle kilometers travelled (VKT) per day varies significantly across and between regions. Generally, vehicles in more suburban or exurban locations will travel farther than in central cities, and thus will require more energy to charge.
- The efficiency of the region's vehicle fleet.
- Temperature extremes, which can reduce vehicles' efficiency.
- Available charging time.
- Charging efficiencies.
- Other factors.

AES has developed a model to determine appropriate charging performance requirements for different geographic regions, which was applied to the City of Calgary and the City of Edmonton (the Cities). In brief, the model used: VKT data from the Cities; weather data; information about passenger vehicle fleet composition; and reasonable assumptions about resident driving patterns, including arrival and departure times, and the number of vehicles not driving on a given day. The VKT data used for the Cities is only valid for residential buildings within the city limits of Calgary and Edmonton, respectively. The model assumes that almost all EV charging occurs at home, with very limited use of public or workplace charging; of course, vehicles on long trips that extend beyond their range would need additional charging.

The model determines the maximum number of vehicles that may load share across a circuit of a given electrical power capacity, while ensuring that there are no more than:

- 10% of days when vehicles are not fully charged overnight.
- 1% of days when vehicles cannot complete the next day's driving. On those 1% of days, drivers would need to augment home charging with visiting a public charging station, workplace charging, etc.

Table 3 summarizes recommended performance requirements determined by the model, organized by average daily weekday vehicle VKT in the City of Calgary. For this study, the City of Calgary reported average daily vehicle VKT per vehicle is 27.7km.

*Table 3: Summary of performance requirements in terms of the maximum amount of sharing recommended on each circuit size for different mean VKT In the City of Calgary.*

| Circuit Breaker Size | Maximum number of EVs (by mean daily weekday VKT) | | | |
|---|---|---|---|---|
| | 35km or less | 40km | 45km | 50km |
| **20A** | 1 | | | |
| **30A** | 1 | 1 | 1 | 1 |
| **40A** | 4 | 3 | 3 | 2 |
| **50A** | 5 | 4 | 4 | 3 |
| **60A** | 7 | 6 | 5 | 4 |
| **70A** | 8 | 7 | 6 | 5 |
| **80A** | 10 | 8 | 7 | 6 |
| **100A** | 12 | 11 | 9 | 8 |
| **125A** | 15 | 14 | 12 | 11 |

Table 4 summarizes recommended performance requirements determined by the model, organized by average daily weekday vehicle VKT in the City of Edmonton. For this study, the City of Edmonton reported average daily vehicle VKT per vehicle is 31.4km.

*Table 4: Summary of performance requirements in terms of the maximum amount of sharing recommended on each circuit size for different mean VKT in the City of Edmonton*

| Circuit Breaker Size | Maximum number of EVs (by mean daily weekday VKT) | | | |
|---|---|---|---|---|
| | 35km or less | 40km | 45km | 50km |
| **20A** | 1 | | | |
| **30A** | 1 | 1 | 1 | 1 |
| **40A** | 4 | 3 | 3 | 2 |
| **50A** | 5 | 4 | 3 | 3 |
| **60A** | 6 | 5 | 4 | 4 |
| **70A** | 8 | 6 | 5 | 5 |
| **80A** | 10 | 8 | 7 | 6 |
| **100A** | 12 | 10 | 9 | 7 |
| **125A** | 15 | 13 | 11 | 10 |

AES recommends that jurisdictions not adopt performance requirements for new construction that allow for higher levels of load sharing than are presented for jurisdictions with VKT of 30km in Table 3 above. The rationale for such a minimum baseline performance standard for all communities is that:

- Some vehicles may not accept less than 8A.
- It is anticipated prospective EV drivers will have expectations for speed of charging and quality of service that greater degrees of load management will not meet.
- EV charging service providers have indicated hesitancy to service buildings with greater levels of load sharing, which may limit availability of EVEMS systems for buildings designed for higher levels of load management.

- Average VKTs may increase in the future. The introduction of greater use of ride-hailing and car-sharing, and reduction in the number of parking spaces in new developments and associated decline in car ownership, may increase average VKTs.
- The growing tendency for larger vehicles in Canada may decrease future fleet efficiencies.

## 3.1 IMPLICATIONS FOR EV CHARGING PERFORMANCE REQUIREMENTS

AES's model suggests 4-share on a 40A circuit is sufficient for communities with daily average VKTs of 35km or less, which includes the Cities of Calgary and Edmonton. For this study, the City of Calgary reported average daily vehicle VKT per vehicle is 27.7km, Edmonton reported 31.4km.

More suburban communities, near Calgary or Edmonton, with longer VKTs could consider adopting more stringent performance requirements in accordance with their communities' average VKT values in Table 3 and Table 4, if they are proximal to Calgary or Edmonton, respectively. However, this study does not provide sufficient information or data to inform the EV Ready requirements for cities outside of Calgary and Edmonton. The VKT data used to inform this study was only for residence's withing the city boundaries of Calgary and Edmonton.

Less stringent performance requirements would not provide for full reliance on home charging. Adopting less stringent performance requirements would effectively require that some drivers augment home charging with workplace charging or public charging, and/or that daily driving distances decline in the future.

# 4. EV Charging Infrastructure Cost Analysis

This section reviews analysis of the electrical designs and associated costs of providing EV Ready parking in three residential building archetypes common to the Cities of Calgary and Edmonton. For each archetype, a range of different electrical design scenarios were developed. The scenarios' electrical designs included different load sharing strategies, as well as service monitoring strategies.

Costs for each scenario were estimated, relative to a baseline development with no EV charging infrastructure. Additionally, the cost of implementing the same electrical systems in a retrofit context were estimated; this analysis is intended to serve as a rough estimate of the cost of retrofitting buildings to feature EV charging infrastructure.

There is no increased permitting cost for EV charging infrastructure in new construction in the City of Calgary or the City of Edmonton [16] [17]. All new buildings require an electrical permit and therefore this is not an increased cost over the baseline development previously mentioned.

This costing analysis does not include the purchase or installation cost of EVSE or ongoing fees for EVEMS, as these costs are not expected to be required to be borne by building developer. However, a brief discussion of these costs is provided in Section 5.4.

Details of the electrical designs for different scenarios and of the costing analysis are provided in Appendices as follows:

- **Appendix A:** Archetype details and load calculations.
- **Appendix B:** Single line diagrams.
- **Appendix C:** Parking layout drawings.
- **Appendix D:** Costing estimates.
- **Appendix E:** Cost categories.

## 4.1 ABOUT THE ARCHETYPES

Three residential development archetypes were assessed: A high-rise residential development, a mid-rise residential development, and a townhouse development. These building archetypes are common in the Calgary and Edmonton areas and were derived from actual development applications in the City of Calgary. A summary of the archetypes is provided in Table 5. EV Ready parking was designed for resident parking only, and not visitor parking stalls.

*Table 5. Overview of parking for each archetype.*

| # | Archetype | Storeys | Number of Units | Parking Stalls | |
|---|---|---|---|---|---|
| | | | | Resident | Visitor |
| 1 | High-Rise | 17 | 334 | 204 | 36 |
| 2 | Mid-Rise | 6 | 169 | 169 | 17 |
| 3 | Townhouse | 3 | 16 | 8 | 0 |

## 4.2 EV READY SCENARIOS

The sub-sections below summarize the different electrical design configurations and associated EVEMS control schemes for the development archetypes.

### 4.2.1 High-Rise

Table  summarizes the EV Ready configuration scenarios considered for the high-rise development, including:

- **C1** features dedicated 40A circuits to each parking space.
- **C2** features 4-share on 40A circuits.
- **C3** features 10-share on 80A circuits.
- **C4** features 4-share on 40A circuits with service monitoring.

*Table 6: High-rise scenarios summary.*

| # | Electrical configuration description | % Residential Parking that is EV Ready | Nominal EVSE Power (kW) | EV Ready Spaces per Branch Circuit | Circuit Breaker Rating (A) | Max Current (A) |
|---|---|---|---|---|---|---|
| **C1** | Dedicated 40A circuit | 100% | 6.7 | 1 | 40 | 32 |
| **C2** | 4-share on 40A | 100% | 6.7 | 4 | 40 | 32 |
| **C3** | 10-share on 80A | 100% | 6.7 | 10 | 80 | 64 |
| **C4** | 4-share on 40A with service monitoring | 100% | 6.7 | 4 | 40 | 32 |

### 4.2.2 Mid-Rise

Table  summarizes the EV Ready configuration scenarios considered for the mid-rise development:

- **C1** features dedicated 40A circuits to each parking space.
- **C2** features 4-share on 40A circuits.
- **C3** features 10-share on 80A circuits.

*Table 7: Mid-rise scenarios summary.*

| # | Electrical configuration description | % Residential Parking that is EV Ready | Nominal EVSE Power (kW) | EV Ready Spaces per Branch Circuit | Circuit Breaker Rating (A) | Max Current (A) |
|---|---|---|---|---|---|---|
| **C1** | Dedicated 40A circuit | 100% | 6.7 | 1 | 40 | 32 |
| **C2** | 4-share on 40A | 100% | 6.7 | 4 | 40 | 32 |
| **C3** | 10-share on 80A | 100% | 6.7 | 10 | 80 | 64 |

### 4.2.3 Townhouse

Table  summarizes the EV Ready configuration scenarios considered for the townhouse development:

- **C1** features dedicated 40A circuits to each parking space.
- **C2** features 4-share on 40A circuits.
- **C3** features 8-share on 70A circuit to each garage

*Table 8: Townhouse scenarios summary.*

| # | Electrical configuration description | % Residential Parking that is EV Ready | Nominal EVSE Power (kW) | EV Ready Spaces per Branch Circuit | Circuit Breaker Rating (A) | Max Current (A) |
|---|---|---|---|---|---|---|
| **C1** | Dedicated 40A circuit | 100% | 6.7 | 1 | 40 | 32 |
| **C2** | 4-share on 40A | 100% | 6.7 | 4 | 40 | 32 |
| **C3** | 8-share on 70A | 100% | 6.7 | 8 | 70 | 32 |

The townhouse archetype used for this study features a shared carport for the residential parking stalls. This design is understood to be more common in the townhouses being developed in Calgary and Edmonton. The shared carport layout allows for more efficient EV load sharing than in designs where each unit has a garage. This is because load sharing between garages is not practical, nor allowed under Canadian Electrical Code (CEC) rule 26-564(a) [1].

## 4.3 COSTING ANALYSIS FOR NEW DEVELOPMENTS

This section summarizes the results of the costing analysis for the three archetypes. This costing analysis is specific to construction in Alberta, using RSMeans data for the Calgary and Edmonton market.

### 4.3.1 High-Rise Residential

Figure 7 summarizes the estimated costs per EV Ready parking space for the high-rise archetype. Costs are broken down into different categories of costs, including metering; communications systems; EV panels and cabling; feeders; and increases to utility service / transformer rating. The systems included in these categories are further summarized in Appendix E.

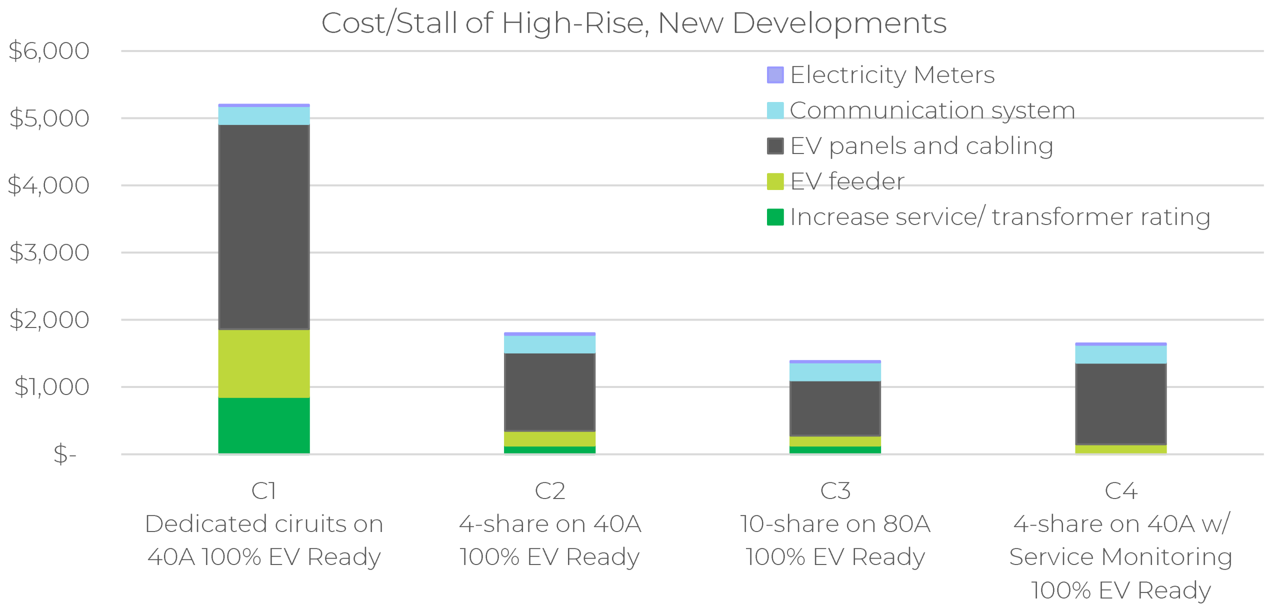



*Figure 7 Cost of EV charging infrastructure for the high-rise archetype*

### 4.3.2 Mid-Rise Residential

Figure 8 summarizes the estimated costs for EV Ready infrastructure per stall in the mid-rise archetype.

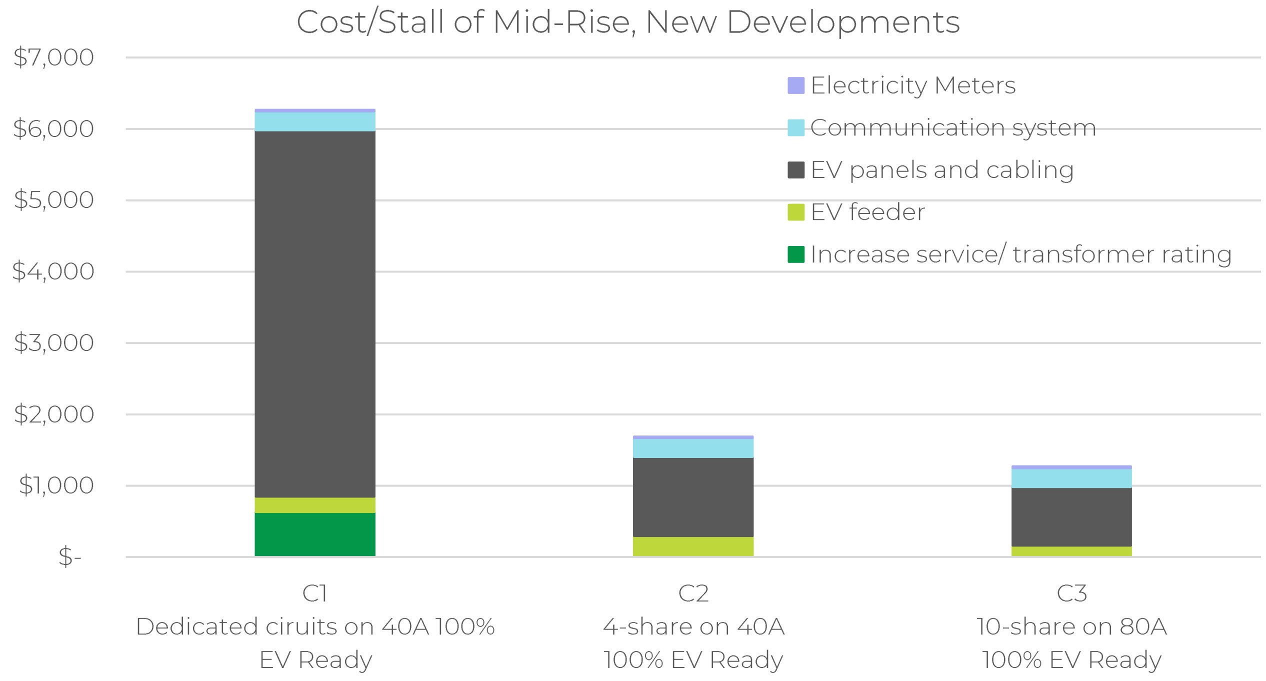



*Figure 8 Cost of EV charging infrastructure for the mid-rise archetype*

### 4.3.3 Townhouse

Figure 9 shows the cost per parking space for EV Ready parking for the townhouse archetype for new developments.

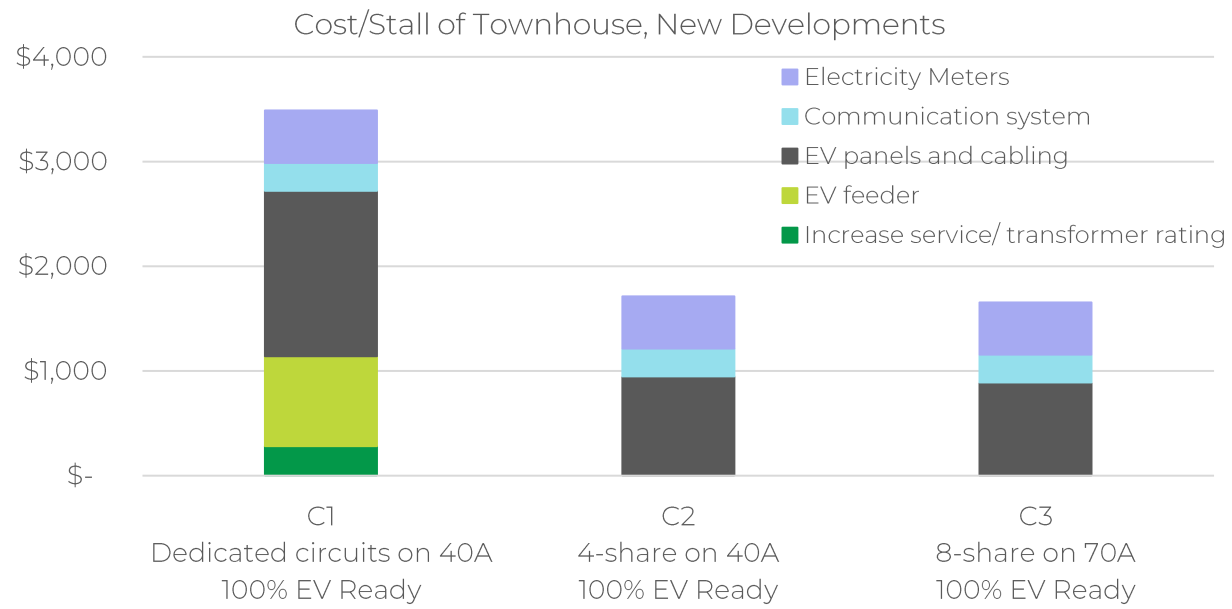



*Figure 9 Cost of EV charging infrastructure for the townhouse archetype*

## 4.4 STRATEGIES TO CONTROL THE COST ASSOCIATED WITH ELECTRICAL SERVICE EXPANSIONS

This study includes cost estimates to increase service sizes and transformer ratings. However, the costs charged to new developments that upgrade service sizes can vary substantially, depending on the nature of electric utility works that will be required to provide electrical service of the necessary capacity to the site.

Electrical service expansion costs can differ substantially between different development sites, depending on the nature of the capital works that a distribution utility would need to take to provide service to a site. It is possible that EV charging infrastructure can increase the required capacity of the electrical service that a development would otherwise feature, and that in some instances this can result in relatively large increases in developments' capital contribution. In these instances, developers and designers are recommended to consider designing for the use of service monitoring, to avoid needing to increase the capacity of developments' service; in turn, this design strategy can avoid incurring the costs associated with a larger service size.

## 4.5 COSTING ANALYSIS FOR EXISTING DEVELOPMENTS

This section provides a rough estimate of the cost to implement EV Ready parking in a retrofit context, if new construction were not made 100% EV Ready. As noted in section 2.4, it is considerably more complicated and costly to implement EV charging infrastructure in a retrofit context, as opposed to making new construction EV Ready. Costs per parking space for comprehensive 100% EV Ready retrofits will typically be less per parking space than if done incrementally, in AES's experience, but still considerably more than future-proofing new construction to be 100% EV Ready.

The following figures represent estimates to compare the cost of 100% EV Ready parking in new construction to the cost of incremental additions of EV Ready parking, as described in section 2.4. Figure 10, 11, and Figure 12, outline the costs for high-rise, mid-rise, and townhouse, respectively. Estimates were made by assigning a cost multiplier for each component of the electrical system. See Appendix D for details of these cost estimates.

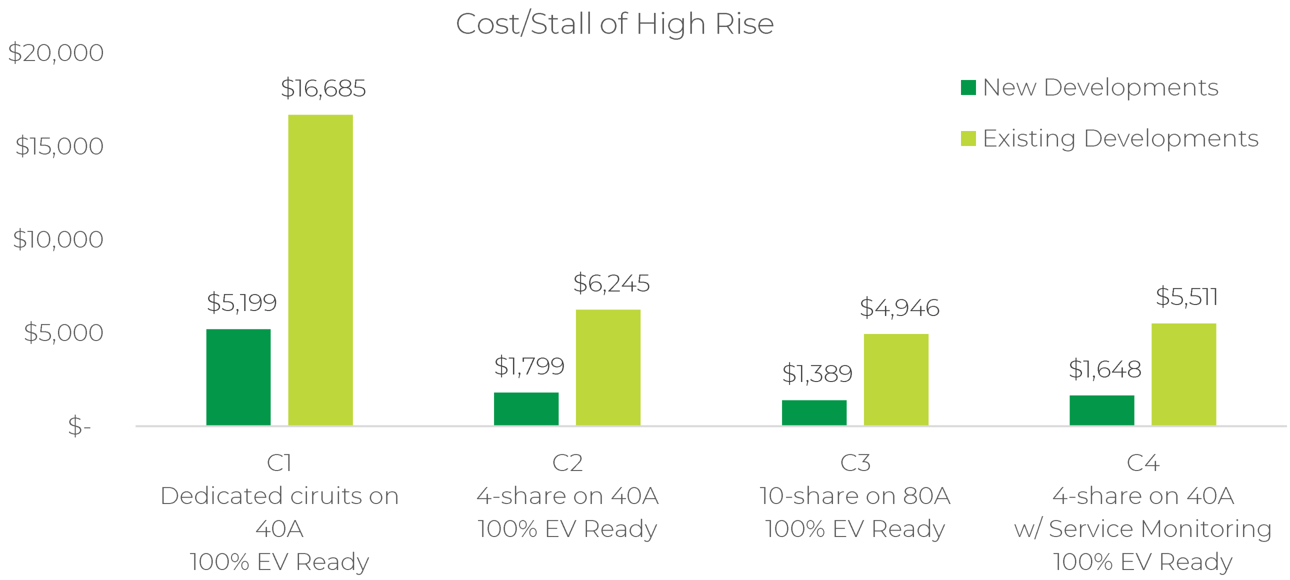
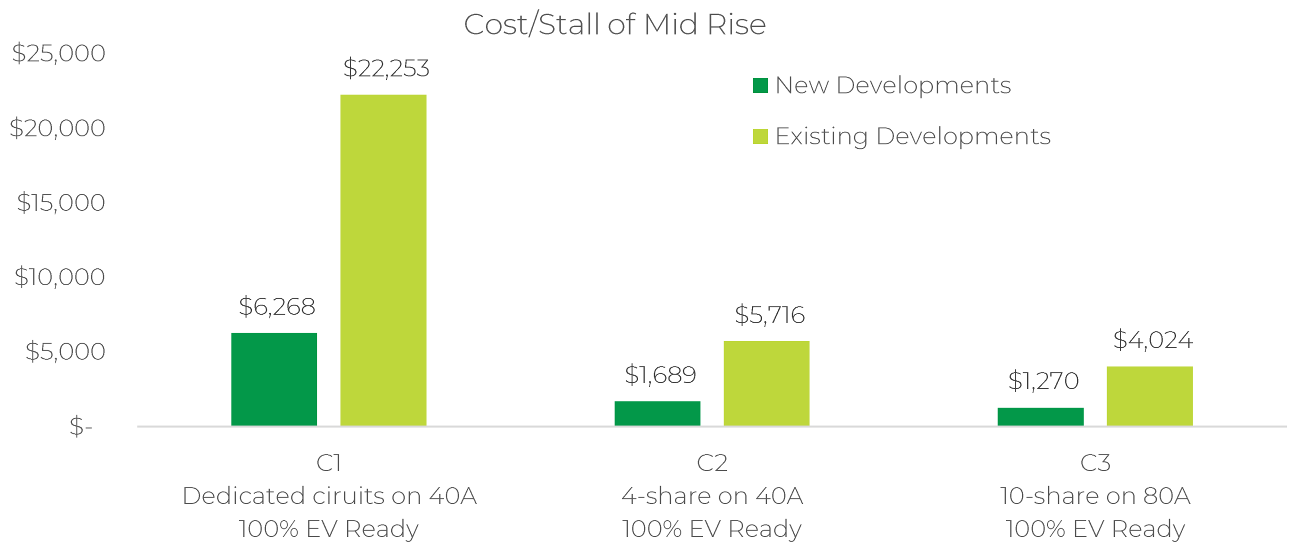



*Figure 10 Comparison of cost per energized parking stall of EV charging infrastructure for new and existing developments for the high-rise archetype*




*11 Comparison of cost per energized parking stall of EV charging infrastructure for new and existing developments for the mid-rise archetype*

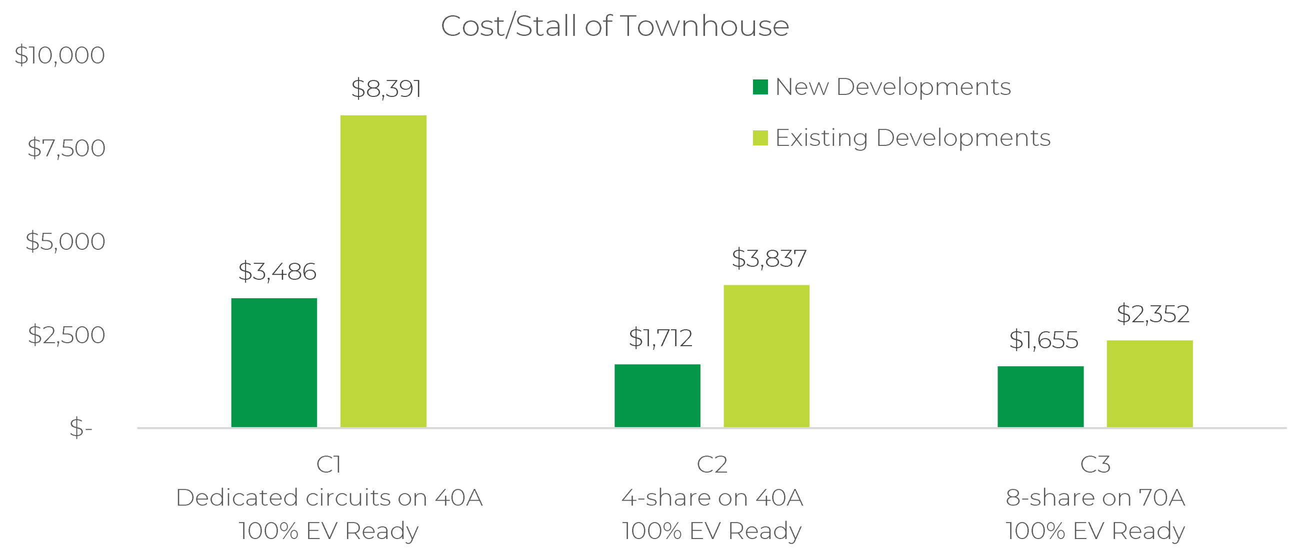



*Figure 12 Comparison of cost per unit of EV charging infrastructure for new and existing developments for the townhouse archetype*

# 5. Operating EV Charging Infrastructure

This study focuses on the cost of EV Ready infrastructure for new developments. It does not forecast operating costs for use of this infrastructure. This section provides commentary on the costs to end users of EVSE; EV charging services, including EVEMS; and electricity.

### 5.1.1 EVSE Costs

The cost of residential level 2 EVSE varies depending on the power level, built-in load sharing, and whether the EVSE can communicate over some network for the purposes of EV energy management and other services (i.e. "smart charging station"). In AES's experience, installed costs for 7.2kW smart EVSE with appropriate for residential applications range from approximately $1000 to $2000+, depending on the vendor.

Developments with dedicated circuits could use "dumb" EVSE without network connectivity. These EVSE are typically lower cost (e.g. $300 to $1000+). However, use of dumb EVSE may entail higher ongoing utility costs, due to higher demand charges, and inability to respond to utility price signals.

### 5.1.2 EV Charging Services and EVEMS Costs

In EV charging configurations that use EVEMS, EV charging service providers will typically be engaged by multifamily buildings. They will provide EVSE, EVEMS, and services such as billing drivers for electricity costs, reporting usage data, and customer assistance.

Many EVEMS systems currently rely on subscription fees charged on a per station basis. If system communications are achieved via cellular networks, this also includes a network fee. Experience at AES Engineering indicates subscription fees for EVEMS and billing management systems are approximately $240 per station per year, including network fees. RMI estimates network fees to be between $200 USD and $250 USD per station per year, with additional maintenance contracts which could cost $575 USD per charger per year, but which vary widely depending on site specific parameters [18]. Subscription fees can significantly increase operating costs of charging stations. Systems and business models that entail reduced or no subscription fees may increase in the future.

When selecting an EV charging service provider, the design should consider the communication method used by the provider. Many providers use cellular networks for communication because of the reliability and availability. Each building should be considered on a case-by-case basis and factors to consider include:

- Ease of installation.
- Future-proof solution.
- Reliable network.

- Availability of connectivity in the specific location (eg. Indoor vs outdoor applications).

### 5.1.3 Electricity Costs

As noted in section 2.1, the electricity costs for passenger EVs will be well below fossil fuel costs under a wide range of assumptions. The costs for electricity will depend on the rate charged (e.g. residential rates; commercial rates; special EV charging rates that may emerge in the future). Building owners and condominium will typically adopt user fees for EV drivers, recovering the cost of electricity paid to utilities from drivers. Figure 13 illustrates a common process, whereby EV owners repay the costs of electricity paid by the condomium, by means of an EV network service provider.

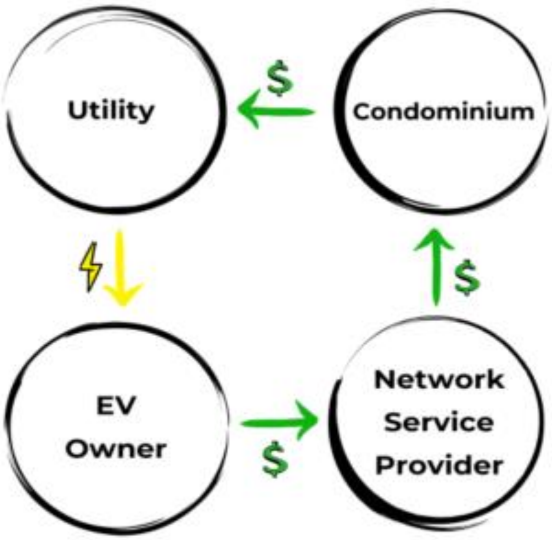



*Figure 13 Payment structure for EV charging in condominiums with networked EVEMS*

# 6. Conclusion

Local governments are increasingly requiring 100% of residential parking in new developments to be EV Ready. This report provides relevant context, background information, and summarizes design and costing analysis for three residential building archetypes common to Calgary and Edmonton.

This costing analysis suggests that in the high-rise and mid-rise archetypes, it is possible to implement 100% EV Ready parking for approximately $1250 to $1400 per parking space. For the townhouse archetype, parking can be made EV Ready at a cost of approximately $1700 or less per parking space. These costs represent a small fraction of the cost for a new development to provide onsite parking. Moreover, future-proofing buildings with this EV charging infrastructure will realize significant value for drivers, enabling them to adopt EVs and benefit from their associated savings in total cost of vehicle ownership. The costing analysis indicates that EV charging infrastructure retrofits will be much more costly and complicated than futureproofing new construction with 100% EV Ready parking.

It is recommended that local governments implement 100% EV Ready requirements for residential parking in new developments.

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# Appendix A: Archetype details and load calculations

## LOAD CALCULATION SUMMARY

| | BASELINE (KW) | CONFIGURATION | EV CHARGING (KW) | TOTAL (KW) |
|---|---|---|---|---|
| ARCHETYPE 1: HIGH-RISE MIXED USE | 2,364 | C1 - Dedicated circuits on 40A, 100% EV Ready | 1,364 | 3,729 |
| | | C2 - 4-share on 40A, 100% EV Ready | 346 | 2,710 |
| | | C3 - 10-share on 80A, 100% EV Ready | 266 | 2,630 |
| | | C4 - 4-share on 40A, 100% EV Ready with service monitoring | 0* | 2,710 |
| ARCHETYPE 2: MID-RISE MULTIFAMILY | 1,808 | C1 - Dedicated circuits on 40A, 100% EV Ready | 1,125 | 2,647 |
| | | C2 - 4-share on 40A, 100% EV Ready | 286 | 1,808 |
| | | C3 - 10-share on 80A, 100% EV Ready | 226 | 1,748 |
| ARCHETYPE 3: TOWNHOUSE | 133 | C1 - Dedicated circuits on 40A, 100% EV Ready | 53 | 186 |
| | | C2 - 4-share on 40A, 100% EV Ready | 13 | 144 |
| | | C3 - 8-share on 70A, 1000% EV Ready | 12 | 144 |

*EVEMS will regulate supply to EVSEs based on building usage to stay within the capacity of electrical equipment

## ARCHETYPE 1: HIGH-RISE MIXED USE

| GENERAL | |
|---|---|
| Space heating | electric |
| Range | electric |
| Air-conditioning | all suites |

| EQUIPMENT SPECIFICATION | | | |
|---|---|---|---|
| TYPE | LOAD (HP) | QTY | EFFICIENCY |
| High Rise Elevators | 75 | 4 | 75% |
| Fire Pump | 100 | 1 | 75% |

| AREAS | | |
|---|---|---|
| TYPE | $ft^2$ | $m^2$ |
| Suites | 189,390 | 17,595 |
| Parking | 104,711 | 9,728 |
| Retail | 11,403 | 1,059 |
| Base building | 12,303 | 1,143 |
| TOTAL | 317,807 | 29,525 |

| SUITES | | | | |
|---|---|---|---|---|
| TYPE | No. | AREA | | |
| | | $ft^2$ | $m^2$ | TOTAL ($m^2$) |
| Unit A | 28 | 630 | 59 | 1,639 |
| Unit B | 28 | 522 | 48 | 1,358 |
| Unit C | 104 | 744 | 69 | 7,188 |
| Unit D | 52 | 489 | 45 | 2,362 |
| Unit E | 34 | 589 | 55 | 1,860 |
| Unit F | 84 | 396 | 37 | 3,090 |
| Unit G | 2 | 520 | 48 | 97 |
| TOTAL | 332 | | | 17,595 |

| SUITE LOADS (KW) | | | | | | | |
|---|---|---|---|---|---|---|---|
| TYPE | FIRST 45 $m^2$ | NEXT 45 $m^2$ | NEXT 90 $m^2$ | NEXT 90 $m^2$ | RANGE | DRYER @ 25% | LOAD (KW) |
| Unit A | 3.5 | 1.5 | 0.0 | 0 | 6 | 1.25 | 12.3 |
| Unit B | 3.5 | 1.5 | 0.0 | 0 | 6 | 1.25 | 12.3 |
| Unit C | 3.5 | 1.5 | 0.0 | 0 | 6 | 1.25 | 12.3 |
| Unit D | 3.5 | 1.5 | 0.0 | 0 | 6 | 1.25 | 12.3 |
| Unit E | 3.5 | 1.5 | 0.0 | 0 | 6 | 1.25 | 12.3 |
| Unit F | 3.5 | 0.0 | 0.0 | 0 | 6 | 1.25 | 10.8 |
| Unit G | 3.5 | 1.5 | 0.0 | 0 | 6 | 1.25 | 12.3 |

| RESIDENTIAL | |
|---|---|
| ITEM | LOAD (KW) |
| first suite @ 100% | 12.3 |
| 2nd & 3rd @ 65% | 15.9 |
| 4th & 5th @ 40% | 9.8 |
| 6th - 20th @25% | 45.9 |
| remainder @10% | 382.2 |
| electric heating | 735.6 |
| TOTAL | 1,202 |

| EQUIPMENT | | |
|---|---|---|
| ITEM | DEMAND FACTOR | LOAD (KW) |
| High Rise Elevators | 50% | 149.1 |
| Fire Pump | 100% | 99.4 |
| TOTAL | | 248.6 |

| BASE BUILDING | |
|---|---|
| ITEM | LOAD (KW) |
| Basic allowance | 98.7 |
| Mechanical | 266.0 |
| Electric heating | 412.4 |
| TOTAL | 777.1 |

| RETAIL | | |
|---|---|---|
| ITEM | $W/m^2$ | LOAD (KW) |
| Basic allowance | 30 | 31.8 |
| Mechanical | 55 | 58.3 |
| electric heating | 56 | 46.6 |
| TOTAL | | 136.6 |

| PARKING STALLS | |
|---|---|
| TYPE | TOTAL |
| Resident | 204 |
| Visitor | 36 |
| TOTAL | 240 |

| EV CHARGING AND TOTAL LOAD | | | | |
|---|---|---|---|---|
| OPTION | TOTAL EV-READY CCT | DEMAND | TOTAL EV CHARGING POWER (KW) | TOTAL BUILDING LOAD (KW) |
| BUILDING ONLY | | | | |
| Building only | | | | 2,364 |
| RESIDENTIAL EV CHARGING OPTIONS | | | | |
| C1. Dedicated circuits on 40A, 100% EV Ready | 204 | 100% | 1,364 | 3,729 |
| C2. 4-share on 40A, 100% EV Ready | 52 | 100% | 346 | 2,710 |
| C3. 10-share on 80A, 100% EV Ready | 21 | 100% | 266 | 2,630 |
| C4. 4-share on 40A, 100% EV Ready with serv | 52 | 100% | 346 | 2,710 |

## ARCHETYPE 2: MID-RISE MULTIFAMILY

| GENERAL | |
|---|---|
| Space heating | electric |
| Range | electric |
| Air-conditioning | all suites |

| EQUIPMENT SPECIFICATION | | | |
|---|---|---|---|
| TYPE | LOAD (HP) | QTY | EFFICIENCY |
| Mid Rise Elevators | 75 | 3 | 75% |
| Fire Pump | 50 | | 75% |

| AREAS | | |
|---|---|---|
| TYPE | $ft^2$ | $m^2$ |
| Suites | 124,056 | 11,525 |
| Parking | 69,692 | 6,475 |
| Base building | 893 | 83 |
| Retail | 22,653 | 2,105 |
| | | |
| | | |
| TOTAL | 194,641 | 18,083 |

| SUITES | | | | |
|---|---|---|---|---|
| TYPE | No. | AREA | | |
| | | $ft^2$ | $m^2$ | TOTAL ($m^2$) |
| Micro 1 Bed | 28 | 520 | 48 | 1,353 |
| 1 Bed + Den | 46 | 646 | 60 | 2,761 |
| Micro 2 Bed | 19 | 780 | 72 | 1,377 |
| 2 Bed + Den | 72 | 850 | 79 | 5,686 |
| 3 Bed | 4 | 940 | 87 | 349 |
| TOTAL | 169 | | | 11,525 |

| SUITE LOADS (KW) | | | | | | | |
|---|---|---|---|---|---|---|---|
| TYPE | FIRST 45 $m^2$ | NEXT 45 $m^2$ | NEXT 90 $m^2$ | NEXT 90 $m^2$ | RANGE | DRYER @ 25% | LOAD (KW) |
| Micro 1 Bed | 3.5 | 1.5 | 0.0 | 0 | 6 | 1.25 | 12.3 |
| 1 Bed + Den | 3.5 | 1.5 | 0.0 | 0 | 6 | 1.25 | 12.3 |
| Micro 2 Bed | 3.5 | 1.5 | 0.0 | 0 | 6 | 1.25 | 12.3 |
| 2 Bed + Den | 3.5 | 1.5 | 0.0 | 0 | 6 | 1.25 | 12.3 |
| 3 Bed | 3.5 | 1.5 | 0.0 | 0 | 6 | 1.25 | 12.3 |

| RESIDENTIAL | |
|---|---|
| ITEM | LOAD (KW) |
| first suite @ 100% | 12.3 |
| $2^{nd}$ & $3^{rd}$ @ 65% | 15.9 |
| $4^{th}$ & $5^{th}$ @ 40% | 9.8 |
| $6^{th}$ - $20^{th}$ @25% | 45.9 |
| remainder @10% | 182.5 |
| Electric Heating | 482.7 |
| TOTAL | 749 |

| EQUIPMENT | | |
|---|---|---|
| ITEM | DEMAND FACTOR | LOAD (KW) |
| Elevators | 50% | 111.9 |
| Fire Pump | 100% | 0.0 |
| TOTAL | | 111.9 |

| BASE BUILDING | |
|---|---|
| ITEM | LOAD (KW) |
| Basic allowance | 44.7 |
| Mechanical | 131.9 |
| Electric Heating | 217.7 |
| TOTAL | 394.3 |

| RETAIL | | |
|---|---|---|
| ITEM | $W/m^2$ | LOAD (KW) |
| Basic allowance | 30 | 63.1 |
| Mechanical | 55 | 115.7 |
| Electric Heating | 56 | 87.7 |
| TOTAL | | 266.6 |

| PARKING STALLS | |
|---|---|
| TYPE | TOTAL |
| Resident | 169 |
| Visitor | 17 |
| TOTAL | 186 |

| EV CHARGING AND TOTAL LOAD | | | | |
|---|---|---|---|---|
| OPTION | TOTAL EV-READY CCT | DEMAND | TOTAL EV CHARGING POWER (KW) | TOTAL BUILDING LOAD (KW) |
| BUILDING ONLY | | | | |
| Building Only | | | — | 1,522 |
| RESIDENTIAL EV CHARGING OPTIONS | | | | |
| C1. Dedicated circuits on 40A, 100% EV Read | 169 | 100% | 1,125 | 2,647 |
| C2. 4-share on 40A, 100% EV Ready | 43 | 100% | 286 | 1,808 |
| C3. 10-share on 80A, 100% EV Ready | 17 | 100% | 226 | 1,748 |

## ARCHETYPE 3: TOWNHOUSE

| GENERAL | |
|---|---|
| Space heating | electric |
| Range | electric |
| Air-conditioning | all suites |

| AREAS | | |
|---|---|---|
| TYPE | $ft^2$ | $m^2$ |
| Townhomes | 13,562 | 1,260 |
| | | |
| TOTAL | 13,562 | 1,260 |

| UNITS | | | | |
|---|---|---|---|---|
| TYPE | No. | AREA | | |
| | | $ft^2$ | $m^2$ | TOTAL ($m^2$) |
| Micro Suite | 8 | 484 | 45 | 360 |
| 3 Bed, 2 Stories | 6 | 1,292 | 120 | 720 |
| 3 Bed | 2 | 969 | 90 | 180 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | 16 | | | 1,260 |

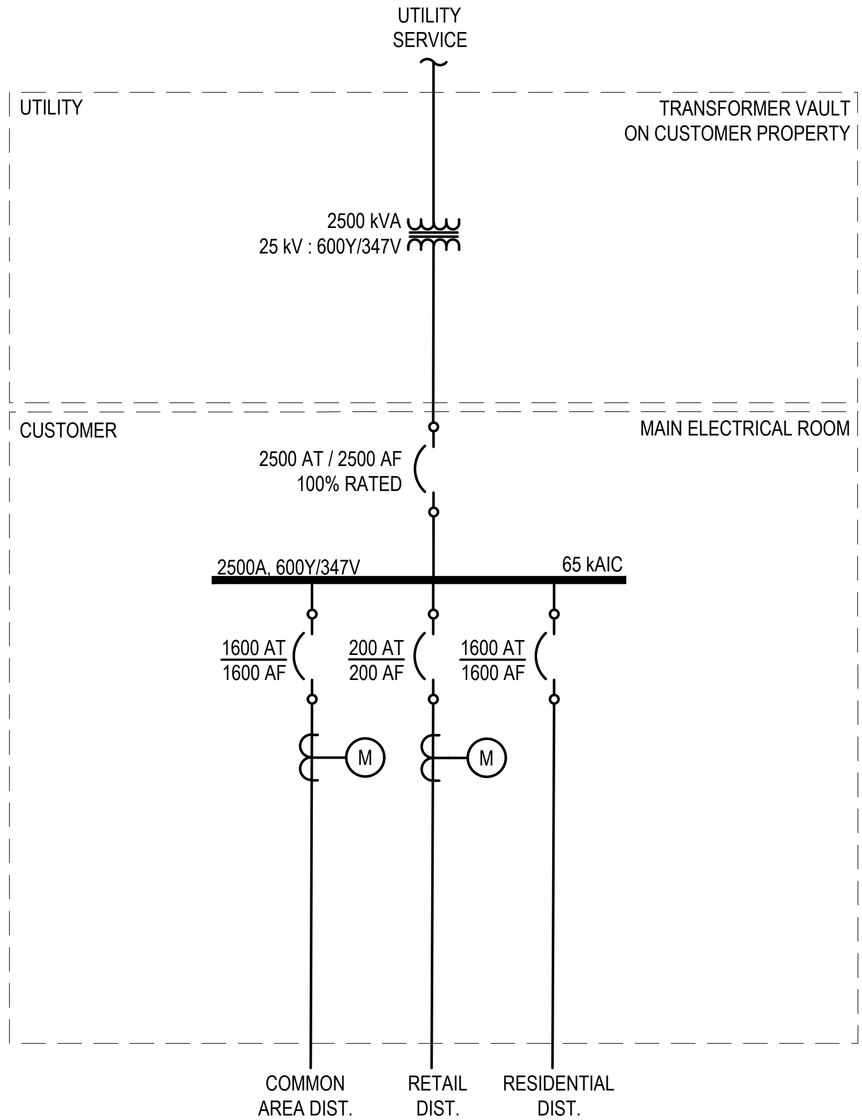
| UNIT LOADS (KW) | | | | | | | |
|---|---|---|---|---|---|---|---|
| TYPE | FIRST 90 $m^2$ | NEXT 90 $m^2$ | NEXT 90 $m^2$ | NEXT 90 $m^2$ | RANGE | DRYER @ 25% | LOAD (KW) |
| Micro Suite | 5.0 | 0.0 | 0.0 | 0.0 | 6 | 1.25 | 12.3 |
| 3 Bed, 2 stories | 5.0 | 1.0 | 0.0 | 0.0 | 6 | 1.25 | 13.3 |
| 3 Bed, 2 stories | 5.0 | 0.0 | 0.0 | 0.0 | 6 | 1.25 | 12.3 |

| RESIDENTIAL | |
|---|---|
| ITEM | LOAD (KW) |
| first suite @ 100% | 13.3 |
| 2nd & 3rd @ 65% | 17.2 |
| 4th & 5th @ 40% | 10.6 |
| 6th - 20th @25% | 36.4 |
| remainder @10% | 0.0 |
| electric heating | 55.0 |
| TOTAL | 132.5 |

| PARKING STALLS | |
|---|---|
| TYPE | TOTAL |
| Resident | 8 |
| Visitor | 0 |
| TOTAL | 8 |

| EV CHARGING AND TOTAL LOAD | | | | |
|---|---|---|---|---|
| OPTION | TOTAL EV-READY CCT | DF | TOTAL EV CHARGING POWER (KW) | TOTAL BUILDING LOAD (KW) |
| BUILDING ONLY | | | | |
| Building Only | | | — | 133 |
| RESIDENTIAL EV CHARGING OPTIONS | | | | |
| C1. Dedicated circuits on 40A, 100% EV Read | 8 | 100% | 53 | 186 |
| C2. 4-share on 40A, 100% EV Ready | 2 | 100% | 13 | 146 |
| C3. 8-share on 70A, 1000% EV Ready | 1 | 100% | 12 | 144 |

# Appendix B: Single line diagrams

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CALGARY | **VANCOUVER** | VICTORIA

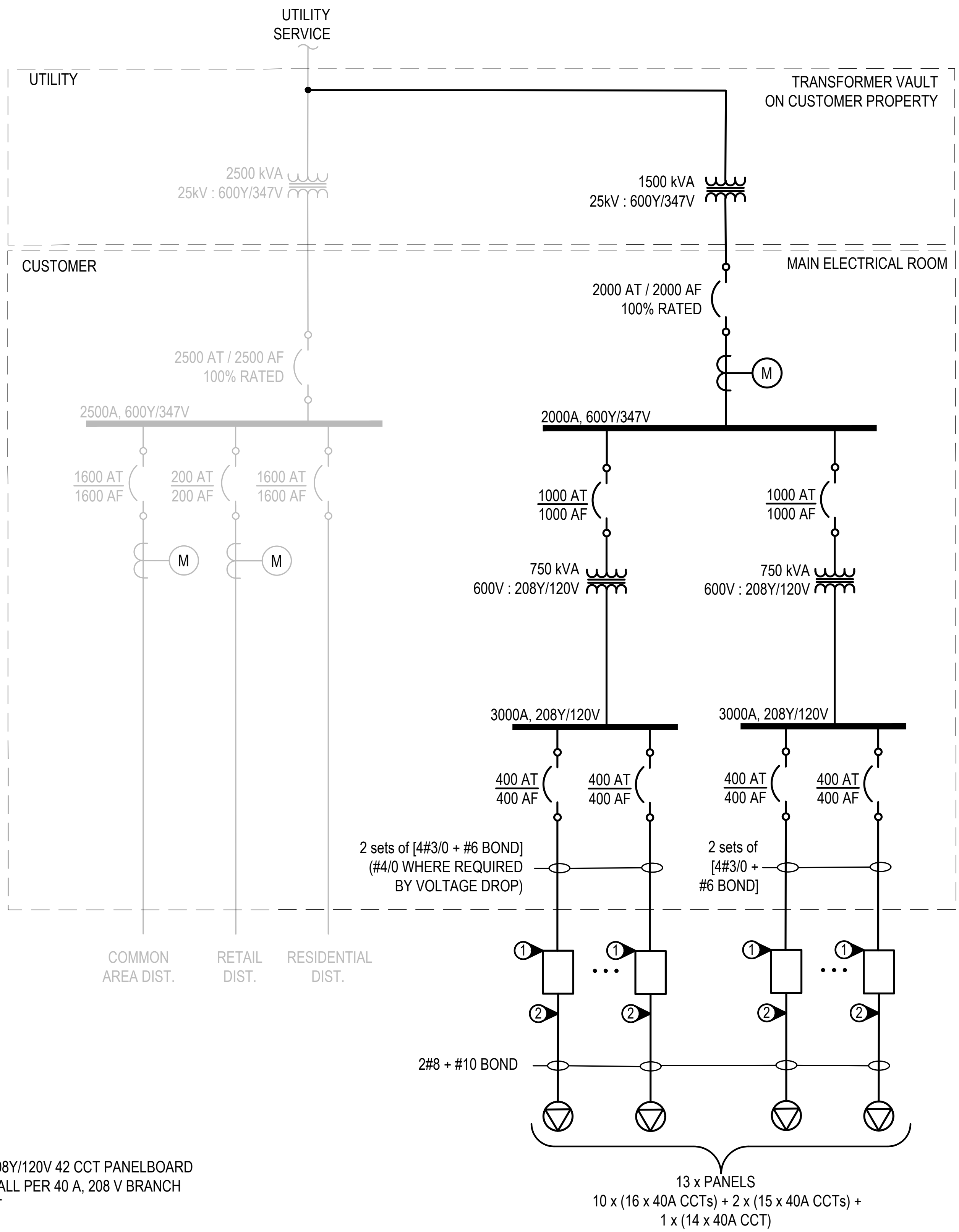
project

CITY OF CALGARY & CITY OF EDMONTON
EV CHARGING COSTING STUDY

drawing title

HIGH RISE
BASELINE

| | | | |
|---|---|---|---|
| designed JC | scale AS NOTED | date 12-08-2021 | |
| drawn JC | project no. 2-21-418 | | |
| checked RB | drawing no. E-00 | | rev. 1 |
| approved RB | | | |




KEYNOTES:

1. 400A, 208Y/120V 42 CCT PANELBOARD
2. 1 EV STALL PER 40 A, 208 V BRANCH CIRCUIT

GENERAL NOTES:

A) TOTAL CIRCUITS: 204
B) TOTAL EVSE OUTLETS: 204
C) CABLE SIZING BASED ON COPPER CABLES

| consultant | project | designed | scale | date |
| --- | --- | --- | --- | --- |
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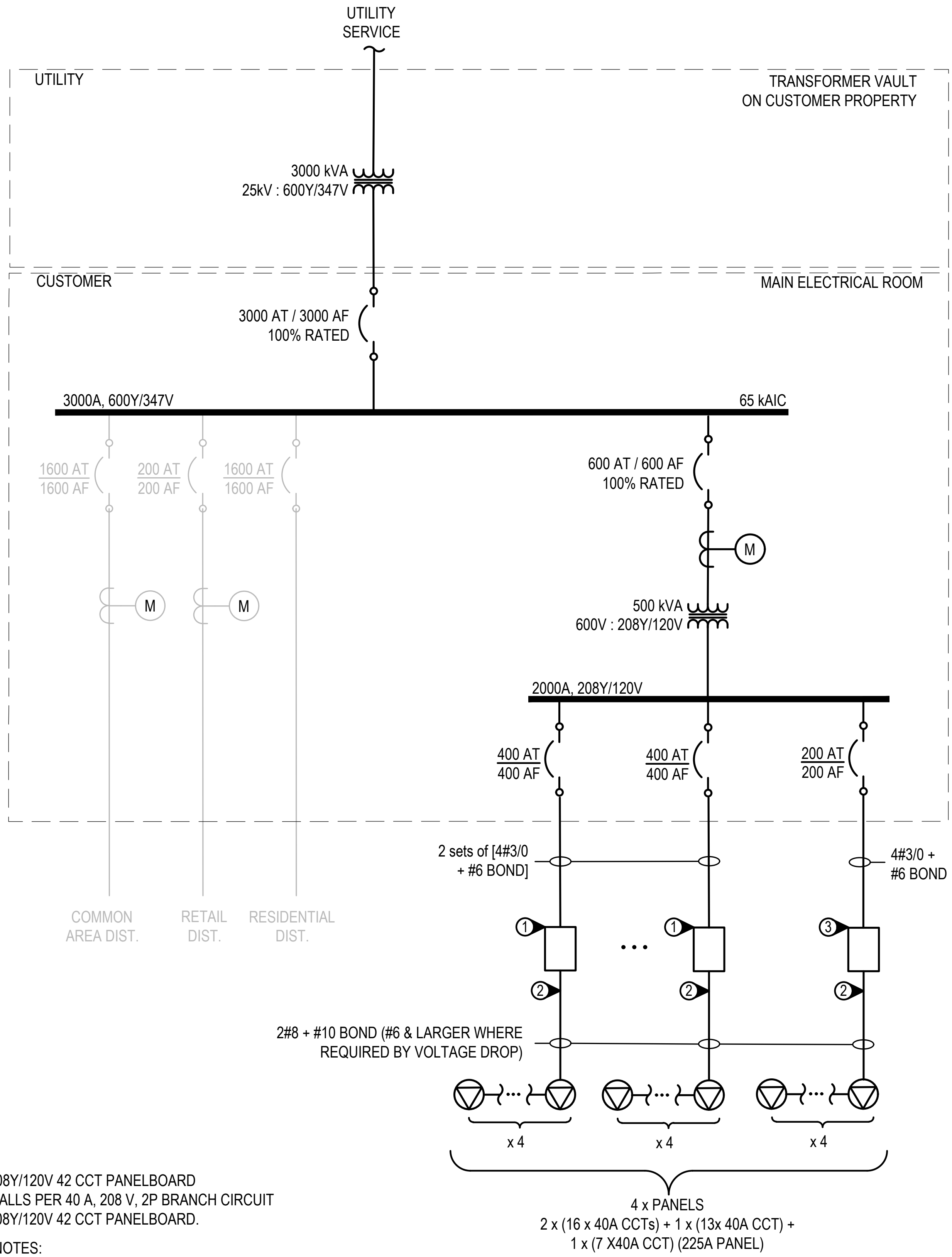
| | | drawn: JC | project no.: 2-21-418 | |
| | drawing title: HIGH RISE<br>C1. DEDICATED CIRCUITS ON 40A, 100% EV READY | checked: RB | drawing no.: E-01 | rev.: 1 |
| | | approved: RB | | |




KEYNOTES:

1. 400A, 208Y/120V 42 CCT PANELBOARD
2. 4 EV STALLS PER 40 A, 208 V, 2P BRANCH CIRCUIT
3. 225A, 208Y/120V 42 CCT PANELBOARD.

GENERAL NOTES:

A) TOTAL EVSE CIRCUITS: 52
B) TOTAL EVSE OUTLETS: 204
C) CABLE SIZING BASED ON COPPER CABLES

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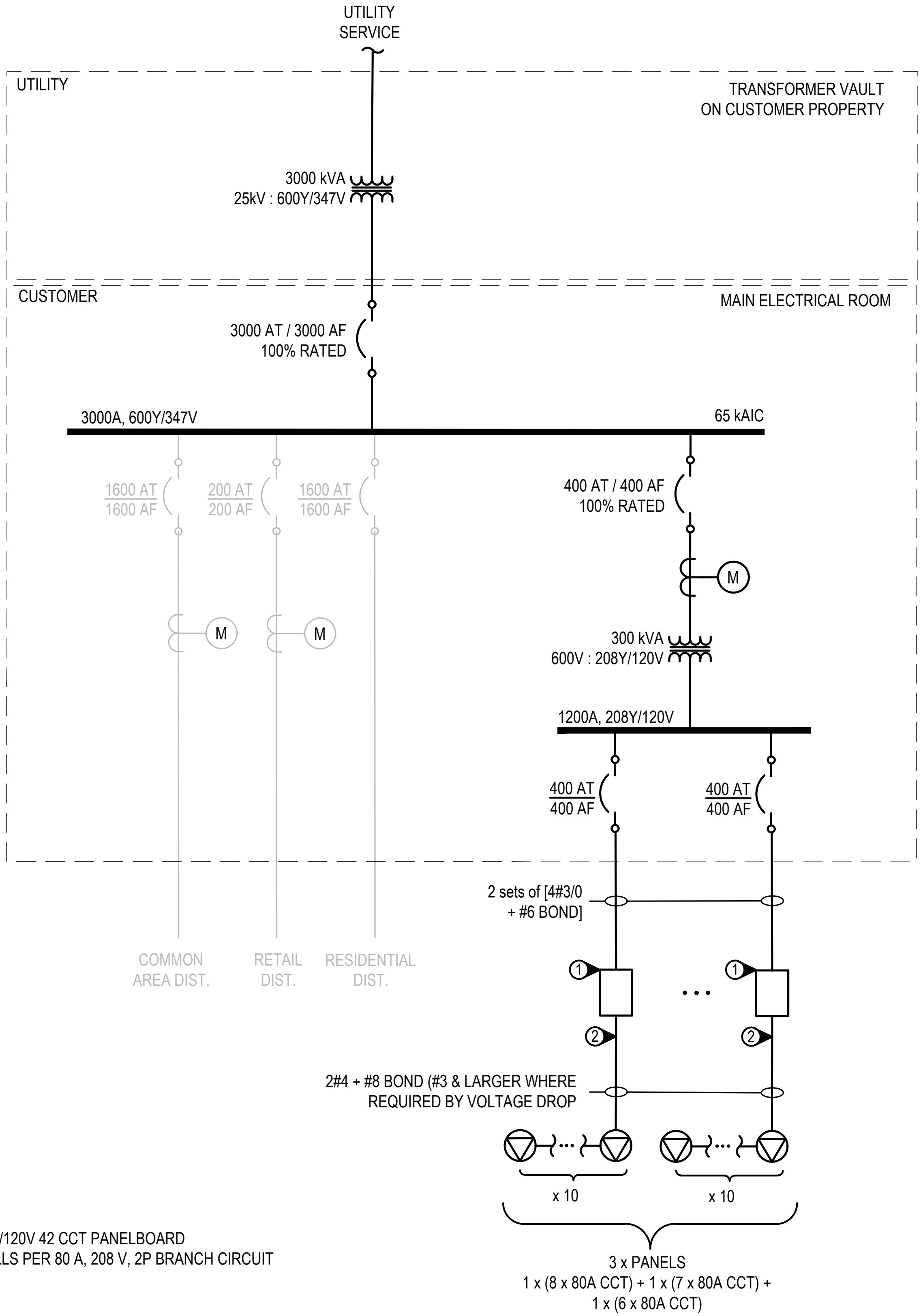
project

CITY OF CALGARY & CITY OF EDMONTON
EV CHARGING COSTING STUDY

drawing title

HIGH RISE
C2. 4-SHARE ON 40A, 100% EV READY

| designed | JC | scale | AS NOTED | date | 12-08-2021 |
|---|---|---|---|---|---|
| drawn | JC | project no. | 2-21-418 | | |
| checked | RB | drawing no. | E-02 | rev. | 1 |
| approved | RB | | | | |




KEYNOTES:

1. 400A, 208Y/120V 42 CCT PANELBOARD
2. 10 EV STALLS PER 80 A, 208 V, 2P BRANCH CIRCUIT

GENERAL NOTES:

A) TOTAL EVSE CIRCUITS: 21
B) TOTAL EVSE OUTLETS: 204
C) CABLE SIZING BASED ON COPPER CABLES

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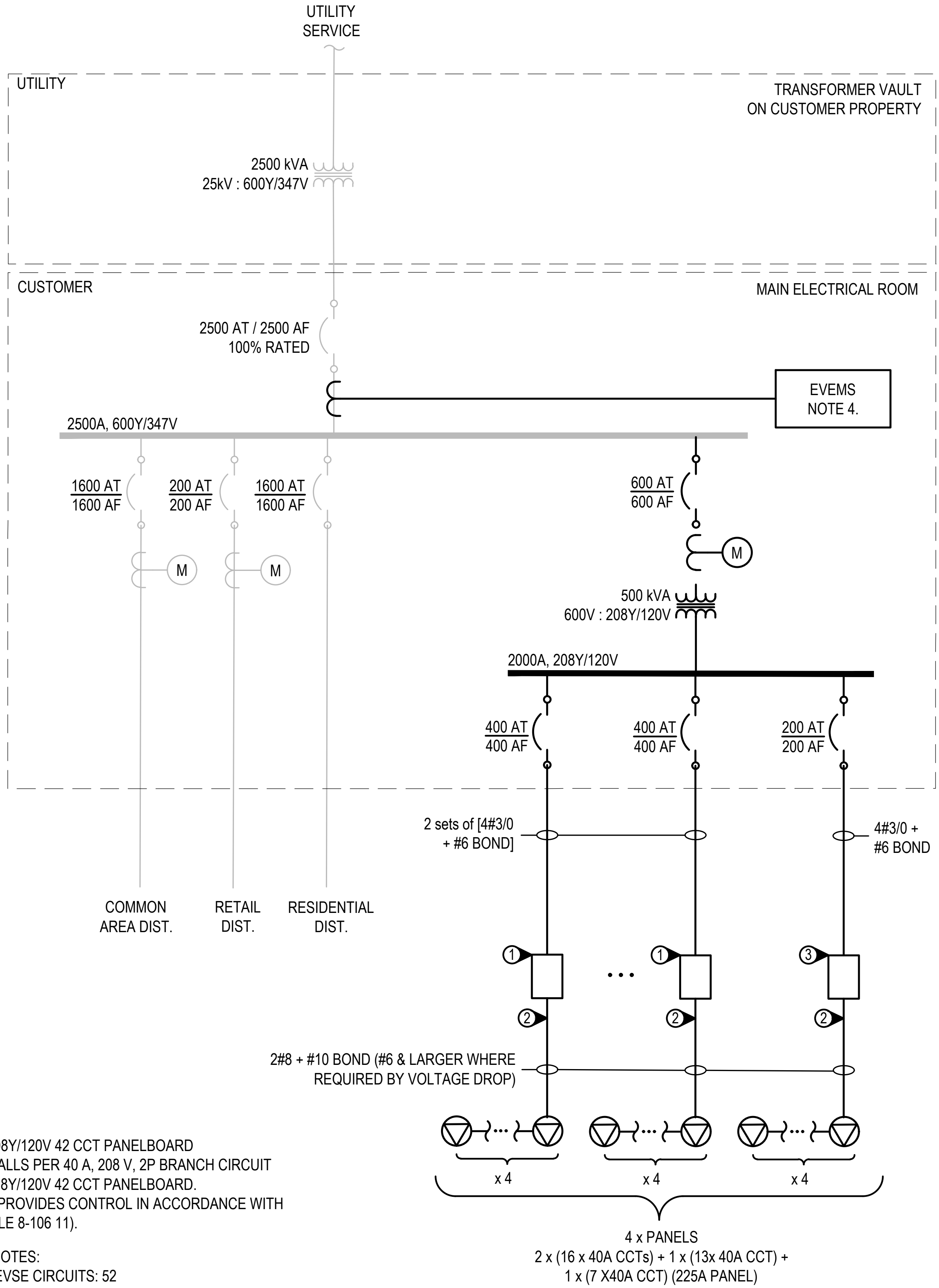
# CITY OF CALGARY & CITY OF EDMONTON EV CHARGING COSTING STUDY

drawing title

## HIGH RISE
## C3. 10-SHARE ON 80A, 100% EV READY

| | | |
|---|---|---|
| designed JC | scale AS NOTED | date 12-08-2021 |
| drawn JC | project no. 2-21-418 | |
| checked RB | drawing no. E-03 | rev. 1 |
| approved RB | | |




KEYNOTES:

1. 400A, 208Y/120V 42 CCT PANELBOARD
2. 4 EV STALLS PER 40 A, 208 V, 2P BRANCH CIRCUIT
3. 225A, 208Y/120V 42 CCT PANELBOARD.
4. EVEMS PROVIDES CONTROL IN ACCORDANCE WITH CEC RULE 8-106 11).

GENERAL NOTES:

A) TOTAL EVSE CIRCUITS: 52
B) TOTAL EVSE OUTLETS: 204
C) CABLE SIZING BASED ON COPPER CABLES

| consultant | project | designed | scale | date |
|---|---|---|---|---|
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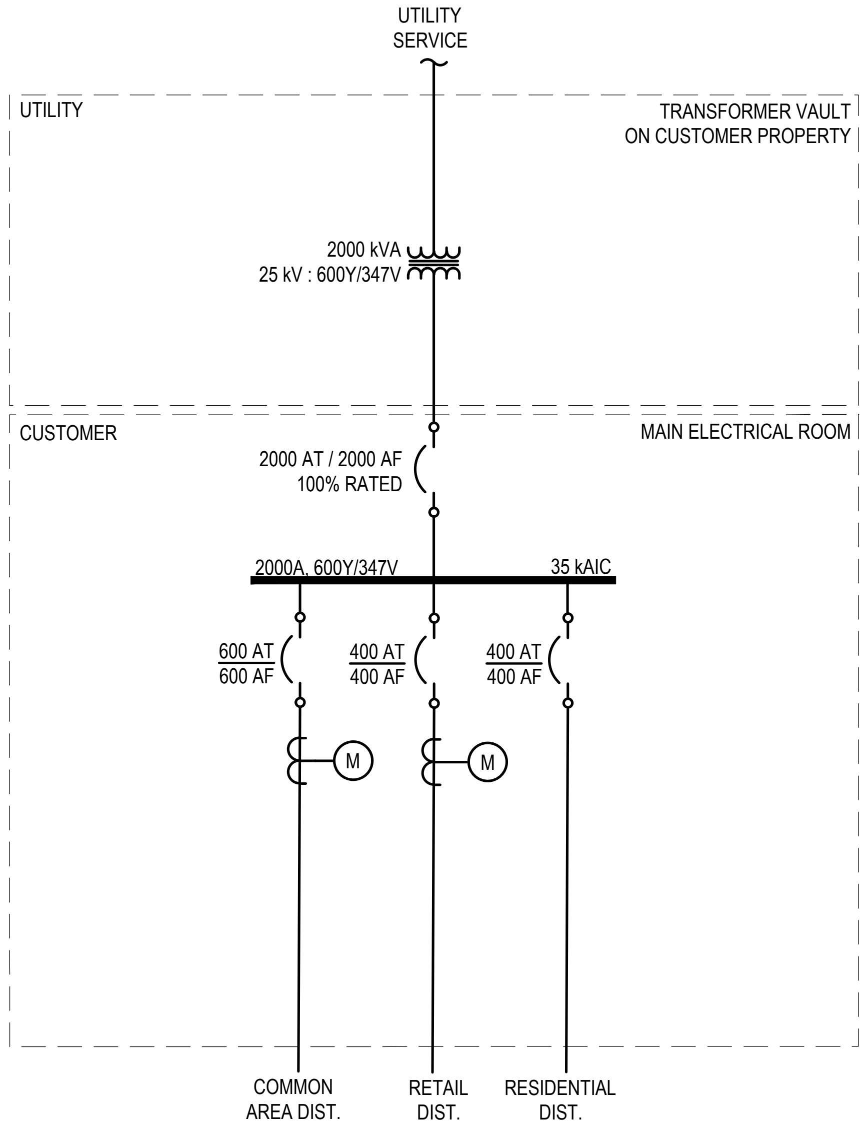
| | | drawn: JC | project no.: 2-21-418 | |
| | drawing title: HIGH RISE<br>C4. 4-SHARE ON 40A, 100% EV READY<br>/W SERVICE MONITORING | checked: RB | drawing no.: E-04 | rev.: 1 |
| | | approved: RB | | |

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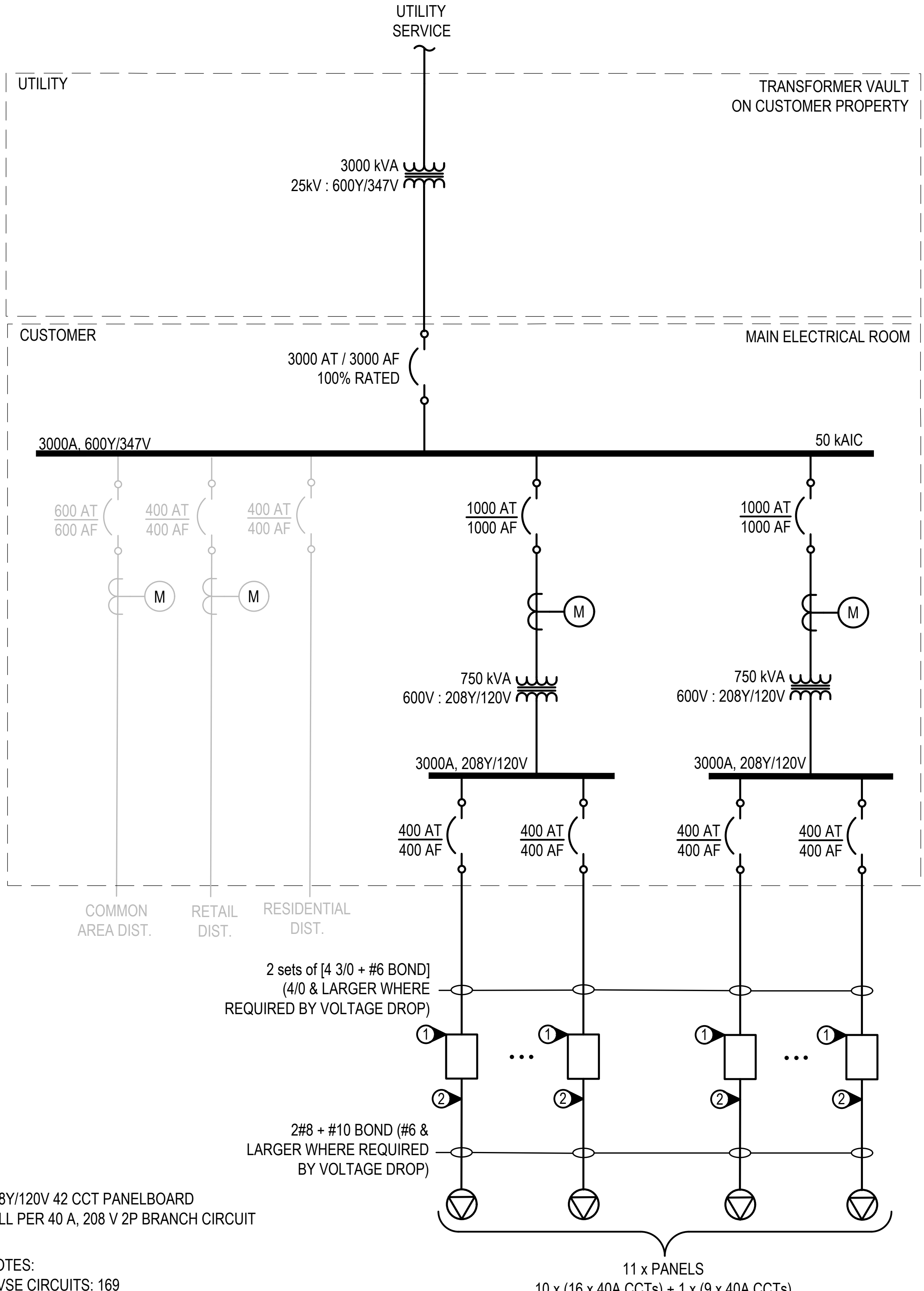
project

CITY OF CALGARY & CITY OF EDMONTON
EV CHARGING COSTING STUDY

drawing title

MID RISE
BASELINE

| | | | |
|---|---|---|---|
| designed JC | scale AS NOTED | date 12-08-2021 | |
| drawn JC | project no. 2-21-418 | | |
| checked RB | drawing no. E-10 | | rev. 1 |
| approved RB | | | |




KEYNOTES:
1. 400 A, 208Y/120V 42 CCT PANELBOARD
2. 1 EV STALL PER 40 A, 208 V 2P BRANCH CIRCUIT

GENERAL NOTES:
A) TOTAL EVSE CIRCUITS: 169
B) TOTAL EVSE OUTLETS: 169
C) CABLE SIZING BASED ON COPPER CABLES

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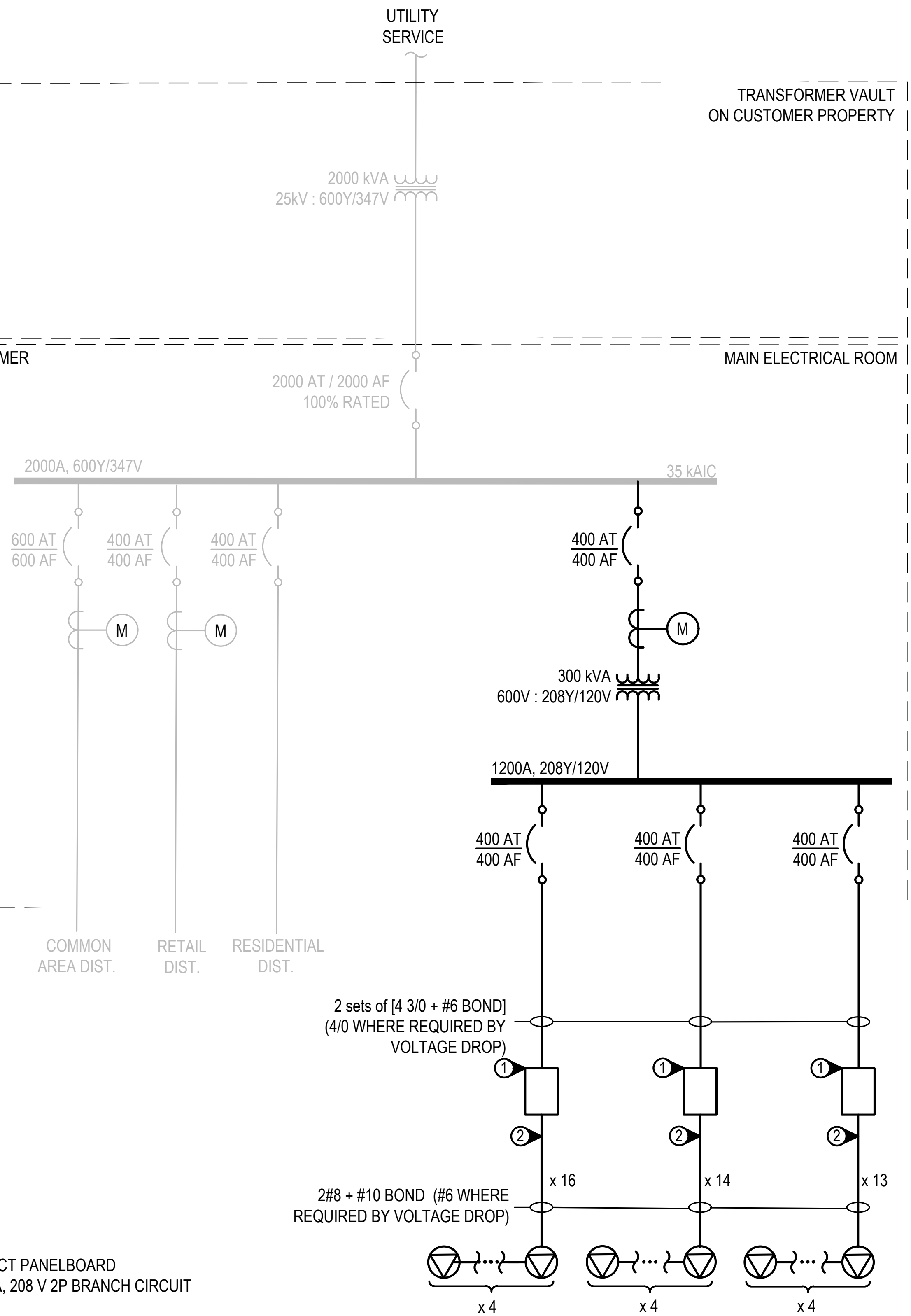
CITY OF CALGARY & CITY OF EDMONTON
EV CHARGING COSTING STUDY

drawing title
MID RISE
C1. DEDICATED CIRCUITS ON 40A, 100% EV READY

| designed | JC | scale | AS NOTED | date | 12-08-2021 |
|---|---|---|---|---|---|
| drawn | JC | project no. | 2-21-418 | | |
| checked | RB | drawing no. | E-11 | rev. | 1 |
| approved | RB | | | | |



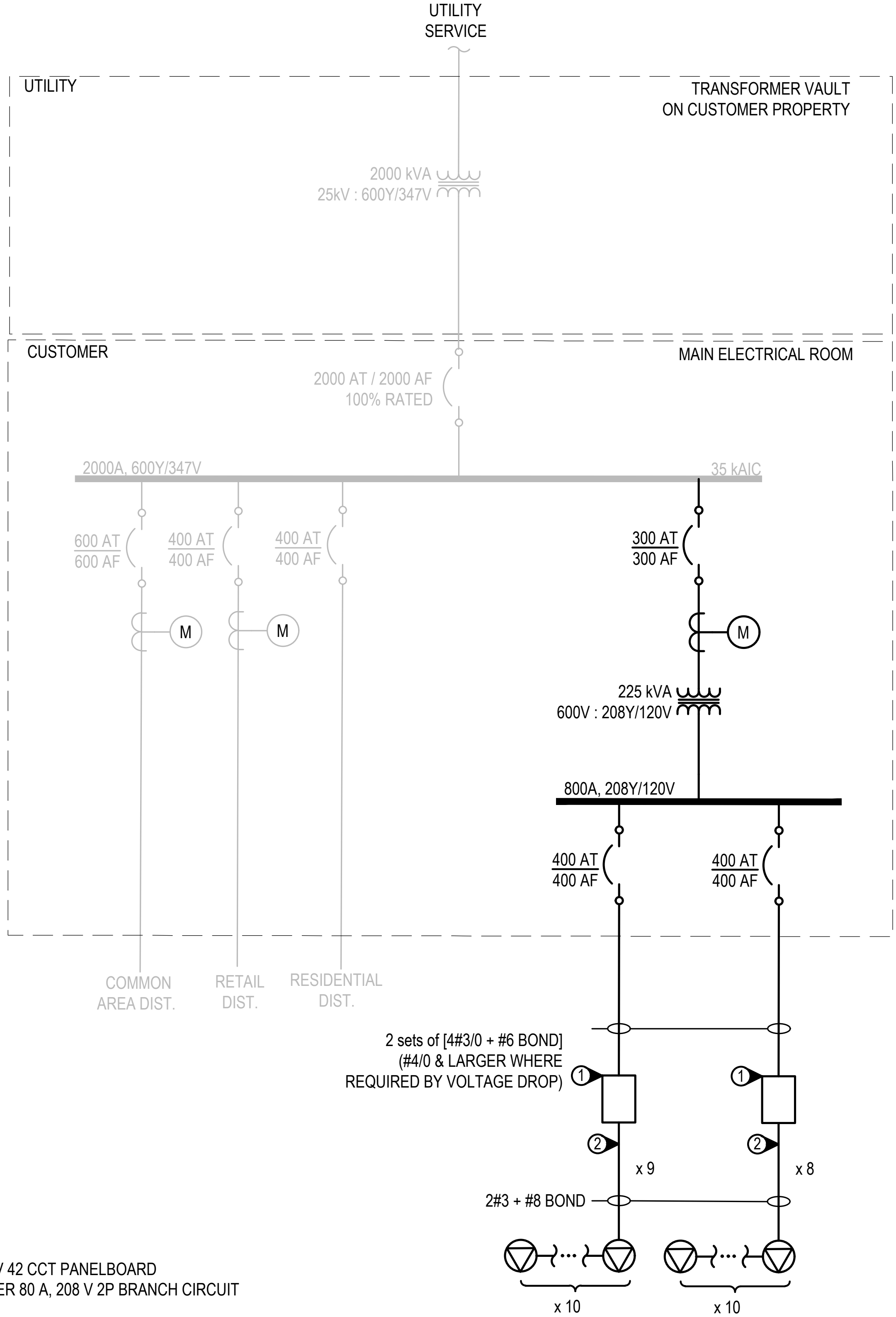

KEYNOTES:

1. 400 A, 208Y/120V 42 CCT PANELBOARD
2. 4 EV STALLS PER 40 A, 208 V 2P BRANCH CIRCUIT

GENERAL NOTES:

A) TOTAL EVSE CIRCUITS: 43
B) TOTAL EVSE OUTLETS: 169
C) CABLE SIZING BASED ON COPPER CABLES

| consultant | project | designed | scale | date |
|---|---|---|---|---|
| AES Designing A Better Tomorrow, 505 Burrard Street, Suite 950, Vancouver, BC V7X 1M4, 604.569.6500 \| www.aesengr.com, CALGARY \| VANCOUVER \| VICTORIA | CITY OF CALGARY & CITY OF EDMONTON EV CHARGING COSTING STUDY | JC | AS NOTED | 12-08-2021 |
| | | drawn: JC | project no.: 2-21-418 | |
| | drawing title: MID RISE C2. 4-SHARE ON 40A, 100% EV READY | checked: RB | drawing no.: E-12 | rev.: 1 |
| | | approved: RB | | |




KEYNOTES:
1. 400 A, 208Y/120V 42 CCT PANELBOARD
2. 10 EV STALLS PER 80 A, 208 V 2P BRANCH CIRCUIT

GENERAL NOTES:
A) TOTAL EVSE CIRCUITS: 17
B) TOTAL EVSE OUTLETS: 169
C) CABLE SIZING BASED ON COPPER CABLES

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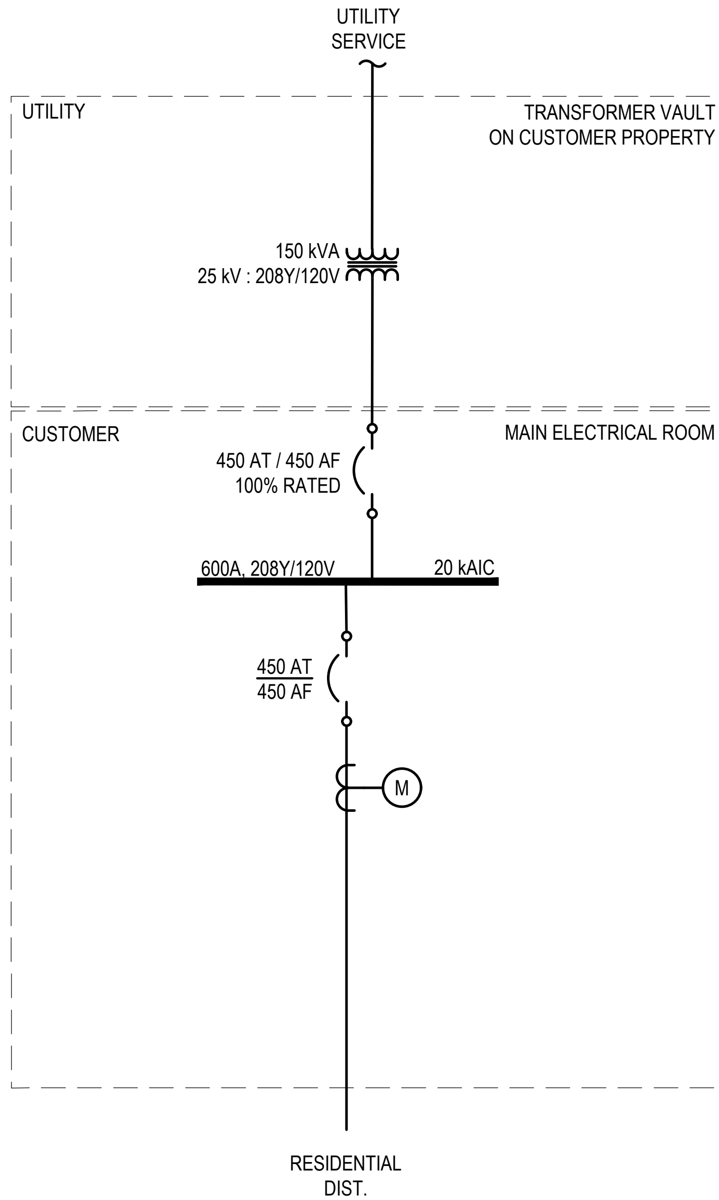
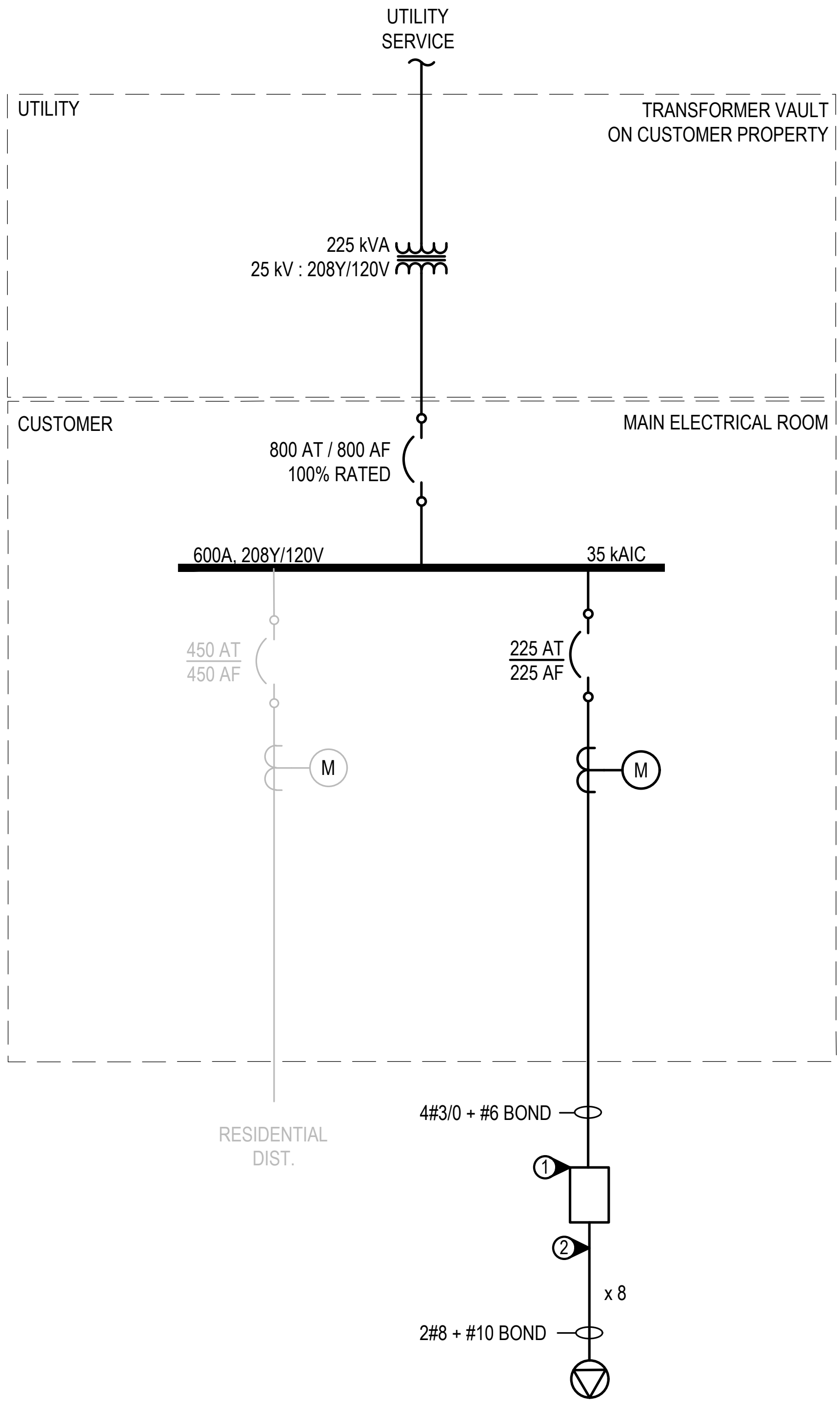
EV CHARGING COSTING STUDY

drawing title
MID RISE
C3. 10-SHARE ON 80A, 100% EV READY

| designed JC | scale AS NOTED | date 12-08-2021 |
|---|---|---|
| drawn JC | project no. 2-21-418 | |
| checked RB | drawing no. E-13 | rev. 1 |
| approved RB | | |




| | | | | |
|---|---|---|---|---|
| consultant: AES Designing A Better Tomorrow, 505 Burrard Street, Suite 950, Vancouver, BC V7X 1M4, 604.569.6500 \| www.aesengr.com, CALGARY \| VANCOUVER \| VICTORIA | project: CITY OF CALGARY & CITY OF EDMONTON EV CHARGING COSTING STUDY | designed: JC | scale: AS NOTED | date: 12-08-2021 |
| | | drawn: JC | project no.: 2-21-418 | |
| | drawing title: TOWNHOUSE BASELINE | checked: RB | drawing no.: E-20 | rev.: 1 |
| | | approved: RB | | |




KEYNOTES:

1. 225A, 208Y/120V 18 CCT PANELBOARD
2. 1 EV STALL PER 40 A, 208 V BRANCH CIRCUIT

GENERAL NOTES:

A) CABLE SIZING BASED ON COPPER CABLES

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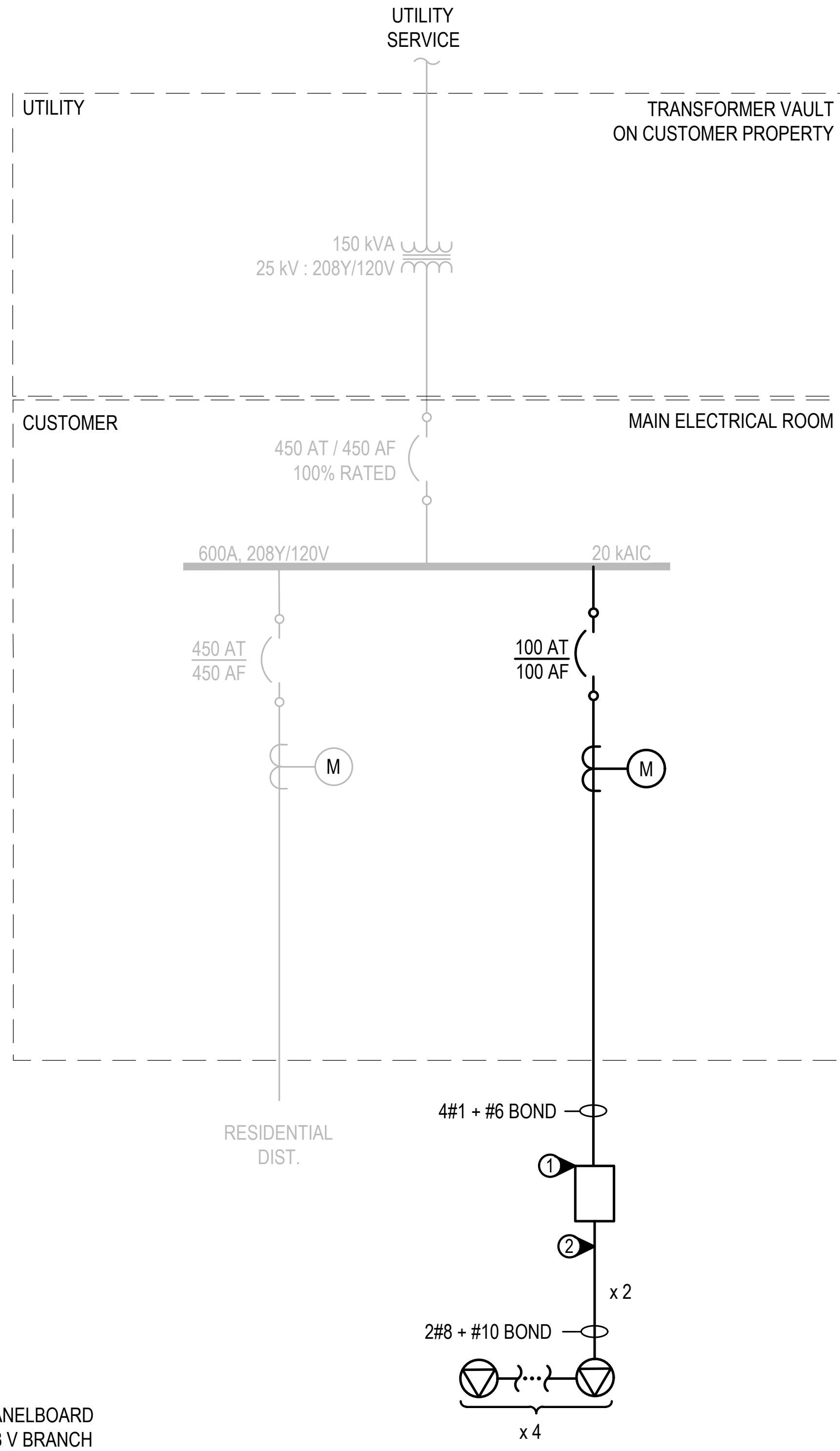
# CITY OF CALGARY & CITY OF EDMONTON
# EV CHARGING COSTING STUDY

drawing title

## TOWNHOUSE
## C1. DEDICATED CIRCUITS ON 40A, 100% EV READY

| | | | |
|---|---|---|---|
| designed: JC | scale: AS NOTED | date: 12-08-2021 | |
| drawn: JC | project no.: 2-21-418 | | |
| checked: RB | drawing no.: E-21 | | rev.: 1 |
| approved: RB | | | |




KEYNOTES:
1. 125A, 208Y/120V 18 CCT PANELBOARD
2. 4 EV STALLS PER 40 A, 208 V BRANCH CIRCUIT

GENERAL NOTES:
A) CABLE SIZING BASED ON COPPER CABLES

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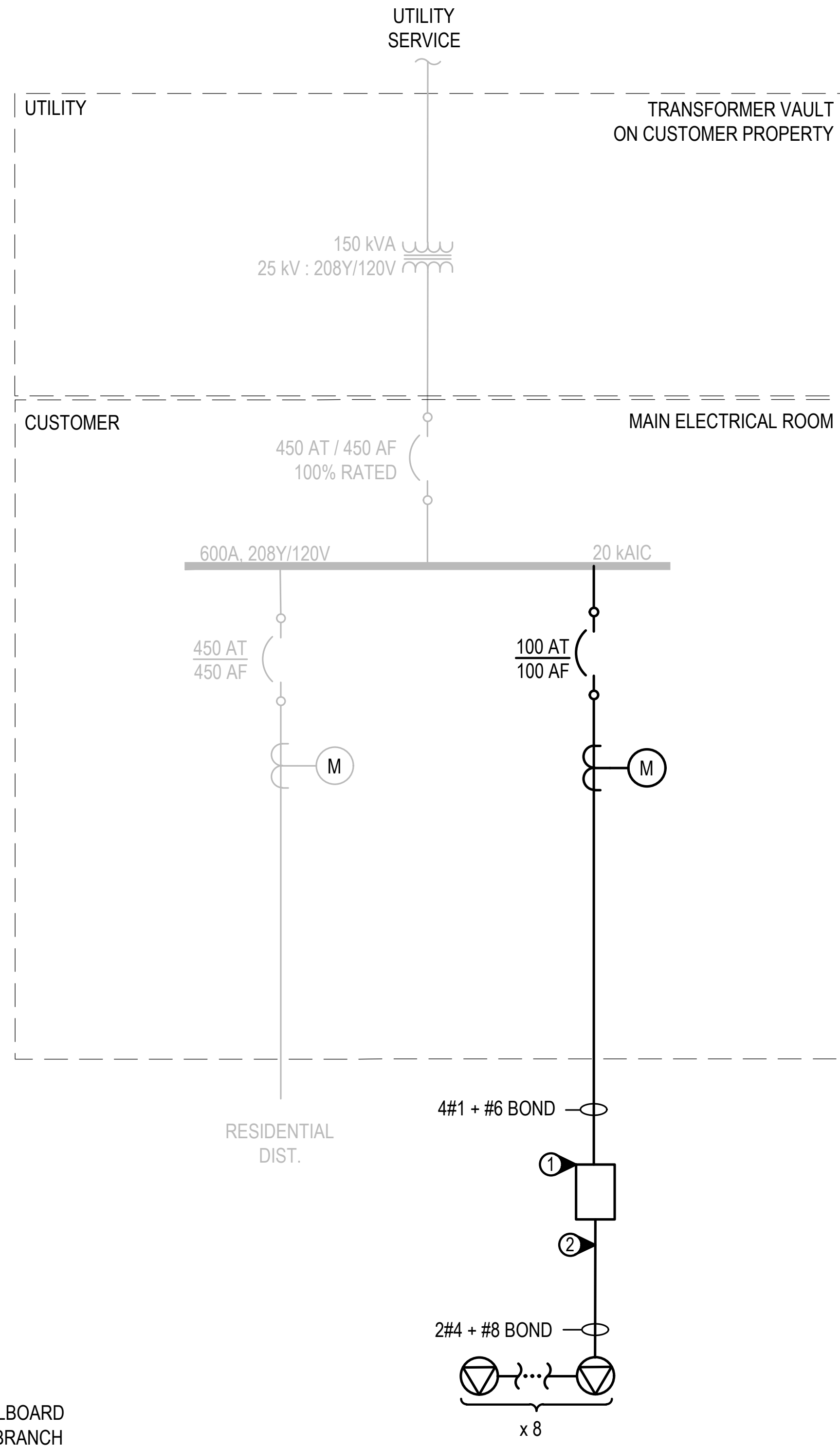
CITY OF CALGARY & CITY OF EDMONTON
EV CHARGING COSTING STUDY

drawing title

TOWNHOUSE
C2. 4-SHARE ON 40A, 100% EV READY

| designed | scale | date |
|---|---|---|
| JC | AS NOTED | 12-08-2021 |
| drawn: JC | project no.: 2-21-418 | |
| checked: RB | drawing no.: E-22 | rev.: 1 |
| approved: RB | | |




KEYNOTES:
1. 125A, 208Y/120V 18 CCT PANELBOARD
2. 8 EV STALLS PER 70 A, 208 V BRANCH CIRCUIT

GENERAL NOTES:
A) CABLE SIZING BASED ON COPPER CABLES

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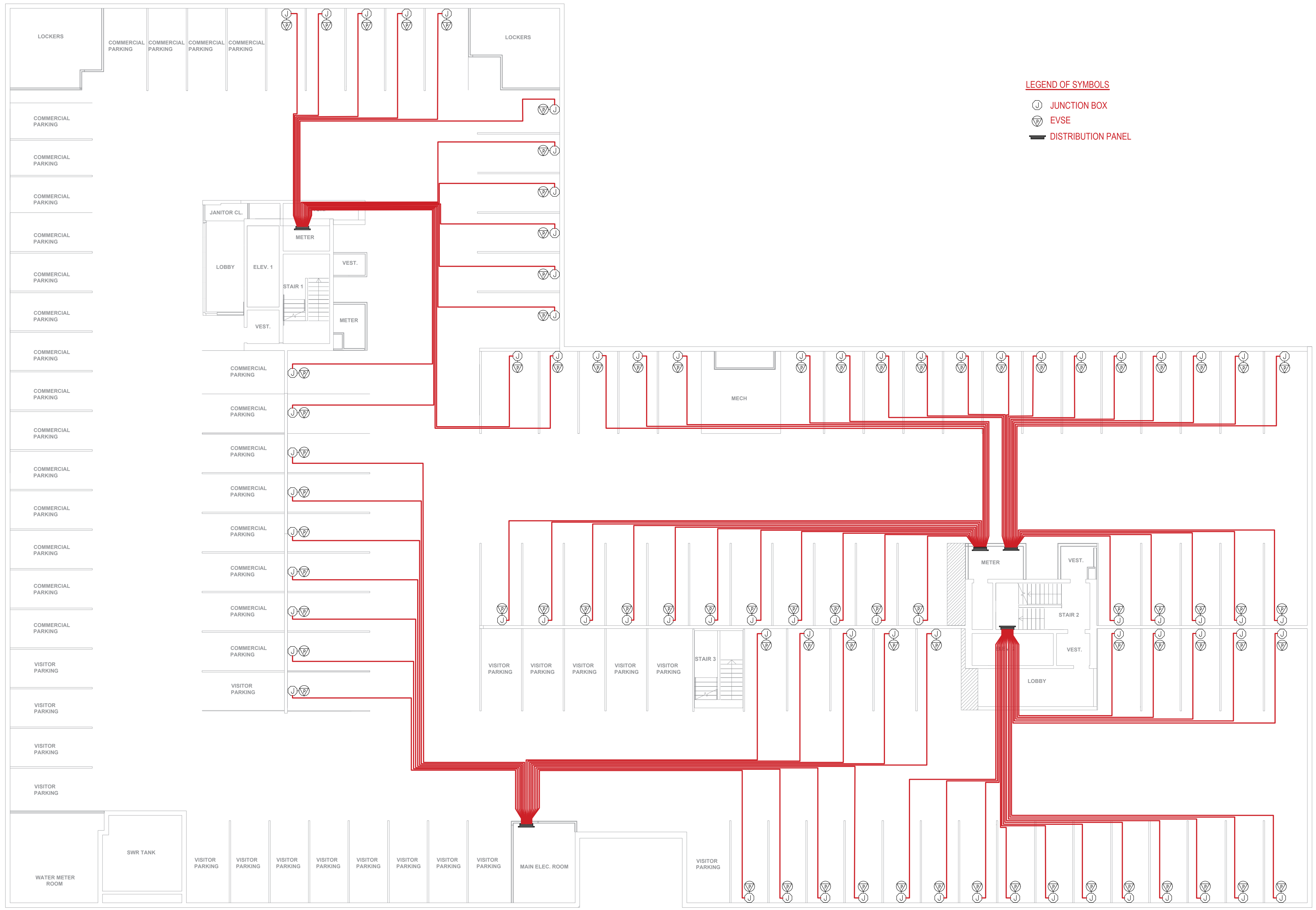
project
# CITY OF CALGARY & CITY OF EDMONTON
# EV CHARGING COSTING STUDY

drawing title
## TOWNHOUSE
## C3. 8-SHARE ON 70A, 100% EV READY

| | | | |
|---|---|---|---|
| designed JC | scale AS NOTED | date 12-08-2021 | |
| drawn JC | project no. 2-21-418 | | |
| checked RB | drawing no. E-23 | | rev. 1 |
| approved RB | | | |

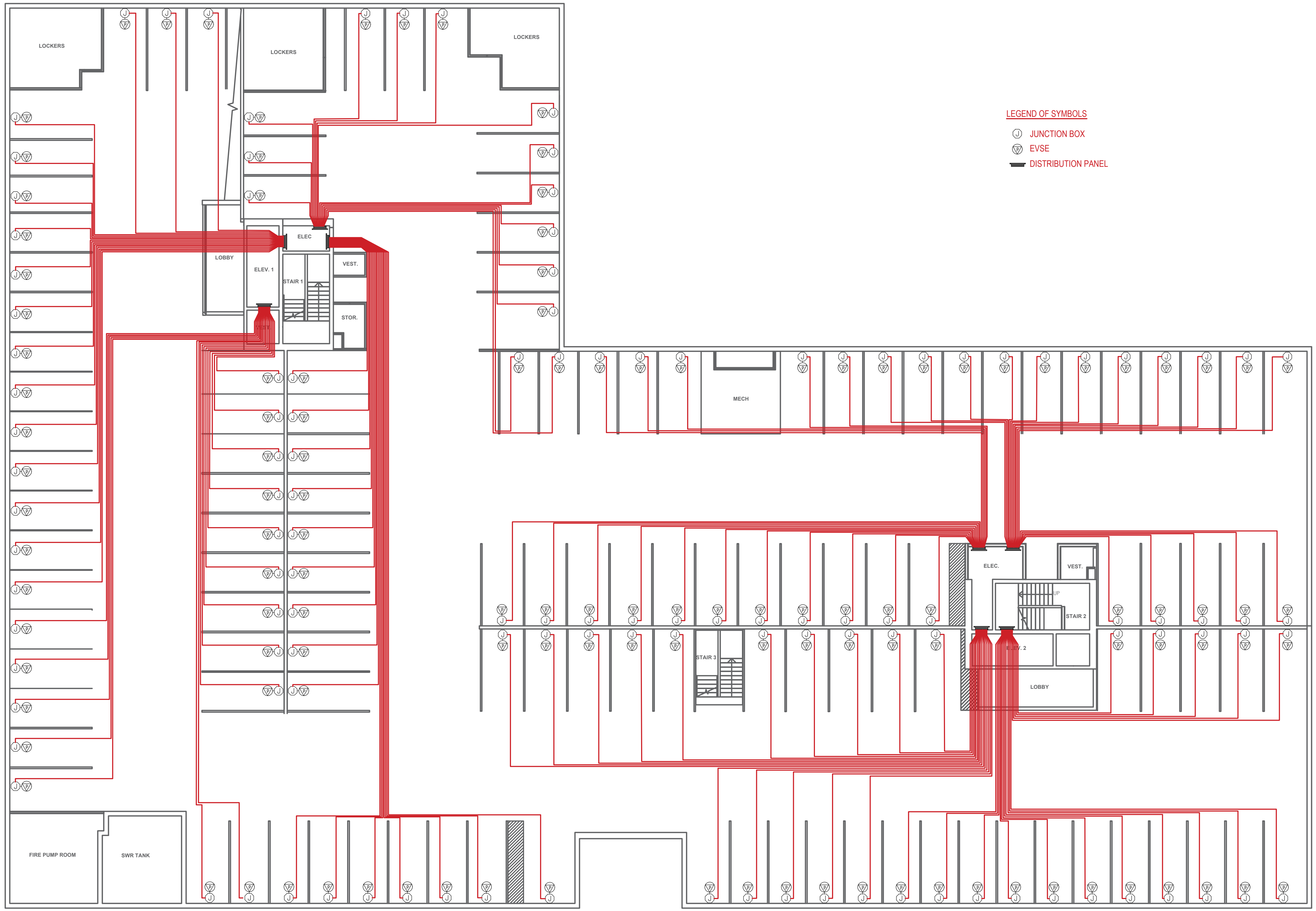
# Appendix C: Parking layout drawings




LEGEND OF SYMBOLS

- JUNCTION BOX
- EVSE
- DISTRIBUTION PANEL

| | |
|---|---|
| seal | |
| consultant | AES Designing A Better Tomorrow<br>505 Burrard Street, Suite 950, Vancouver, BC V7X 1M4<br>604.569.6500 \| www.aesengr.com<br>CALGARY \| VANCOUVER \| VICTORIA |
| project | CITIES OF CALGARY & EDMONTON EV COSTING STUDY |
| drawing title | HIGH RISE P2<br>C1. DEDICATED ON 40A, 100% EV READY |
| designed | JC |
| drawn | JC |
| checked | RB |
| approved | RB |
| scale | AS NOTED |
| date | JAN 28, 2022 |
| project no. | 2-21-418 |
| drawing no. | E-102-P2 |
| rev. | 2 |




| | | | |
|---|---|---|---|
| seal | consultant | project | designed JC |
| | AES Designing A Better Tomorrow | CITIES OF CALGARY & EDMONTON EV COSTING STUDY | scale AS NOTED |
| | | | date JAN 28, 2022 |
| | | drawing title | drawn JC |
| | | HIGH RISE P3 C1. DEDICATED ON 40A, 100% EV READY | project no. 2-21-418 |
| | | | checked RB |
| | | | drawing no. E-102-P3 |
| | | | approved RB |
| | | | rev. 2 |

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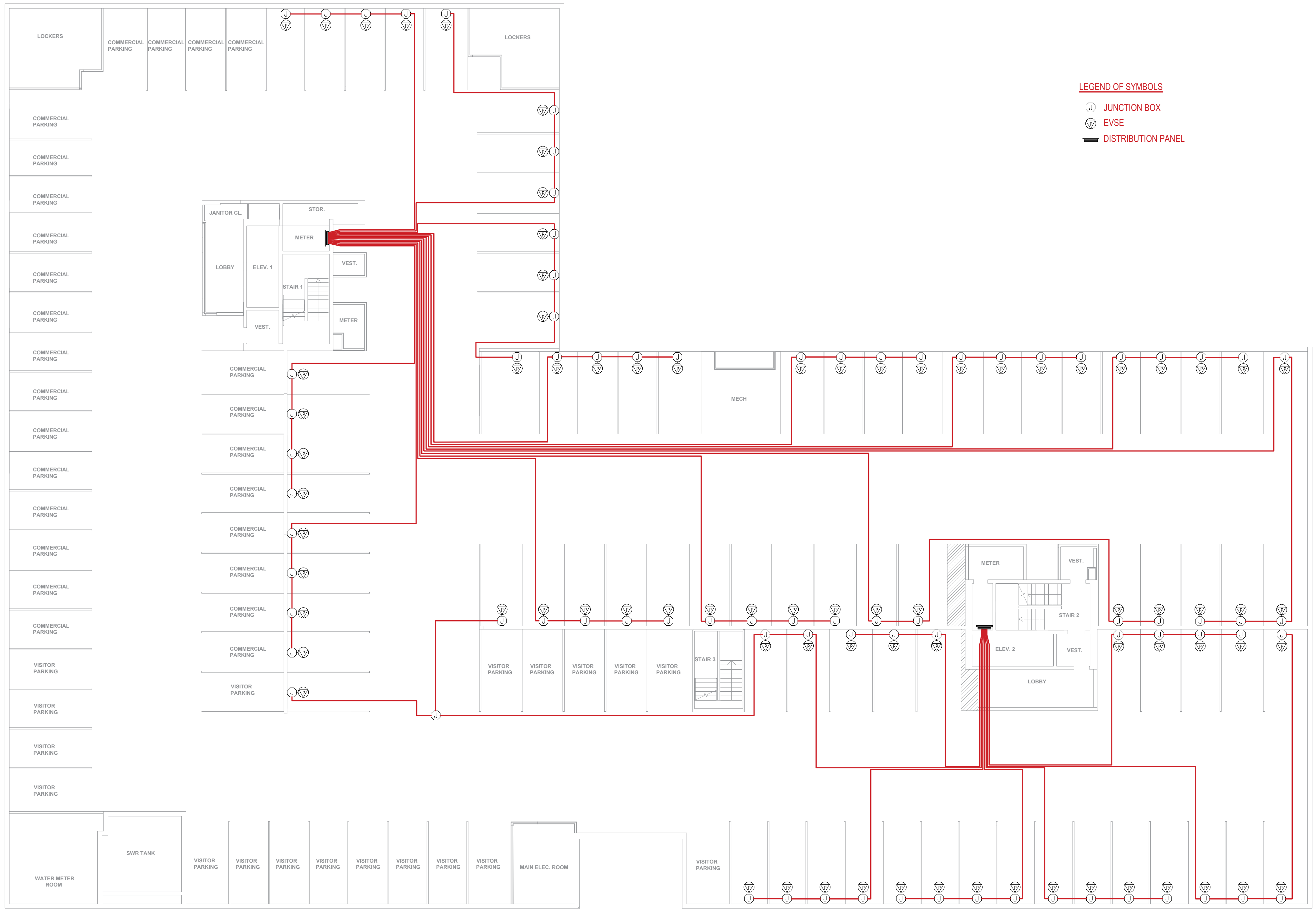
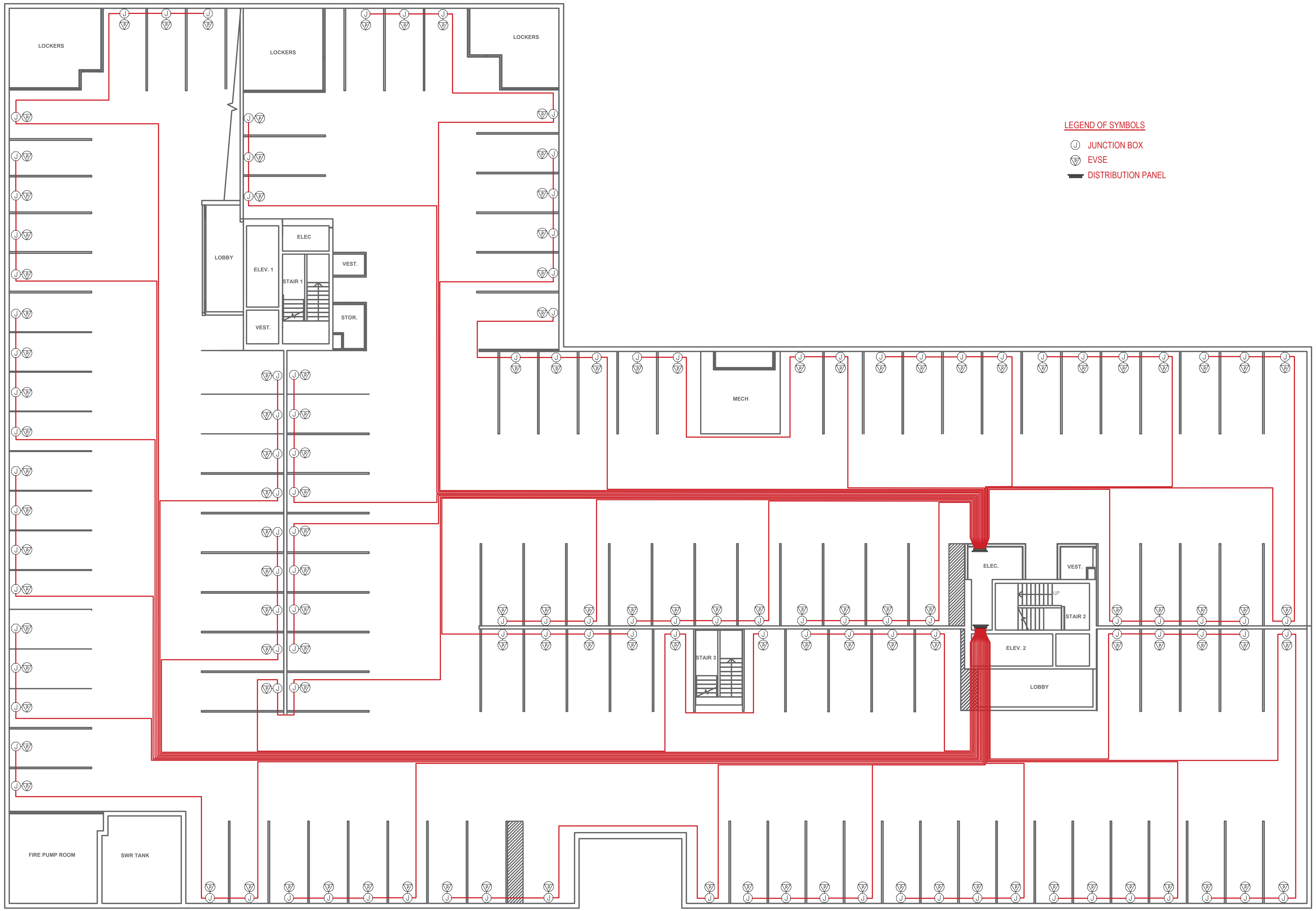



LEGEND OF SYMBOLS

- JUNCTION BOX
- EVSE
- DISTRIBUTION PANEL

| seal | consultant | project | | |
|---|---|---|---|---|
| | AES<br>Designing A Better Tomorrow<br>505 Burrard Street, Suite 950, Vancouver, BC V7X 1M4<br>604.569.6500 \| www.aesengr.com<br>CALGARY \| VANCOUVER \| VICTORIA | CITIES OF CALGARY & EDMONTON<br>EV COSTING STUDY | | |
| | | drawing title: HIGH RISE P2<br>C2. 4-SHARE ON 40A, 100% EV READY | | |

| | | | |
|---|---|---|---|
| designed: JC | scale: AS NOTED | date: JAN 28, 2022 | |
| drawn: JC | project no.: 2-21-418 | | |
| checked: RB | drawing no.: E-103-P2 | | rev.: 2 |
| approved: RB | | | |

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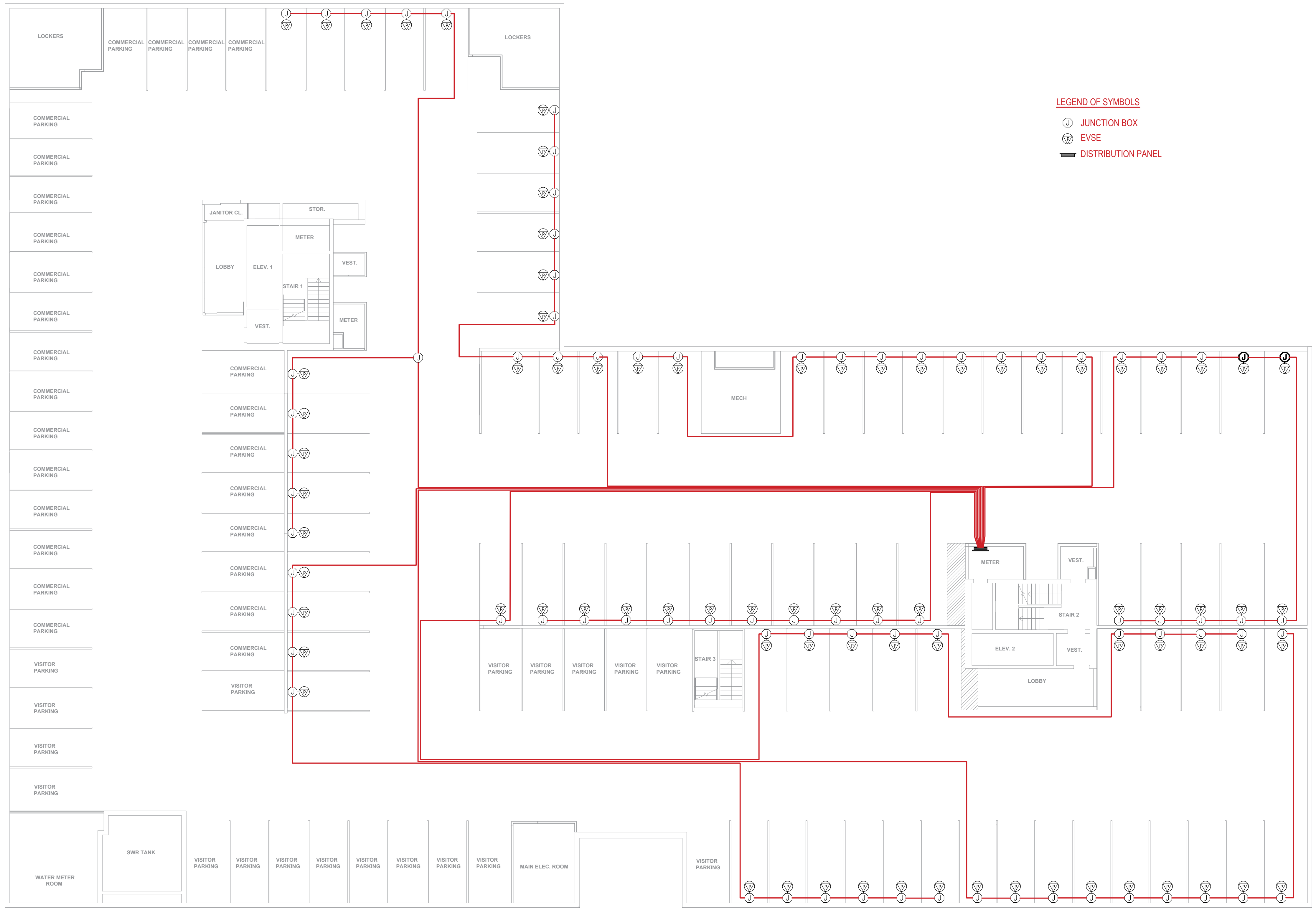
drawing title
HIGH RISE P3
C2. 4-SHARE ON 40A, 100% EV READY

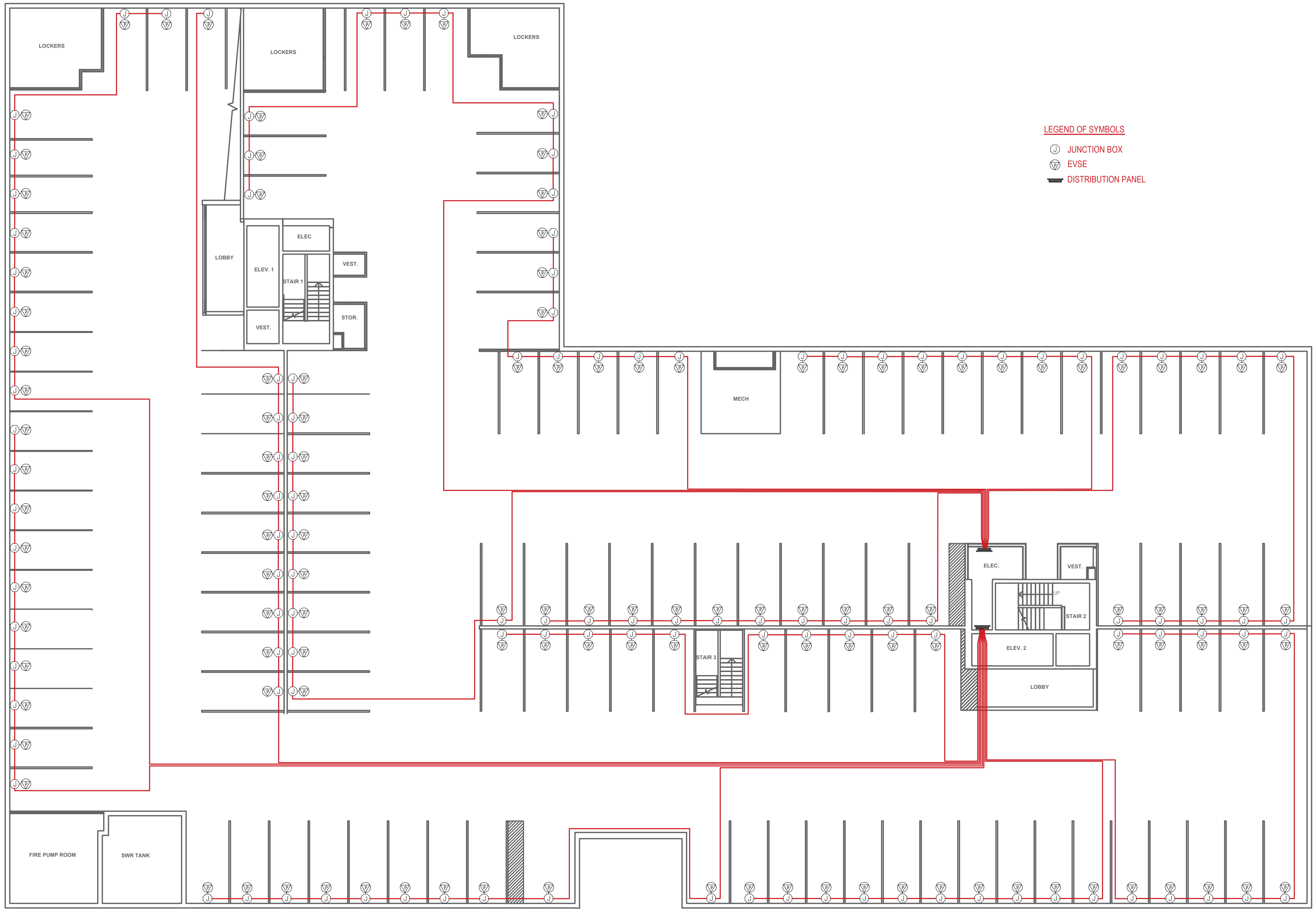
| designed | JC | scale | AS NOTED | date | JAN 28, 2022 |
|---|---|---|---|---|---|
| drawn | JC | project no. | 2-21-418 | | |
| checked | RB | drawing no. | E-103-P3 | rev. | 2 |
| approved | RB | | | | |




LEGEND OF SYMBOLS

- JUNCTION BOX
- EVSE
- DISTRIBUTION PANEL

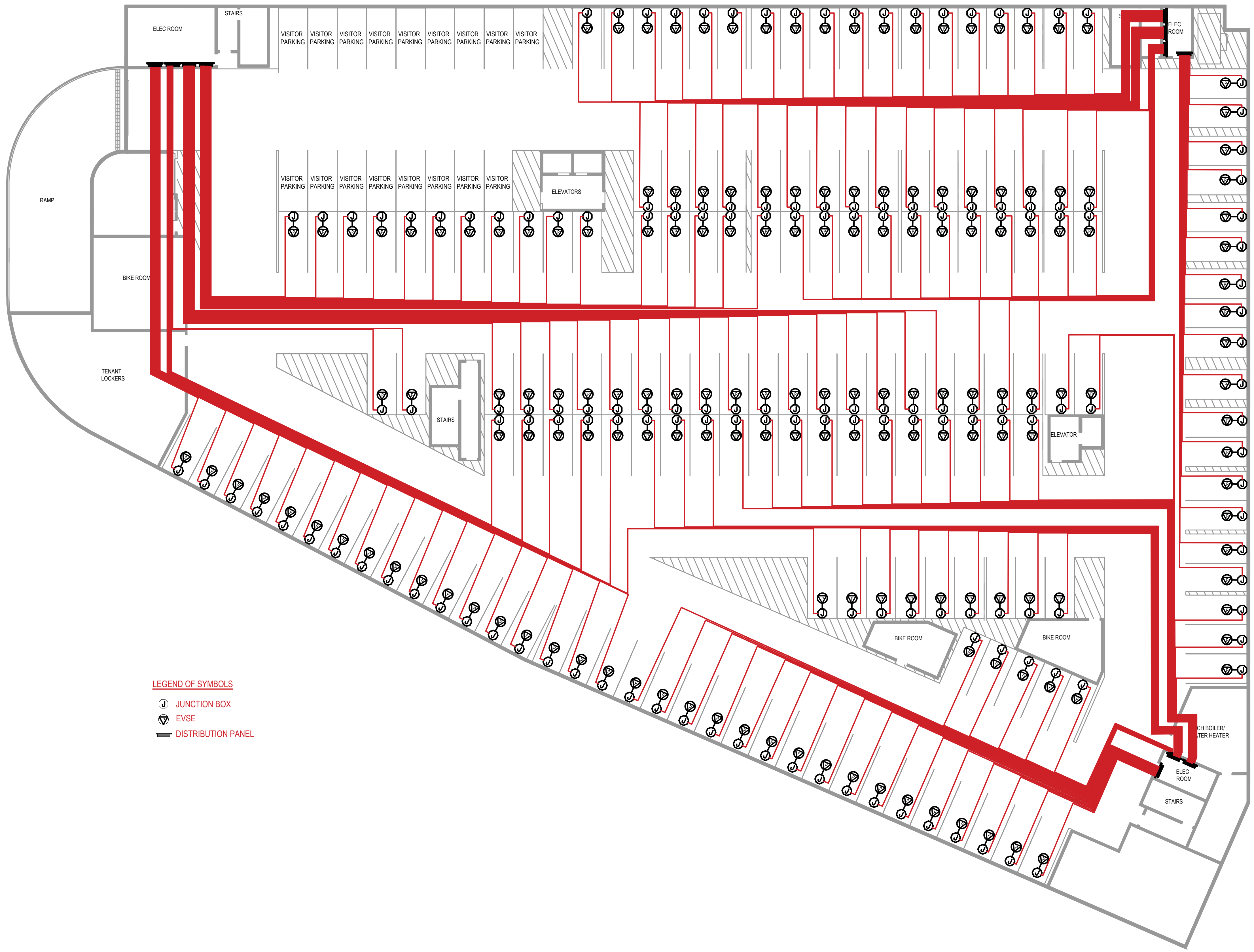
| seal | consultant | project | designed | scale | date |
|---|---|---|---|---|---|
| | AES Designing A Better Tomorrow | CITIES OF CALGARY & EDMONTON EV COSTING STUDY | JC | AS NOTED | JAN 28, 2022 |
| | | drawing title: HIGH RISE P2 C3. 10-SHARE ON 80A, 100% EV READY | drawn: JC | project no.: 2-21-418 | |
| | | | checked: RB | drawing no.: E-104-P2 | rev.: 2 |
| | | | approved: RB | | |



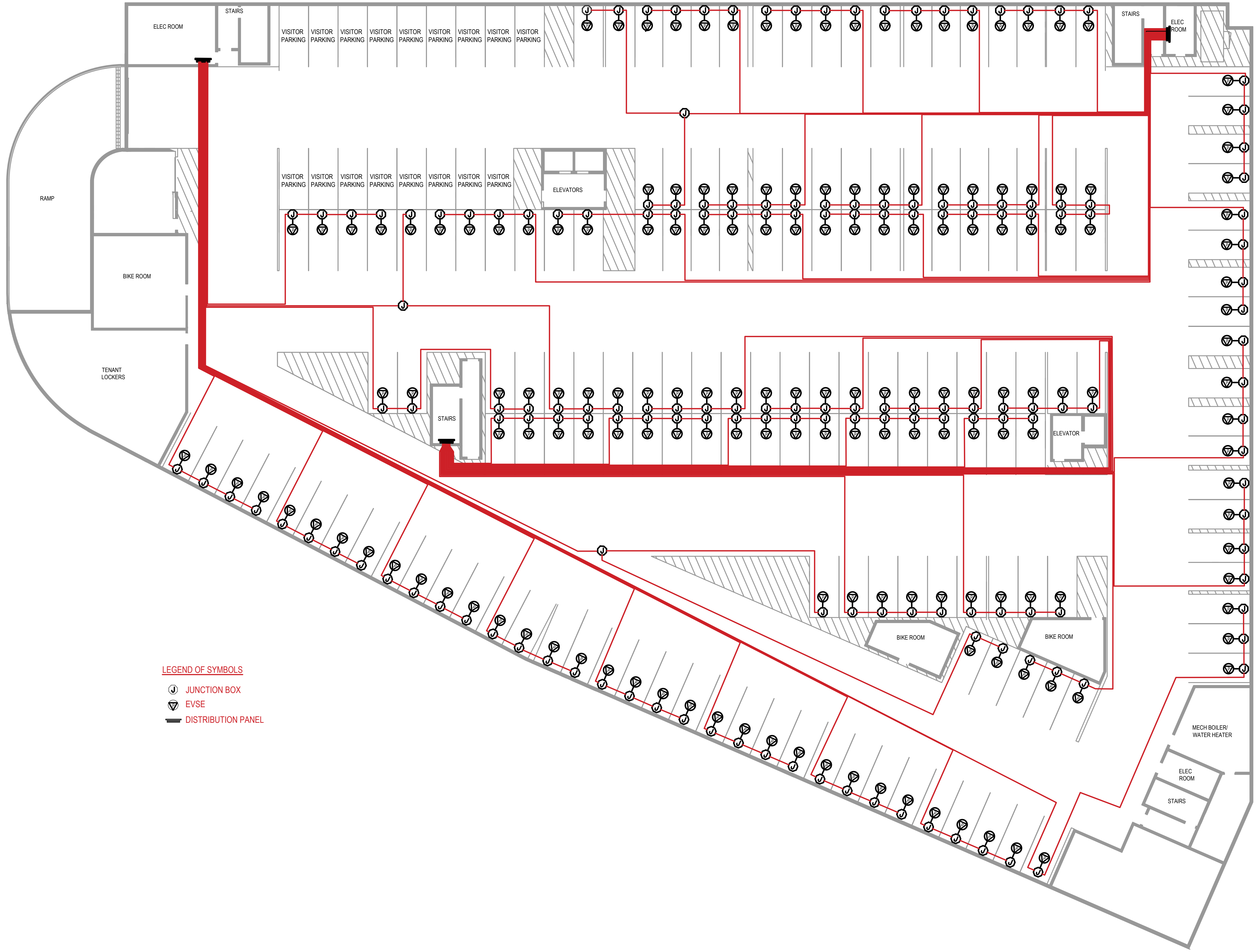

| seal | consultant | project | | |
|---|---|---|---|---|
| | AES Designing A Better Tomorrow | CITIES OF CALGARY & EDMONTON EV COSTING STUDY | | |

drawing title: HIGH RISE P3 C3. 10-SHARE ON 80A, 100% EV READY

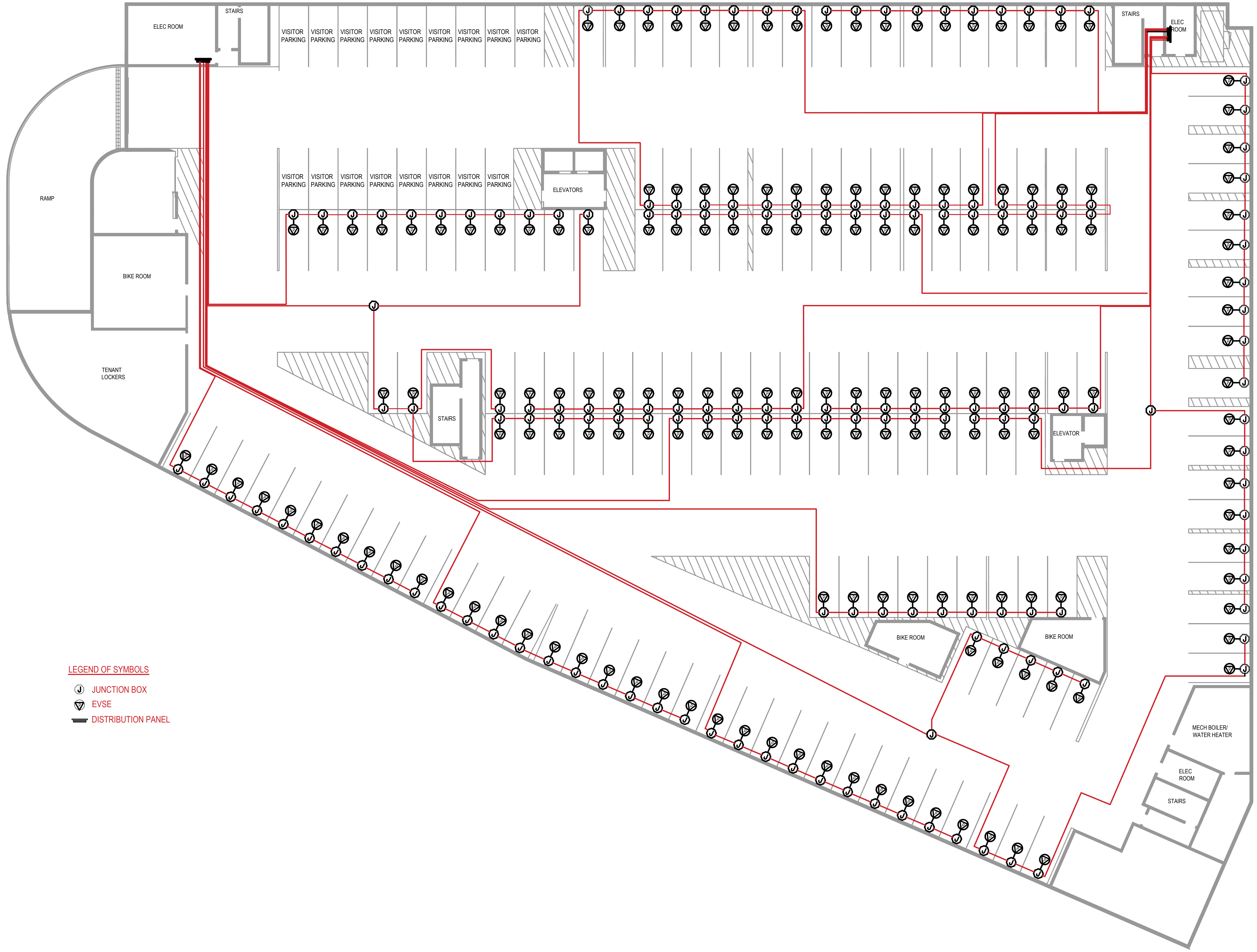
| designed | scale | date |
|---|---|---|
| JC | AS NOTED | JAN 28, 2022 |
| drawn | project no. | |
| JC | 2-21-418 | |
| checked | drawing no. | rev. |
| RB | E-104-P3 | 2 |
| approved | | |
| RB | | |




| seal | consultant | project | designed | scale | date |
|---|---|---|---|---|---|
| | AES Designing A Better Tomorrow 505 Burrard Street, Suite 950, Vancouver, BC V7X 1M4 604.569.6500 \| www.aesengr.com CALGARY \| VANCOUVER \| VICTORIA | CITIES OF CALGARY AND EDMONTON EV COSTING STUDY | JC | AS NOTED | JAN 28, 2022 |
| | | drawing title | drawn | project no. | |
| | | MID RISE C1. DEDICATED ON 40A, 100% EV READY | JC | 2-21-418 | |
| | | | checked | drawing no. | rev. |
| | | | RB | E-202 | 2 |
| | | | approved | | |
| | | | RB | | |




| seal | consultant | project | designed | scale | date |
|---|---|---|---|---|---|
| | AES Designing A Better Tomorrow<br>505 Burrard Street, Suite 950, Vancouver, BC V7X 1M4<br>604.569.6500 \| www.aesengr.com<br>CALGARY \| VANCOUVER \| VICTORIA | CITIES OF CALGARY AND EDMONTON<br>EV COSTING STUDY | JC | AS NOTED | JAN 28, 2022 |
| | | | drawn: JC | project no.: 2-21-418 | |
| | | drawing title: MID RISE<br>C2. 4-SHARE ON 40A, 100% EV READY | checked: RB | drawing no.: E-203 | rev.: 2 |
| | | | approved: RB | | |

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CITIES OF CALGARY AND EDMONTON
EV COSTING STUDY

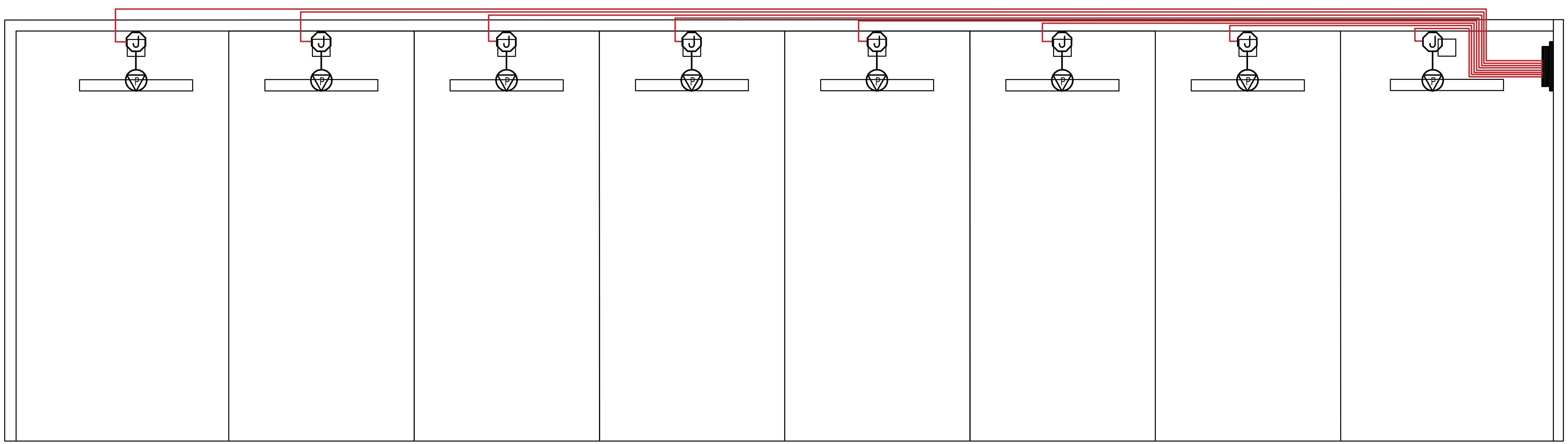
drawing title

MID RISE
C3. 10-SHARE ON 80A, 100% EV READY

| | | | |
|---|---|---|---|
| designed JC | scale AS NOTED | | date JAN 28, 2022 |
| drawn JC | project no. 2-21-418 | | |
| checked RB | drawing no. E-204 | | rev. 2 |
| approved RB | | | |

LEGEND OF SYMBOLS

- JUNCTION BOX
- EVSE
- DISTRIBUTION PANEL

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project

CITIES OF CALGARY AND EDMONTON
EV COSTING STUDY

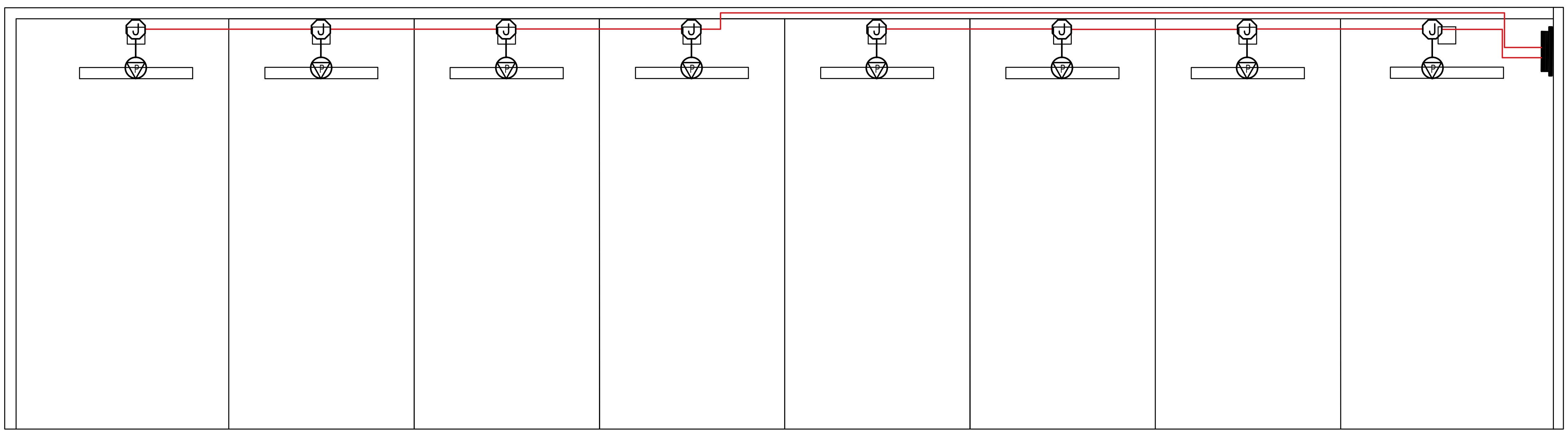
drawing title

TOWNHOUSE
C1. DEDICATED ON 40A, 100% EV READY

| | | |
|---|---|---|
| designed JC | scale AS NOTED | date JAN 28, 2022 |
| drawn JC | project no. 2-21-418 | |
| checked RB | drawing no. E-302 | rev. 2 |
| approved RB | | |

LEGEND OF SYMBOLS

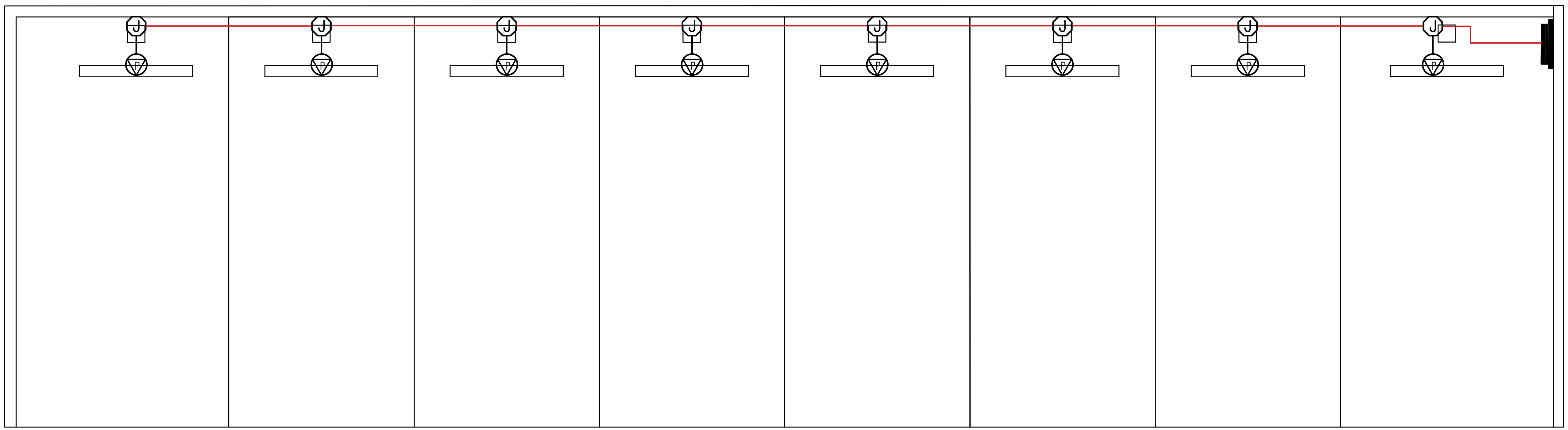
- JUNCTION BOX
- EVSE
- DISTRIBUTION PANEL



| | |
|---|---|
| seal | |
| consultant | AES Designing A Better Tomorrow<br>505 Burrard Street, Suite 950, Vancouver, BC V7X 1M4<br>604.569.6500 \| www.aesengr.com<br>CALGARY \| VANCOUVER \| VICTORIA |
| project | CITIES OF CALGARY AND EDMONTON<br>EV COSTING STUDY |
| drawing title | TOWNHOUSE<br>C2. 4-SHARE ON 40A, 100% EV READY |
| designed | JC |
| drawn | JC |
| checked | RB |
| approved | RB |
| scale | AS NOTED |
| date | JAN 28, 2022 |
| project no. | 2-21-418 |
| drawing no. | E-303 |
| rev. | 1 |

LEGEND OF SYMBOLS

- JUNCTION BOX
- EVSE
- DISTRIBUTION PANEL




| | | | | | |
|---|---|---|---|---|---|
| seal | consultant | project | designed JC | scale AS NOTED | date JAN 28, 2022 |
| | | | drawn JC | project no. 2-21-418 | |
| | | drawing title | checked RB | drawing no. | rev. |
| | | | approved RB | | |

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CALGARY | **VANCOUVER** | VICTORIA

project: CITIES OF CALGARY AND EDMONTON EV COSTING STUDY

drawing title: TOWNHOUSE C1. 4-SHARE ON 40A, 100% EV READY

drawing no.: E-304

rev.: 2

# Appendix D: Costing estimates

## HIGH-RISE RESIDENTIAL

1. Dedicated circuits on 40A, 100% EV Ready

| | |
|---|---|
| Total Level 2 EV-Ready Stalls: | 204 |
| Total Level 2 Circuits: | 204 |
| Existing max. demand (kVA): | 2,364 |
| EVSE max. demand (kVA): | 950 |
| Final max. demand (kVA): | 3,314 |

| No. | DESCRIPTION | UNIT COST ($ or $/ft) | QTY (# or ft) | COST ($) | MULTIPLIER FOR LATER COSTS | LATER COST ($) |
|---|---|---|---|---|---|---|
| ELECTRICAL INFRASTRUCTURE | | | | | | |
| 1 | 25kV splice | 8,500 | 1 | 8,500 | 3 | 25,500 |
| 2 | 25kV loadbreak | 65,000 | 1 | 65,000 | 3 | 195,000 |
| 3 | 25kV :600Y/347V, 1500 kVA transformer | 100,815 | 1 | 100,815 | 3 | 302,445 |
| 4 | Circuit breaker for EV feed distribution board (2000A) | 56,226 | 1 | 56,226 | 3 | 168,679 |
| 5 | EV feed distribution board (2000A) | 13,711 | 1 | 13,711 | 5 | 68,554 |
| 6 | Primary circuit breaker for EV distribution board (1000A) | 23,296 | 2 | 46,593 | 3 | 139,778 |
| 7 | 600V : 208Y/120V, 750 kVA transformer | 26,450 | 2 | 52,899 | 3 | 158,697 |
| 8 | EV distribution board (3000A) | 18,165 | 2 | 36,330 | 5 | 181,651 |
| 9 | Circuit breaker for EV panelboard (400A) | 6,405 | 13 | 83,265 | 3 | 249,795 |
| 10 | Cabling from EV distribution board to panelboard (2 sets of 4#3/0) | 77 | 906 | 70,049 | 2 | 140,098 |
| 11 | Cabling from EV distribution board to panelboard (2 sets of 4#4/0) | 111 | 936 | 103,920 | 2 | 207,841 |
| 12 | Conduit from EV distribution board to panelboard (2 sets of 53mm (2")) | 33 | 906 | 29,718 | 5 | 148,591 |
| 13 | Conduit from EV distribution board to panelboard (2 sets of 63mm (2 1/2")) | 45 | 936 | 42,100 | 5 | 210,501 |
| 14 | EV panelboard breaker (40A) | 220 | 204 | 44,830 | 2 | 89,660 |
| 15 | 400A MLO, 208Y/120V, 42 cct panelboard | 2,499 | 13 | 32,484 | 3 | 97,451 |
| 16 | Cabling from panelboard to EVSE (2#8) | 4 | 17352 | 77,010 | 2 | 154,020 |
| 18 | Conduit from panelboard to EVSE (21mm (3/4")) | 8 | 17352 | 138,946 | 5 | 694,728 |
| 19 | Communication system | 54,264 | 1 | 54,264 | 3 | 162,792 |
| 20 | Utility meter | 3,990 | 1 | 3,990 | 2 | 7,980 |

| | | |
|---|---|---|
| Cost ($) | 1,060,650 | 3,403,759 |
| Cost ($ per stall) | 5,199 | 16,685 |

## HIGH-RISE RESIDENTIAL
## 2. 4-share on 40A, 100% EV Ready

| | |
|---|---|
| Total Level 2 EV-Ready Stalls: | 204 |
| Total Level 2 Circuits: | 96 |
| Existing max. demand (kVA): | 2,364 |
| EVSE max. demand (kVA): | 639 |
| Final max. demand (kVA): | 3,003 |

| No. | DESCRIPTION | UNIT COST ($ or $/ft) | QTY (# or ft) | COST ($) | MULTIPLIER FOR LATER COSTS | LATER COST ($) |
|---|---|---|---|---|---|---|
| ELECTRICAL INFRASTRUCTURE | | | | | | |
| 1 | Increased rating of 25kV:600Y/347V main transformer (2500kVA to 3000kVA) | 10,676 | 1 | 10,676 | 8 | 80,066 |
| 2 | Increased rating of circuit breaker for main switchboard (2500A to 3000A) | 11,869 | 1 | 11,869 | 3 | 35,608 |
| 3 | Increased rating of main distribution board (2500A to 3000A) | 3,712 | 1 | 3,712 | 8 | 27,840 |
| 4 | 600V : 208Y/120V, 500 kVA transformer | 16,731 | 1 | 16,731 | 3 | 50,193 |
| 5 | Circuit breaker for EV distribution board (600A) | 14,534 | 1 | 14,534 | 3 | 43,602 |
| 6 | EV distribution board (2000A) | 13,711 | 1 | 13,711 | 5 | 68,554 |
| 7 | Circuit breaker for EV panelboard (400A) | 6,405 | 3 | 19,215 | 3 | 57,645 |
| 8 | Circuit breaker for EV panelboard (200A) | 3,753 | 1 | 3,753 | 3 | 11,260 |
| 9 | Cabling from EV distribution board to panelboard (4#3/0) | 39 | 118 | 4,552 | 2 | 9,104 |
| 10 | Cabling from EV distribution board to panelboard (2 sets of 4#3/0) | 77 | 376 | 29,036 | 2 | 58,072 |
| 11 | Conduit from EV distribution board to panelboard (53mm (2")) | 16 | 118 | 1,931 | 5 | 9,656 |
| 12 | Conduit from EV distribution board to panelboard (2 sets of 53mm (2")) | 33 | 376 | 12,318 | 5 | 61,592 |
| 13 | EV panelboard breaker (40A) | 220 | 53 | 11,647 | 2 | 23,294 |
| 14 | 400A MLO, 208Y/120V, 42 cct panelboard | 2,499 | 3 | 7,496 | 3 | 22,489 |
| 15 | 225A MLO, 208Y/120V, 42 cct panelboard | 1,739 | 1 | 1,739 | 3 | 5,217 |
| 16 | Cabling from panelboard to EVSE (2#8) | 4 | 643 | 2,854 | 2 | 5,708 |
| 17 | Cabling from panelboard to EVSE (2#6) | 7 | 4245 | 27,759 | 2 | 55,517 |
| 18 | Cabling from panelboard to EVSE (2#4) | 9 | 3537 | 32,911 | 2 | 65,822 |
| 19 | Conduit from panelboard to EVSE (21mm (3/4")) | 8 | 643 | 5,149 | 5 | 25,745 |
| 20 | Conduit from panelboard to EVSE (27mm (1")) | 10 | 7782 | 77,246 | 5 | 386,232 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 21 | Communication system | 54,264 | 1 | 54,264 | 3 | 162,792 |
| 22 | Utility meter | 3,990 | 1 | 3,990 | 2 | 7,980 |
| | Cost ($) | | | 367,094 | | 1,273,989 |
| | Cost ($ per stall) | | | 1,799 | | 6,245 |

## HIGH-RISE RESIDENTIAL
### 3. 10-share on 80A, 100% EV Ready

| | |
|---|---|
| Total Level 2 EV-Ready Stalls: | 204 |
| Total Level 2 Circuits: | 21 |
| Existing max. demand (kVA): | 2,364 |
| EVSE max. demand (kVA): | 280 |
| Final max. demand (kVA): | 2,644 |

| No. | DESCRIPTION | UNIT COST ($ or $/ft) | QTY (# or ft) | COST ($) | MULTIPLIER FOR LATER COSTS | LATER COST ($) |
|---|---|---|---|---|---|---|
| ELECTRICAL INFRASTRUCTURE | | | | | | |
| 1 | Increased rating of 25kV:600Y/347V main transformer (2500kVA to 3000kVA) | 10,676 | 1 | 10,676 | 8 | 80,066 |
| 2 | Increased rating of circuit breaker for main switchboard (2500A to 3000A) | 11,869 | 1 | 11,869 | 3 | 35,608 |
| 3 | Increased rating of main distribution board (2500A to 3000A) | 3,712 | 1 | 3,712 | 3 | 11,136 |
| 4 | 600V : 208Y/120V, 300 kVA transformer | 11,913 | 1 | 11,913 | 8 | 89,348 |
| 5 | Circuit breaker for EV distribution board (400A) | 6,405 | 1 | 6,405 | 3 | 19,215 |
| 6 | EV distribution board (1200A) | 12,342 | 1 | 12,342 | 5 | 61,711 |
| 7 | Circuit breaker for EV panelboard (400A) | 6,405 | 3 | 19,215 | 3 | 57,645 |
| 8 | Cabling from EV distribution board to panelboard (2 sets of 4#3/0) | 77 | 338 | 26,120 | 2 | 52,240 |
| 9 | Conduit from EV distribution board to panelboard (2 sets of 53mm (2")) | 33 | 338 | 11,081 | 5 | 55,406 |
| 10 | EV panelboard breaker (80A) | 441 | 21 | 9,257 | 2 | 18,514 |
| 11 | 400A MLO, 208Y/120V, 42 cct panelboard | 2,499 | 3 | 7,496 | 3 | 22,489 |
| 12 | Cabling from panelboard to EVSE (2#4) | 9 | 696 | 6,472 | 2 | 12,945 |
| 13 | Cabling from panelboard to EVSE (2#3) | 12 | 1365 | 15,979 | 2 | 31,959 |
| 14 | Cabling from panelboard to EVSE (2#2) | 14 | 1788 | 24,243 | 2 | 48,486 |
| 15 | Conduit from panelboard to EVSE (35mm (1 1/4")) | 13 | 3848 | 48,282 | 5 | 241,412 |
| 16 | Communication system | 54,264 | 1 | 54,264 | 3 | 162,792 |
| 17 | Utility meter | 3,990 | 1 | 3,990 | 2 | 7,980 |
| | Cost ($) | | | 283,317 | | 1,008,951 |

| | | |
|---|---|---|
| Cost ($ per stall) | 1,389 | 4,946 |

## HIGH-RISE RESIDENTIAL

### 4. 4-share on 40A, 100% EV Ready w/ Service Monitoring

| | |
|---|---|
| Total Level 2 EV-Ready Stalls: | 204 |
| Total Level 2 Circuits: | 52 |
| Existing max. demand (kVA): | 2,364 |
| EVSE max. demand (kVA): | 346 |
| Final max. demand (kVA): | 2,364 |

| No. | DESCRIPTION | UNIT COST ($ or $/ft) | QTY (# or ft) | COST ($) | MULTIPLIER FOR LATER COSTS | LATER COST ($) |
|---|---|---|---|---|---|---|
| ELECTRICAL INFRASTRUCTURE | | | | | | |
| 1 | Circuit breaker for EV distribution board (600A) | 14,534 | 1 | 14,534 | 3 | 43,602 |
| 2 | 600V : 208Y/120V, 500 kVA transformer | 16,731 | 1 | 16,731 | 3 | 50,193 |
| 3 | EV distribution board (2000A) | 13,711 | 1 | 13,711 | 5 | 68,554 |
| 4 | Circuit breaker for EV panelboard (400A) | 6,405 | 3 | 19,215 | 3 | 57,645 |
| 5 | Circuit breaker for EV panelboard (200A) | 3,753 | 1 | 3,753 | 3 | 11,260 |
| 6 | Cabling from EV distribution board to panelboard (4#3/0) | 39 | 118 | 4,552 | 2 | 9,104 |
| 7 | Cabling from EV distribution board to panelboard (2 sets of 4#3/0) | 77 | 376 | 29,036 | 2 | 58,072 |
| 8 | Conduit from EV distribution board to panelboard (53mm (2")) | 16 | 118 | 1,931 | 5 | 9,656 |
| 9 | Conduit from EV distribution board to panelboard (2 sets of 53mm (2")) | 33 | 376 | 12,318 | 5 | 61,592 |
| 10 | EV panelboard breaker (40A) | 220 | 53 | 11,647 | 2 | 23,294 |
| 11 | 400A MLO, 208Y/120V, 42 cct panelboard | 2,499 | 3 | 7,496 | 3 | 22,489 |
| 12 | 225A MLO, 208Y/120V, 42 cct panelboard | 1,739 | 1 | 1,739 | 3 | 5,217 |
| 16 | Cabling from panelboard to EVSE (2#8) | 4 | 643 | 2,854 | 2 | 5,708 |
| 17 | Cabling from panelboard to EVSE (2#6) | 7 | 4843 | 31,663 | 2 | 63,326 |
| 18 | Cabling from panelboard to EVSE (2#4) | 9 | 3537 | 32,911 | 2 | 65,822 |
| 19 | Conduit from panelboard to EVSE (21mm (3/4")) | 8 | 643 | 5,149 | 5 | 25,745 |
| 20 | Conduit from panelboard to EVSE (27mm (1")) | 10 | 8379 | 83,173 | 5 | 415,867 |
| 16 | Communication system | 54,264 | 1 | 54,264 | 3 | 162,792 |
| 17 | Utility meter | 3,990 | 1 | 3,990 | 2 | 7,980 |
| 18 | EVEMS | 15,000 | 1 | 15,000 | 3 | 45,000 |
| | Cost ($) | | | 336,134 | | 1,124,316 |

| | | |
|---|---|---|
| Cost ($ per stall) | 1,648 | 5,511 |

## MID-RISE RESIDENTIAL

### 1. Dedicated circuits on 40A, 100% EV Ready

| | |
|---|---|
| Total Level 2 EV-Ready Stalls: | 169 |
| Total Level 2 Circuits: | 169 |
| Existing max. demand (kVA): | 1,522 |
| EVSE max. demand (kVA): | 787 |
| Final max. demand (kVA): | 2,309 |

| No. | DESCRIPTION | UNIT COST ($ or $/ft) | QTY (# or ft) | COST ($) | MULTIPLIER FOR LATER COSTS | LATER COST ($) |
|---|---|---|---|---|---|---|
| ELECTRICAL INFRASTRUCTURE | | | | | | |
| 1 | Increased rating of 25kV : 600Y/347V main transformer (2000kVA to 3000kVA) | 10,676 | 1 | 10,676 | 8 | 80,066 |
| 2 | Increased rating of main circuit breaker (2000A to 3000A) | 9,845 | 1 | 9,845 | 3 | 29,536 |
| 3 | Increase rating of main distribution board (2000A to 3000A) | 3,712 | 1 | 3,712 | 8 | 27,840 |
| 4 | Primary circuit breaker for EV feed (1000A) | 14,711 | 2 | 29,421 | 3 | 88,264 |
| 5 | 600V : 208Y/120V, 750 kVA transformer | 26,450 | 2 | 52,899 | 8 | 396,743 |
| 6 | EV distribution board (3000A) | 18,165 | 2 | 36,330 | 5 | 181,651 |
| 7 | Circuit breaker for EV panelboard (400A) | 6,405 | 11 | 70,455 | 3 | 211,365 |
| 8 | EV panelboard breaker (40A) | 220 | 169 | 37,139 | 2 | 74,277 |
| 9 | 400A MLO, 208Y/120V, 42 cct panelboard | 2,499 | 11 | 27,486 | 3 | 82,459 |
| 10 | Cabling from EV distribution board to panelboard (2 sets of 4#3/0) | 77 | 119 | 9,231 | 2 | 18,461 |
| 11 | Cabling from EV distribution board to panelboard (2 sets of 4#4/0) | 109 | 1253 | 136,882 | 2 | 273,764 |
| 12 | Cabling from EV distribution board to panelboard (2 sets of 4 250kcmil) | 119 | 1139 | 135,200 | 2 | 270,400 |
| 13 | Conduit from EV distribution board to panelboard (2 sets of 53mm (2")) | 35 | 119 | 4,180 | 5 | 20,899 |
| 14 | Conduit from EV distribution board to panelboard (2 sets of 63mm (2 1/2")) | 45 | 1253 | 56,389 | 5 | 281,947 |
| 15 | Conduit from EV distribution board to panelboard (2 sets of 78mm (3")) | 61 | 1139 | 69,363 | 5 | 346,813 |
| 16 | Cabling from panelboard to EVSE (2#8) | 4 | 13344 | 59,220 | 2 | 118,440 |
| 17 | Cabling from panelboard to EVSE (2#6) | 6 | 4931 | 30,993 | 2 | 61,985 |
| 18 | Cabling from panelboard to EVSE (2#4) | 8 | 4160 | 33,815 | 2 | 67,631 |
| 19 | Conduit from panelboard to EVSE (21mm/ (3/4")) | 8 | 13344 | 106,848 | 5 | 534,240 |
| 20 | Conduit from panelboard to EVSE (27mm/ (1")) | 10 | 9091 | 90,240 | 5 | 451,201 |
| 21 | Communication system | 44,954 | 1 | 44,954 | 3 | 134,862 |
| 22 | Utility meter | 3,990 | 1 | 3,990 | 2 | 7,980 |

| | | |
|---|---|---|
| Cost ($) | 1,059,268 | 3,760,825 |
| Cost ($ per stall) | 6,268 | 22,253 |

## MID-RISE RESIDENTIAL
## 2. 4-share on 40A, 100% EV Ready

| | |
|---|---|
| Total Level 2 EV-Ready Stalls: | 169 |
| Total Level 2 Circuits: | 43 |
| Existing max. demand (kVA): | 1,522 |
| EVSE max. demand (kVA): | 286 |
| Final max. demand (kVA): | 1,808 |

| No. | DESCRIPTION | UNIT COST ($ or $/ft) | QTY (# or ft) | COST ($) | MULTIPLIER FOR LATER COSTS | LATER COST ($) |
|---|---|---|---|---|---|---|
| ELECTRICAL INFRASTRUCTURE | | | | | | |
| 1 | Circuit breaker for EV distribution board (400A) | 6,405 | 1 | 6,405 | 3 | 19,215 |
| 2 | 600V : 208Y/120V, 300 kVA transformer | 11,913 | 1 | 11,913 | 3 | 35,739 |
| 3 | EV distribution board (1200A) | 12,342 | 1 | 12,342 | 5 | 61,711 |
| 4 | Circuit breaker for EV panelboard (400A) | 6,405 | 3 | 19,215 | 5 | 96,075 |
| 5 | Cabling from EV switchboard to panelboard (2 sets of 4#3/0) | 77 | 252 | 19,450 | 2 | 38,901 |
| 6 | Cabling from EV swithcboard to panelboard (2 sets of 4#4/0) | 109 | 313 | 34,220 | 2 | 68,441 |
| 7 | Conduit from EV switchboard to panelboard (2 sets of 53mm (2")) | 33 | 252 | 8,252 | 5 | 41,259 |
| 8 | Conduit from EV switchboard to panelboard (2 sets of 63mm (2 1/2")) | 45 | 313 | 14,097 | 5 | 70,487 |
| 9 | EV panelboard breaker (40A) | 220 | 43 | 9,450 | 2 | 18,899 |
| 10 | 400A MLO, 208Y/120V, 42 cct panelboard | 2,499 | 3 | 7,496 | 3 | 22,489 |
| 11 | Cabling from panelboard to EVSE (2#8) | 4 | 1596 | 7,082 | 2 | 14,164 |
| 12 | Cabling from panelboard to EVSE (2#6) | 6 | 5168 | 32,482 | 2 | 64,963 |
| 13 | Conduit from panelboard to EVSE (21mm (3/4")) | 8 | 1596 | 12,778 | 5 | 63,890 |
| 14 | Conduit from panelboard to EVSE (27mm (1")) | 8 | 5168 | 41,382 | 5 | 206,908 |
| 15 | Communication system | 44,954 | 1 | 44,954 | 3 | 134,862 |
| 16 | Utility meter | 3,990 | 1 | 3,990 | 2 | 7,980 |
| | Cost ($) | | | 285,508 | | 965,982 |
| | Cost ($ per stall) | | | 1,689 | | 5,716 |

## MID-RISE RESIDENTIAL
### 3. 10-share on 80A, 100% EV Ready

| | |
|---|---|
| Total Level 2 EV-Ready Stalls: | 169 |
| Total Level 2 Circuits: | 17 |
| Existing max. demand (kVA): | 1,522 |
| EVSE max. demand (kVA): | 226 |
| Final max. demand (kVA): | 1,748 |

| No. | DESCRIPTION | UNIT COST ($ or $/ft) | QTY (# or ft) | COST ($) | MULTIPLIER FOR LATER COSTS | LATER COST ($) |
|---|---|---|---|---|---|---|
| ELECTRICAL INFRASTRUCTURE | | | | | | |
| 1 | Circuit breaker for EV distribution board (300A) | 6,405 | 1 | 6,405 | 3 | 19,215 |
| 2 | 600V : 208Y/120V, 225 kVA transformer | 9,496 | 1 | 9,496 | 3 | 28,487 |
| 3 | EV distribution board (800A) | 11,288 | 1 | 11,288 | 5 | 56,438 |
| 4 | Circuit breaker for EV panelboard (400A) | 6,405 | 2 | 12,810 | 3 | 38,430 |
| 5 | Cabling from switchboard to panelboard (2 sets of 4#3/0) | 77 | 30 | 2,308 | 2 | 4,615 |
| 6 | Cabling from EV swithcboard to panelboard (2 sets of 4#4/0) | 109 | 313 | 34,220 | 2 | 68,441 |
| 7 | Conduit from EV switchboard to panelboard (2 sets of 53mm (2")) | 33 | 30 | 979 | 5 | 4,895 |
| 8 | Conduit from EV switchboard to panelboard (2 sets of 63mm (2 1/2")) | 45 | 313 | 14,097 | 5 | 70,487 |
| 9 | EV panelboard breaker (80A) | 441 | 17 | 7,494 | 2 | 14,988 |
| 10 | 400A MLO, 208Y/120V, 42 cct panelboard | 2,499 | 2 | 4,998 | 3 | 14,993 |
| 11 | Cabling from panelboard to EVSE (2#3) | 10 | 3117 | 30,738 | 2 | 61,477 |
| 12 | Conduit from panelboard to EVSE (27mm (1")) | 10 | 3117 | 30,936 | 5 | 154,680 |
| 13 | Communication system | 44,954 | 1 | 44,954 | 3 | 134,862 |
| 14 | Utility meter | 3,990 | 1 | 3,990 | 2 | 7,980 |
| | Cost ($) | | | 214,713 | | 679,988 |
| | Cost ($ per stall) | | | 1,270 | | 4,024 |

## TOWNHOUSE

### 1. Dedicated 40A. 100% EV Ready

| | |
|---|---|
| Total Level 2 EV-Ready Stalls: | 8 |
| Total Level 2 Circuits: | 8 |
| Existing max. demand (kVA): | 133 |
| EVSE max. demand (kVA): | 53 |
| Final max. demand (kVA): | 186 |

| No. | DESCRIPTION | UNIT COST ($ or $/ft) | QTY (# or ft) | COST ($) | MULTIPLIER FOR LATER COSTS | LATER COST ($) |
|---|---|---|---|---|---|---|
| ELECTRICAL INFRASTRUCTURE | | | | | | |
| 1 | Increased rating of 25kV : 208Y/120V main transformer (150kVA to 225kVA) | 2,261 | 1 | 2,261 | 8 | 16,954 |
| 2 | Increased rating of main circuit breaker (450A to 800A) | 5,450 | 1 | 5,450 | 3 | 16,350 |
| 3 | Increased rating of main distribution board (450A to 800A) | 1,409 | 1 | 1,409 | 3 | 4,227 |
| 4 | Primary circuit breaker for EV feed (225A) | 3,677 | 1 | 3,677 | 3 | 11,032 |
| 5 | Cabling from distribution board (4#3/0) | 40 | 16 | 649 | 2 | 1,298 |
| 6 | Conduit from distribution board (53mm (2")) | 16 | 16 | 269 | 5 | 1,345 |
| 7 | Circuit breaker for EV panelboard (40A) | 220 | 8 | 1,758 | 2 | 3,516 |
| 8 | 225A MLO, 208Y/120V, 18 cct panelboard | 3,364 | 1 | 3,364 | 3 | 10,093 |
| 9 | Cabling from panelboard to EVSE (2#8) | 2 | 292 | 598 | 2 | 1,197 |
| 10 | Conduit from panelboard to EVSE (21mm (3/4")) | 8 | 292 | 2,338 | 5 | 11,690 |
| 11 | Communication system | 2,128 | 1 | 2,128 | 3 | 6,384 |
| 12 | Utility meter | 3,990 | 1 | 3,990 | 2 | 7,980 |
| | Cost ($) | | | 27,892 | | 67,132 |
| | Cost ($ per stall) | | | 3,486 | | 8,391 |

## TOWNHOUSE
## 2. 4 Share on 40A, 100% EV Ready

| | |
|---|---|
| Total Level 2 EV-Ready Stalls: | 8 |
| Total Level 2 Circuits: | 2 |
| Existing max. demand (kVA): | 133 |
| EVSE max. demand (kVA): | 0 |
| Final max. demand (kVA): | 133 |

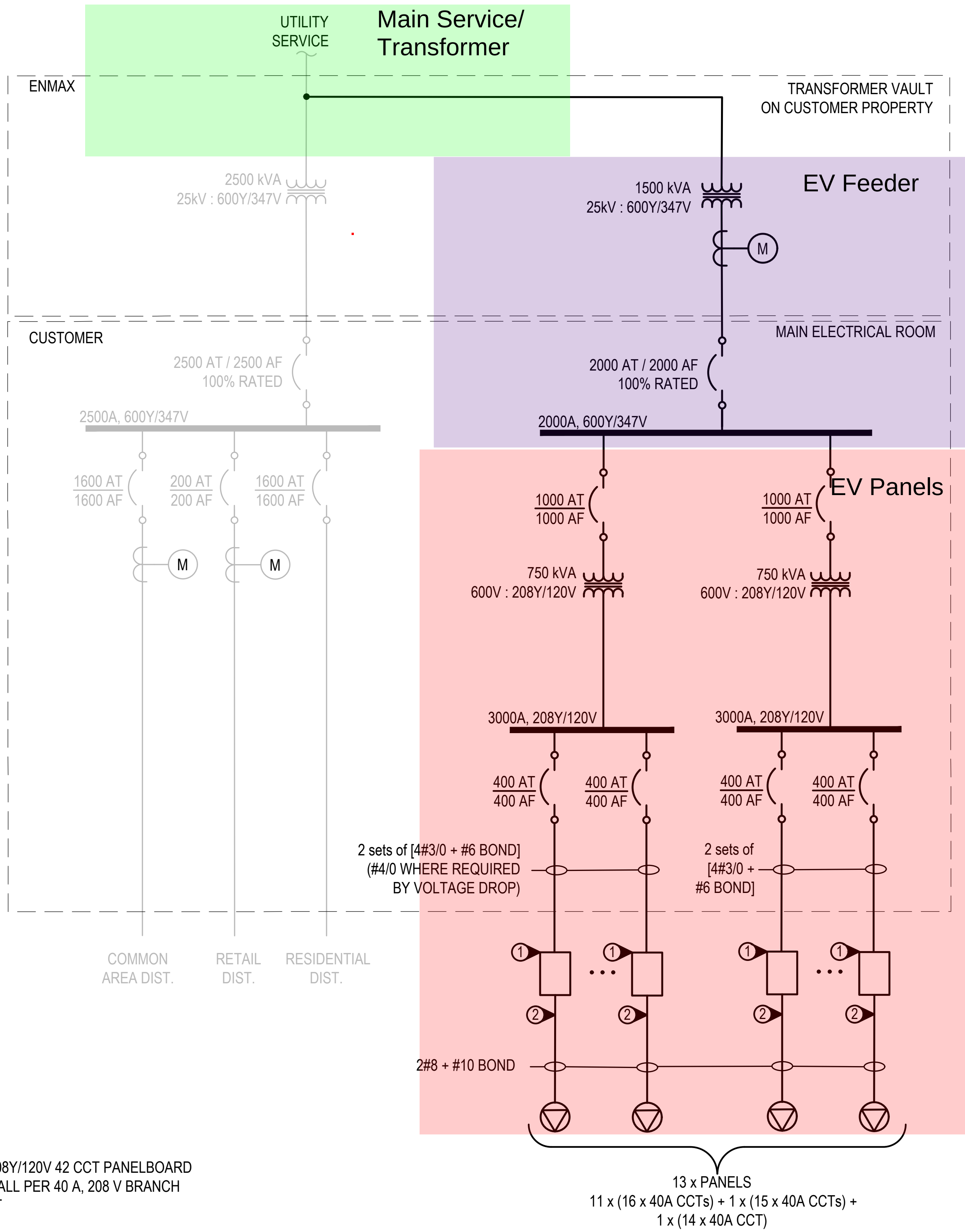
| No. | DESCRIPTION | UNIT COST ($ or $/ft) | QTY (# or ft) | COST ($) | MULTIPLIER FOR LATER COSTS | LATER COST ($) |
|---|---|---|---|---|---|---|
| ELECTRICAL INFRASTRUCTURE | | | | | | |
| 1 | Primary circuit breaker for EV feed (100A) | 1,731 | 1 | 1,731 | 3 | 5,193 |
| 2 | Cabling from distribution board (4#1) | 25 | 16 | 410 | 2 | 819 |
| 3 | Conduit from distribution board 53mm (2")) | 16 | 16 | 269 | 5 | 1,345 |
| 4 | Circuit breaker for EV panelboard (40A) | 220 | 2 | 440 | 2 | 879 |
| 5 | 125A MLO, 208Y/120V, 18 cct panelboard | 3,364 | 1 | 3,364 | 3 | 10,093 |
| 6 | Cabling from panelboard to EVSE (2#8) | 4 | 110 | 486 | 2 | 973 |
| 7 | Conduit from panelboard to EVSE (21mm (3/4")) | 8 | 110 | 877 | 5 | 4,387 |
| 8 | Communication system | 2,128 | 1 | 2,128 | 3 | 6,384 |
| 9 | Utility meter | 3,990 | 1 | 3,990 | 2 | 7,980 |
| | Cost ($) | | | 13,695 | | 30,696 |
| | Cost ($ per stall) | | | 1,712 | | 3,837 |

## TOWNHOUSE
### 3. 8 Share on 70A, 100% EV Ready

| | |
|---|---|
| Total Level 2 EV-Ready Stalls: | 8 |
| Total Level 2 Circuits: | 2 |
| Existing max. demand (kVA): | 133 |
| EVSE max. demand (kVA): | 0 |
| Final max. demand (kVA): | 133 |

| No. | DESCRIPTION | UNIT COST ($ or $/ft) | QTY (# or ft) | COST ($) | MULTIPLIER FOR LATER COSTS | LATER COST ($) |
|---|---|---|---|---|---|---|
| ELECTRICAL INFRASTRUCTURE | | | | | | |
| 1 | Primary circuit breaker for EV feed (100A) | 1,731 | 1 | 1,731 | 3 | 5,193 |
| 2 | Cabling from distribution board (4#1) | 25 | 16 | 410 | 2 | 819 |
| 3 | Conduit from distribution board 53mm (2")) | 16 | 16 | 269 | 5 | 1,345 |
| 4 | 125A MLO, 208Y/120V, 18 cct panelboard | 3,364 | 1 | 3,364 | 3 | 10,093 |
| 5 | Circuit breaker for EV panelboard (70A) | 441 | 1 | 441 | 2 | 882 |
| 6 | Cabling from panelboard to EVSE (2#8) | 4 | 73 | 324 | 2 | 648 |
| 7 | Conduit from panelboard to EVSE (21mm (3/4")) | 8 | 73 | 585 | 5 | 2,923 |
| 8 | Communication system | 2,128 | 1 | 2,128 | 3 | 6,384 |
| 9 | Utility meter | 3,990 | 1 | 3,990 | 2 | 7,980 |
| | Cost ($) | | | 13,241 | | 18,816 |
| | Cost ($ per stall) | | | 1,655 | | 2,352 |

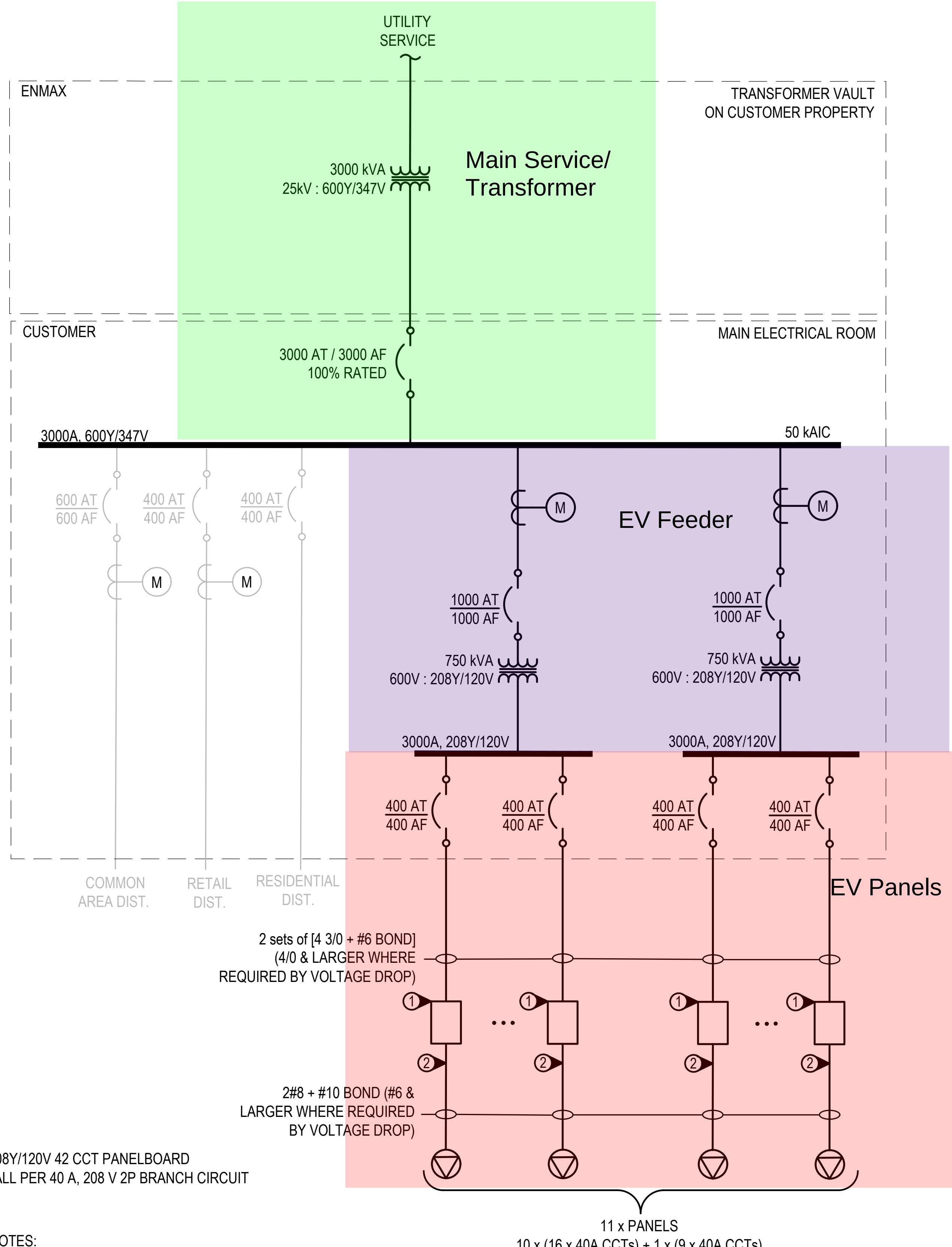
# Appendix E: Cost categories




KEYNOTES:
1. 400A, 208Y/120V 42 CCT PANELBOARD
2. 1 EV STALL PER 40 A, 208 V BRANCH CIRCUIT

GENERAL NOTES:
A) TOTAL CIRCUITS: 204
B) TOTAL EVSE OUTLETS: 204

| | | |
|---|---|---|
| consultant: AES — Designing A Better Tomorrow, 505 Burrard Street, Suite 950, Vancouver, BC V7X 1M4, 604.569.6500 \| www.aesengr.com, CALGARY \| VANCOUVER \| VICTORIA | project: CITY OF CALGARY & CITY OF EDMONTON EV CHARGING COSTING STUDY | designed: JC; scale: AS NOTED; date: |
| | drawing title: HIGH RISE — C1. DEDICATED CIRCUITS ON 40A, 100% EV READY | drawn: JC; project no. 2-21-418 |
| | | checked; approved; drawing no. E-01; rev. A |




KEYNOTES:
1. 400 A, 208Y/120V 42 CCT PANELBOARD
2. 1 EV STALL PER 40 A, 208 V 2P BRANCH CIRCUIT

GENERAL NOTES:
A) TOTAL EVSE CIRCUITS: 169
B) TOTAL EVSE OUTLETS: 169

consultant

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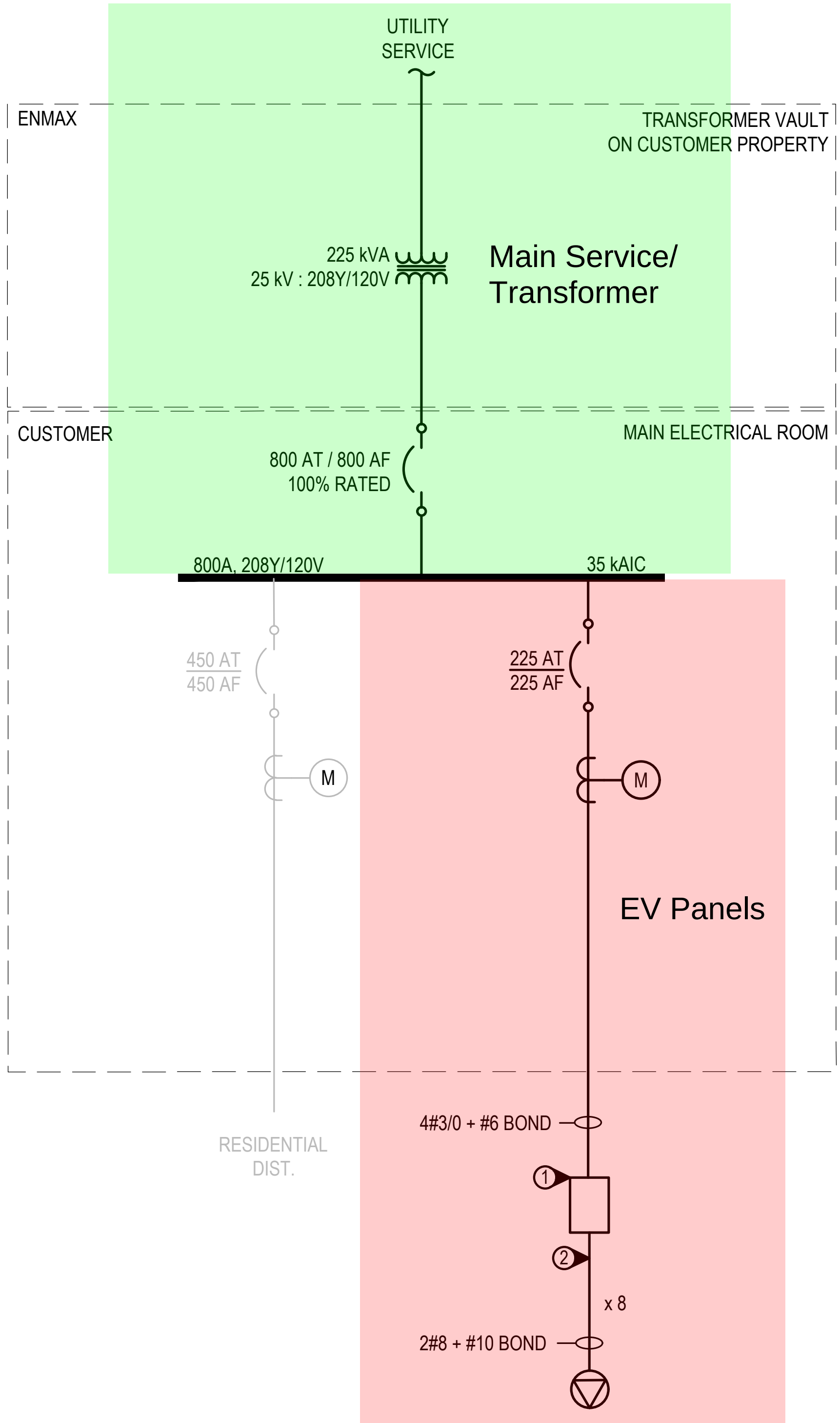
project

CITY OF CALGARY & CITY OF EDMONTON
EV CHARGING COSTING STUDY

drawing title

MID RISE
C1. DEDICATED CIRCUITS ON 40A, 100% EV READY

| | | |
|---|---|---|
| designed JC | scale AS NOTED | date |
| drawn JC | project no. 2-21-418 | |
| checked | drawing no. E-11 | rev. A |
| approved | | |




KEYNOTES:

1. 225A, 208Y/120V 42 CCT PANELBOARD
2. 1 EV STALL PER 40 A, 208 V BRANCH CIRCUIT

consultant

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project

CITY OF CALGARY & CITY OF EDMONTON
EV CHARGING COSTING STUDY

drawing title

TOWNHOUSE
C1. DEDICATED CIRCUITS ON 40A, 100% EV READY

| designed | scale | date |
|---|---|---|
| JC | AS NOTED | |
| drawn | project no. | |
| JC | 2-21-418 | |
| checked | drawing no. | rev. |
| approved | E-21 | A |