Hazards Analysis and Risk Assessment
Final Report

Goleta Cortona Drive
Energy Storage Project

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List of Acronyms and Definitions

Acronym	Definition
Ah	Amp hour
APCD	Air Pollution Control District
ARB	Air Resources Board
BMS	Battery Management System
BSS	Battery Storage System
CAPCOA	California Air Pollution Control Officers Association
CFC	California Fire Code
CGA	Compressed Gas Association
CPUC	California Public Utilities Commission
EPA	Environmental Protection Agency
ERPG	Emergency Response Planning Guidelines: Developed by the American Industrial Hygiene Association. ERPG-2 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action. ERPG-3 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
ESS	Energy Storage Systems
GWh	Gigawatt hour (equal to 1,000 MWhs)
HVAC	Heating Ventilation and Air Conditioning
IDLH	Immediately Dangerous to Life and Health: developed by National Institute for Occupational Safety and Health (NIOSH)
IEEE	Institute of Electrical and Electronics Engineers
kWH	Kilawatt hour
MWhr	Megawatt hour (equal to 1,000 kWH)
NCA	Lithium Nickel Cobalt Aluminum
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NRTL	OSHAs Nationally Recognized Testing Laboratory
OEHHA	Office of Environmental Health Hazard Assessment
REL	Reference Exposure Level
Thermal Runaway	During the thermal runaway, the battery temperature increases due to exothermic reactions. In turn, the increased temperature accelerates those degradation reactions and the system destabilizes, potentially releasing flammable and toxic gasses..
TS	Toxic Score
UL	Underwriters Laboratory
SBCAPCD	Santa Barbara County Air Pollution Control District
Whr	Watt hour

1.0 Introduction

Goleta Energy Storage, LLC. proposes to install a battery storage system with an approximate capacity of 60 megawatts in the town of Goleta, CA and with a layout substantially similar to the layout in the proposed site plan. The Goleta Facility will be a battery storage system that is owned and operated by Goleta Energy Storage, LLC. The Battery Storage Project (Project) would provide additional capacity to increase grid reliability and resiliency, integrate renewable energy resources, and facilitate the orderly retirement of aging natural gas power plants. The Project would provide increased electrical reliability and stability to the local grid by storing electricity in the battery systems from grid-based electrical generation systems and then releasing the power into the grid during peak periods when electricity is needed, reducing the consumption of fossil-fuels and the emissions of greenhouse gasses.

This report examines the potential upset and malfunction scenarios that could occur at the facility that could result in health risk and flammable gas production and potential resulting impacts on public receptors. The facility would not have any health risk or flammable impacts during normal operations. Potential impacts to onsite personnel or emergency response personnel are outside the scope of this analysis.

2.0 Project Description

The Project site would be located at 6864 Cortona Drive in Goleta, CA. The proposed Project location would be located immediately north of industrial and office areas; south of undeveloped space planned for residential apartment development (the Cortona Apartments, FEIR 2014); west of the M-Special Brewery; and east of Storke Road. Figure 1 shows the location of the proposed battery storage facility. The site is currently developed as parking areas and a shed. Exhibit F includes a site plan.

The Project would involve the installation of self-contained energy storage and management cabinets (called a Megapack) containing battery modules designed and manufactured by Tesla. Each cabinet would hold 17 modules of batteries, with each module holding about 12,636 battery cells. An operations and maintenance control enclosure would also be located on the Project site. The cabinets would be placed at the site outdoors. There will be no walk-in or inhabitable facilities in the proposed Project design.

The operations and maintenance control enclosure would be physically small footprint (i.e similar to a desktop computer) and is typically located within or adjacent to the substation, along with the rest of the site's communications equipment. It would not be a walk-in type enclosure. The operations and maintenance control enclosure houses the external communication interface over TCP (Modbus, DNP3.0 or REST) to the utility, network operator or customer SCADA systems. The Controller communicates to each Megapack over a private TCP network. Each Megapack is controlled by the inverter: based on the signal received from the controller, the Megapack will trigger the charge or discharge of each battery module. The Controller aggregates real-time information from all the Megapacks and leverages the information to optimize the commands sent to each Megapack.

The proposed battery cell type would be Lithium Nickel Cobalt Aluminum (NCA) manufactured by Tesla. This analysis is conducted for an NCA-type battery.

The facility would be equipped with inverters to convert the DC electricity of the battery systems into AC current used by the electrical grid. There would also be a liquid thermal cooling system integrated into the cabinets to provide cooling to the batteries and power electronics.

Fire prevention systems would include proposed cabinets designed to limit or eliminate the threat of the spread of fire from one cabinet to another, infrared camera monitoring at the site for external fire detection and onsite fire hydrants. See the project description for more details on the fire prevention systems.

The Battery Management System (BMS) would monitor all cell voltages, currents and temperatures and shut down equipment if unsafe conditions are detected.

The Megapacks are equipped with ventilation systems which allow for the removal and combustion of off gassed materials. The design of Megapack includes 33 pressure-sensitive vents (over-pressure vents) and a sparker system. The over-pressure vents and sparker system work in combination with each other to mitigate the risks of deflagration and overpressure events by combusting flammable off-gases before they reach the enclosure's lower flammability limit (LFL). This design essentially ignites the gases very early in a thermal runaway event, before there is time for the gases to build up within the enclosure and become an explosion hazard. Eight sparkers in total are installed at the top of all Megapack battery module bays, just below the over-pressure vents installed within the roof. The sparkers enable a rapid combustion of the hot gases and opening of the closest over-pressure vents. This ensures products of combustion and flames will exit through the roof, without creating a pressure event within the Megapack large enough to blow open doors or expel projectiles from the unit. By keeping all the doors shut during the fire, this also helps ensure that the fire will not propagate to adjacent Megapacks. In addition, the facility would be equipped with fire detection and gas detection systems.

Thermal management of a Megapack is achieved via liquid cooling using a 50/50 mixture of ethylene glycol and water. A typical Megapack includes about 540 liters of coolant. Mechanical damage of a Tesla Energy Product could result in leakage of the coolant.

The Megapack thermal management system also includes 7.6 kg of R134a refrigerant in a sealed system. Mechanical damage of a Megapack could result in a release of the refrigerant.

The electrolyte within Megapack cells includes a volatile hydrocarbon-based liquid and a dissolved lithium salt (which is a source of lithium ions) such as lithium hexafluorophosphate. The electrolyte in a Megapacks cells is absorbed in electrodes within individual sealed cells. The electrolyte reacts with those materials and is consumed during normal operation of the batteries. As such, the Megapack does not contain free liquid electrolyte.

The possibility of a spill of electrolyte from a Megapack is very remote. Electrolyte can be extracted from a single cell using a centrifuge, or under some extreme abuse conditions such as a severe crush. However, it is very difficult to mechanically damage cells in such a way as to cause leakage of electrolyte. Even if a single cell were damaged in a manner that could cause electrolyte leakage, it is extremely difficult to cause a leak from more than a few cells due to any incident.

Figure 1 Project Location

Source: Google Maps imagery date 8/18/2019

3.0 Environmental and Regulatory Setting

There are a number of different lithium battery types including the following:

- Lithium Nickel Cobalt Aluminum (NCA, proposed for this project)
- Lithium Nickel Manganese Cobalt (NMC)
- Lithium Manganese Oxide (LMO)
- Lithium Titanate Oxide (LTO)
- Lithium-Iron Phosphate (LFP)

This study assumed the use of the Lithium Nickel Cobalt Aluminum (NCA) battery type.

Battery Testing Requirements and Regulations
Batteries are subject to several codes and standards. Some of the relevant ones are discussed below.

UL9540: Safety for Energy Storage Systems. The requirement address the inherent design and performance, as well as the interface of the energy storage system with the infrastructure. Addresses construction, performance, electrical, mechanical, environmental, manufacturing and markings.

UL9540A: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems – this test methodology evaluates the fire characteristics of a battery energy storage system that undergoes thermal runaway. The data generated can be used to determine the fire and explosion protection required for an installation of a battery energy storage system

UL1973: Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications - These requirements cover battery systems as defined by this standard for use as energy storage for stationary applications such as for PV, wind turbine storage or for UPS, etc. applications. This standard evaluates the battery system's ability to safely withstand simulated abuse conditions. This standard evaluates the system based upon the manufacturer's specified charge and discharge parameters. Requires that an Energy Storage System (ESS) is not allowed to be an explosion hazard when exposed to an external fire source and that a single cell failure will not result in a cascading thermal runaway of cells.

IEEE C2: This Code covers basic provisions for safeguarding of persons from hazards arising from the installation, operation, or maintenance of (1) conductors and equipment in electric supply stations, and (2) overhead and underground electric supply and communication lines. It also includes work rules for the construction, maintenance, and operation of electric supply and communication lines and equipment. The Code is applicable to the systems and equipment operated by utilities, or similar systems and equipment, of an industrial establishment or complex under the control of qualified persons.

California Fire Code 608 and International Fire Code: Specifies minimum size requiring permits (Lithium, all types, 20 kWh), specifies maximum limits on sizing for battery systems (Lithium all type, 50 kwh each array), seismic and structural design, spacing (minimum 3 feet separation of arrays), vehicle impact protection, testing, maintenance and repairs, maximum quantities within a building (Lithium of 600 kwh), BMS monitoring, shutdown and notification requirements, automatic smoke detector requirements, automatic fire sprinkler systems and ventilation specifications. Section 1210 of the California Fire Code also requires that the battery systems be "listed", which is achieved through testing by an OSHA certified NRTL laboratory (see below).

NFPA 1: The General NFPA Fire Code addressing extracts from other NFPA codes.

NFPA 13: Standard for the Installation of Sprinkler Systems, addresses sprinkler system design approaches, installation, and component options.

NFPA 70: National Electrical Code, addresses electrical design, installation, and inspection.

NFPA 550: Guide to Fire Safety Concepts Tree for Protecting Energy Systems - addresses issues such as utilizing BMS and compatible equipment, ventilation as needed, fire resistive separation, array spacing, signage.

NFPA 855: Standard for the Installation of Stationary Energy Storage Systems - establishes criteria for minimizing the hazards associated with ESS (under development, draft version published).

OSHA NRTL: The OSHA Nationally Recognized Testing Laboratory (NRTL) program recognizes private sector organizations to perform certification for certain products to ensure that they meet the requirements of both the construction and general industry OSHA electrical standards. Each NRTL has a scope of test standards that they are recognized for, and each NRTL uses its own registered certification mark(s) to designate product conformance to the applicable product safety test standards, thereby "listing" the product. After certifying a product, the NRTL authorizes the manufacturer to apply a registered certification mark to the product. If the certification is done under the NRTL program, this mark signifies that the NRTL tested and certified the product, and that the product complies with the requirements of one or more appropriate product safety test standards. Two testing laboratories certified for the electrical components discussed in this analysis are Underwriters Laboratory (UL) and TUVRheinland.

Health Protective Regulations

The California Air Pollution Control Officers Association (CAPCOA) in consultation with the California Air Resources Board (ARB) and Office of Environmental Health Hazard Assessment (OEHHA) implements the Air Toxics "Hot Spots" Information and Assessment Act of 1987 (Air Toxics "Hot Spot" Act, Health and Safety Code §44344.4(c).). The Hot Spots regulation requires the assessment of the potential acute, chronic and cancer health risks associated with facilities. OEHHA also publishes the reference exposure levels (REL) for a range of pollutants, which defines the concentration levels at which pollutants start to generate health effects. The SBCAPCD provides guidance and a spreadsheet tool associated with a facility prioritization protocol.

The National Institute for Occupational Safety and Health (NIOSH) defines the immediately dangerous to life and health (IDLH) standard for pollutants. The American Industrial Hygiene Association has defined Emergency Response Planning Guidelines (ERPGs) to define the levels at which toxic pollutants may cause harm.

The City of Goleta and the County of Santa Barbara have adopted CEQA thresholds that are used to assist the County in classifying the significance of impacts to public safety. The thresholds employ quantitative measures of risk. If a proposed project has the potential to expose the public to toxic or flammable pollutants, then a risk assessment must be undertaken. The thresholds are applicable to a number of industry types including the "use" of specified quantities of regulated substances pursuant to Title 19 of the CCR (the CalARP regulations), or materials that could vaporize or evaporate quickly upon release and could cause risk to the public. Although this project does not "use" any of the substances on the Title 19 list, a number of toxic and flammable substances on the Title 19 list could be emitted if the batteries were to experience a malfunction, including hydrogen chlorine, hydrogen fluoride, nitrogen oxide, phosphine and sulfur dioxide (see below). Therefore, if a battery malfunction could cause the release of these pollutants and the release could impact the public, a detailed risk analysis should be performed.

In 2016, a technical working group comprised of utility and industry representatives worked with the California Public Utilities Commission Safety & Enforcement Division's Risk Assessment and Safety Advisory (RASA) section to develop a set of guidelines for documentation and safe practices at ESS co-located at electric utility substations, power plants or other facilities (CPUC 2017). The guidelines require a safety plan and inspection procedures.

Receptors

There are a number of receptors located near the proposed project site. These are listed below.

Table 1 Distance to Receptors

Receptor	Distance to Battery Cabinets*, feet
Parking Area / Ornamental Fence	18
Property line east side	28
Proposed Apartments	67
M-Special Brewery building	100
Storke Road	100
6868 Cortona	210
6860 Cortona	240
Residences west of Storke	270
Hotel	500

* Distance to actual battery cells within cabinets.

4.0 Assessment Methodology

There will be no emissions from the battery systems associated with the Project during normal operation.

However, in the unlikely event of a battery cell malfunction, such as a thermal runaway reaction or external impact event, the Project could emit pollutants to the atmosphere. For these types of battery cell malfunctions, emissions could be generated due to elevated temperatures within a single storage cell or group of storage cells caused by a runaway reaction. When Li-ion batteries are mistreated with high over-temperature or strong overcharge or suffer damage, they can transit into a so-called “thermal runaway”. During the thermal runaway, the battery temperature increases due to exothermic reactions. In turn, the increased temperature accelerates those degradation reactions and the system destabilizes. At the end of the thermal runaway, battery temperatures higher than 1,000C can be reached and flammable and toxic gases can be released (Golubkov 2015).

This analysis is limited to a reasonable worst-case event. A catastrophic event, such as an airplane impact, run-away vehicle impact, terrorist incident or nearby construction equipment collapse causing impact, could cause multiple megapacks to be destroyed, causing substantial emissions associated with a large-scale fire. A reasonable worst-case event is more limited in scope, defined as a control system failure or a puncture of a module, similar to that conducted as part of the UL 1973 testing, which could cause a runaway reaction in a group of cells. Generally, a reasonable worst-case scenario is more appropriate for a planning scenario as any development project could produce substantial fires and cause impacts to neighboring facilities under a catastrophic scenario.

The Battery Storage System (BSS) will be equipped with monitoring and control systems that will prevent and/or control battery cell malfunctions. However, to determine an unlikely, but reasonable worst-case public health impacts for this analysis, it is assumed that these control systems fail and do not control the battery cell malfunction. For this unlikely event, it is assumed that the battery cell malfunction continues until the Fire Department arrives onsite.

Different manufacturers have developed various studies examining the potential scenarios related to battery malfunctions, although most of these studies are proprietary. Some studies have been independently performed for agencies, including by Det Norske Veritas (DNVGL 2017) conducted for the New York State Energy Research & Development Authority (NYSERDA) and Consolidated Edison. Other studies include Anderson 2015, Blum 2016, Larsson 2017 and LG Chem (another battery manufacturer) where batteries were exposed to heat sources and off gases were measured. In addition, the battery manufacturer Tesla, has performed testing on a representative system and by DNVGL (DNVGL 2019) where heat was added and forced a burn of the entire enclosure.

Different battery cell malfunctions could produce emissions. These include: (1) an elevated temperature situation due to a runaway reaction with no combustion (venting with no combustion); (2) combustion of the battery due to an elevated temperature situation from a runaway. Studies have shown (Rincon 2017, and proprietary UL9540A testing) that a localized runaway reaction with combustion produces the greatest flow of emissions. Emissions would occur both during the pre-combustion phase and during the combustion phase. During the pre-combustion phase, the off gassed materials would contain flammable and toxic materials. During the combustion phase, most of the off gassed materials would be combusted and hence would contain only low levels of flammable gasses. The off gassed toxics would also be combusted, but a different array toxic combustion products, mostly from the combustion of the plastics used in the Megapacks, would be produced. In addition, during combustion, the heat of combustion would produce substantial plume buoyancy, thereby causing the materials to rise into the air. As the downwind, ground-level impacts could be greater during the pre-combustion phase, both phases are examined in this analysis.

The BSS will be enclosed in cabinets that have venting. It is assumed that the emissions caused by these malfunction scenarios will be vented during the malfunction scenario. As per the Fisher Engineering Report (Fisher 2020 and Exhibit G) and DNVGL 2019 testing, emissions occurred over a period of a few hours. Two reasonable worst-case scenarios are addressed: the loss of 10% of the cells within a Megapack module (multicell event), and the loss of an entire Megapack. For the muticell event malfunction scenario, it is assumed that the release of pollutants to the atmosphere would occur all within one hour as a reasonable worst case. While emissions could occur over a longer period of time, a worst-case analysis is produced if the same quantity of pollutants are released over a shorter period of time, thereby increasing the emission rates and increasing the downwind distance and potential impacts. For the Megapack event, it is assumed that the pollutants are released over a 3.5 hour duration, which is the duration of the UL9540A large-scale fire test.

In addition, as part of the UL 1973 requirements, battery malfunctions and punctures are required to have limited cascading capabilities. Therefore, it is highly unlikely that an entire module or groups of modules would be involved in a single event. Therefore, as a reasonable worst-case for the multicell event, it is assumed that only 10 percent of the cells in a single module would be involved in the battery malfunction. Tesla's historical experience with battery cell malfunctions indicate that this is a very conservative scenario that has not occurred to date with their batteries.

Battery malfunctions can result in the release of toxic materials and/or the release of a flammable gas mixture and subsequent flammable gas vapor cloud with subsequent fire or explosion.

Toxic Pollutants

Toxic pollutants emitted from battery malfunctions are partially dependent on the battery type. For lithium ion batteries, studies indicate that the primary toxic pollutants could be any of the following:

Table 2 Potential Toxic Pollutants from Battery Malfunctions

Pollutant	OEHHA Reference Exposure Level (REL), µg/m3 (ppm)	IDLH (Immediately Dangerous to Life and Health)	ERPG-3 (Emergency Response Planning Guidelines)	ERPG-2 (Emergency Response Planning Guidelines)
Carbon monoxide (CO)	23,000/26.7	1,200 ppm	500 ppm	350 ppm
Hydrogen Chloride (HCL)	2100/3.2	50 ppm	150 ppm	20 ppm
Hydrogen Cyanide (HCN)	340/0.4	50 ppm	25 ppm	10 ppm
Hydrogen Fluoride (HF)	240/0.2	30 ppm	50 ppm	20 ppm
Methanol (CH_3OH)	28,000/37	6,000 ppm	5,000 ppm	1,000 ppm
Nitrogen Oxide (NO_x)	470/0.9	13 ppm	30 ppm	15 ppm
Phosphine (PH_3)**	400/0.6	50 ppm	5 ppm	0.5 ppm

Table 2 Potential Toxic Pollutants from Battery Malfunctions

Pollutant	OEHHA Reference Exposure Level (REL), µg/m3 (ppm)	IDLH (Immediately Dangerous to Life and Health)	ERPG-3 (Emergency Response Planning Guidelines)	ERPG-2 (Emergency Response Planning Guidelines)
Phosphorous Pentafluoride (PF_5)	240/0.2*	50 ppm***	-	-
Phosphoryl Fluoride (POF_3)	240/1.0*	50 ppm	-	-
Styrene	21,000/90	700 ppm	1000 ppm	250 ppm
Sulfur Dioxide (SO_2)	660/1.8	100 ppm	25 ppm	3 ppm
Toluene	37,000/140	500 ppm	1,000 ppm	300 ppm

* Utilized the acute REL for hydrogen fluoride as per OEHHA REL tables for Fluorides chronic are very similar
** OEHHA does not have REL for acute PH3. Estimated based on NIOSH values.
*** The National Institute for Occupational Safety and Health (NIOSH) does not have a listing for PF_5. PF_5 and POF_3 estimated based on general fluorides.
Sources: See Table 3.

Generally, the battery cell will start to off gas if the temperature exceeds 120 ºC (DNVGL 2017).

Several studies have examined the emissions of toxic pollutants from battery off gassing situations, with some studies examining only the concentration of toxic pollutants and others also examining emission rates. The relevant studies are listed in Table 3.

Table 3 Studies on Emissions from Battery Malfunctions

Study	Description	Results
Anderson 2015	Exposure of battery to heat source, off gasses tested. LFP battery, 1.2 kg, 35 Ah	HF: 30-50ppm peak POF_3: 1-2ppm peak HF Rate: 0.01 g/s
Blum 2016	Modules tested with heat exposure until thermal runaways. 100kwh unit by Tesla.	HF: 100 ppm peak
CATL	UL 9540A testing	Composition of off gassing: primary pollutants only. Up to 153.5 L off gas per cell
Larsson 2017	External propane burner used to heat batteries, measured toxic gasses. Examined different battery types	HF: up to 145 ppm peak HF rate: 50 mg/s peak HF rate: 200mg/whr peak POF_3 rate: 22 mg/whr peak
LG Chem	Proprietary data on LFP battery tests. NMC battery type.	HF-0.2ppm PH_3-1.0ppm

Table 3 Studies on Emissions from Battery Malfunctions

Study	Description	Results
		HF rate: 4.7e-7 g/hr PH_3 rate: 2.4e-4 g/hr Up to 244 L off gas per cell
DNVGL 2017	Measured characteristics of a wide range of battery types and failures	release rates per kg of battery weight: HF rate: 1.7e-7 kg/s-kg
DNVGL 2019	Measure characteristics of a Tesla powerpack thermal runaway scenario	Maximum Values: HCL: 538 ppm HF: 183 ppm HCN: 67 ppm
Tesla	Proprietary studies	HF: 500 ppm HCL: 1,000 ppm HCN: 1,600 ppm Methanol: 32 ppm Styrene: 1 ppm Toluene: 3,500 ppm
	Fisher Engineering, 9540A Test Results	HF: 0.5 ppm

Some of the key findings from these studies include the following:

- HF was found to be produced by all battery types.
- For NCA batteries, HCL, HF and HCN are produced (DNVGL 2019).
- PH_3 was only identified by LG Chem for the NMC battery type, not the NCA proposed for this Project. No other studies identified PH_3 as an issue for the NCA battery.
- PF_5 rapidly decomposes to HF and was therefore generally not detected (Anderson 2013).
- POF_3 was found to be not be produced by NCA batteries (Larsson 2017).

It was also found that the average emission rate of HF in a plastics fire can be higher than the average emission rate of a battery fire (DNVGL 2017), indicating that potentially a majority of the toxic emissions from a battery fire are a result of the combustion of the plastic components.

This Risk Assessment reviewed the studies listed in Table 3, including the Fisher Engineering Report (Fisher 2020 and Exhibit G) that summarized the UL9540A large-scale fire testing conducted on the Tesla Megapacks proposed for this study, and utilized the highest toxic and flammable concentrations identified in any of these studies. As a battery off gassing event could have a range of characteristics, utilizing the maximum levels seen in a range of studies ensures a conservative analysis.

Flammable Components and Flammability

Flammable components are also emitted from a battery malfunction. Based upon the studies listed in Table 3, the flammable components could include the following:

Table 4 Potential Flammable Components from Battery Off Gassing

Component	Lower Flammability Limit (LFL), vol%
Acetylene (C_2H_2)	2.5
Butanes (C_4)	1.8
Carbon monoxide (CO)	12.5
Ethane (C_2H_6)	3.0
Ethylene (C_2H_4)	2.7
Hydrogen (H_2)	4.0
Methane (CH_4)	5.0
Pentanes (C_5)	1.4
Propane (C_3H_8)	2.1
Propene (C_3H_6)	2.0

Depending on the combination of these flammable materials, the off gasses could have varying degrees of flammability.

The Tesla manufacturer provided information on the composition of battery off gassing as part of battery testing (DNVGL 2019). These are shown below:

Table 5 Tesla Manufacturer Battery Off Gassing Primary Flammable Components

Component	Mole Percent
Hydrogen (H_2)	24
Carbon monoxide (CO)	34
Methane (CH_4)	4
Ethylene (C_2H_4)	5
Propane (C_2H_8) +	< 1

Note: based on Tesla proprietary testing, worst-case level encountered (most flammable), for single cell level testing. Other components, such as nitrogen and carbon dioxide, are also produced but are not shown due to not being flammable. These are the worst-case components between the UL9540A Testing and the DNVGL studies and are estimates of the pre-combustion off gassed materials.

The Compressed Gas Association (CGA) Publication P-23 provides algorithms for estimating the level of flammability of gas mixtures. The application of this technique to the off gassed materials as provided by the manufacturer as part of the testing (shown in Table 5) indicates that the released vapor/gas would be flammable, with a Q value of over 6.6 and an estimated lower flammability limit of over 8 percent. (This exceeds the Q value flammability limit of 1.0, established by the CGA, indicating the materials is flammable. See Exhibit F (CGA 2015).

Screening and Modeling

In order to estimate the impacts of the off gassing from toxic and flammable emissions, both a screening and a modeling approach were used. The Santa Barbara County APCD prioritization approach (SBCAPCD 1990) for health risks was used for the acute impact of toxic emissions. The screening approach uses the prioritization method developed by the California Air Pollution Control Officers Association (CAPCOA) in consultation with the California Air Resources Board (ARB) and Office of Environmental Health Hazard Assessment (OEHHA) as part of the implementation of the Air Toxics "Hot Spots" Information and Assessment Act of 1987 (Air Toxics "Hot Spot" Act, Health and Safety Code §44344.4(c).). The criteria used by the prioritization method is based on a Total Score (TS) for acute impacts. These score thresholds are as follows:

- High priority facilities with TS greater than 10.0
- Intermediate priority facilities with TS between 1.0 and 10.0
- Low priority facilities with TS less than 1.0

The criteria are based on the application of several conservative air dispersion modeling scenarios coupled with air pollutant toxicities as reported by OEHHA and the Environmental Protection Agency (EPA). For scores falling in the High or Intermediate Priority category, other factors that should be considered that could affect the results may include:

- Population density near the facility,
- Proximity of sensitive receptors to the facility,
- Receptor proximity less than 50 meters,
- Elevated receptors/complex terrain,
- Frequency of nuisance violations,
- Importance of non-inhalation pathway for substance(s) emitted by the facility,
- Presence of non-stack (fugitive) emissions, and
- Stack temperatures and release source terms.

The prioritization utilized guidelines developed by the SBCAPCD (SBCAPCD 1990). For intermediate and high priority facilities, additional analysis utilizing modeling with source and receptor specific factors may be required.

In addition, the Canary© model was run examining the downwind distance to the IDLH and the ERPG levels at 6 feet height (the "flagpole" height). The Canary© model is a computerized model developed by Quest Consulting to estimate the thermodynamic properties of gas mixtures and estimate impact distances of thermal exposure, explosions, vapor clouds and toxic effects.

The AERMOD modeling program was also run with 5 years of meteorological data from the SBCAPCD with the emission source as a point source, taking into account the thermal buoyancy due to elevated temperatures associated with a runaway release. The AERMOD modeling program allows an examination of a wide range of meteorological conditions in order to access a reasonable worst-case impact. This additional modeling was conducted in order to thoroughly access the potential for offsite toxic impacts.

For flammable impacts, the Canary© model was used to determine the distances that flammable vapor clouds could travel with a resulting battery malfunction scenario under different meteorological conditions. The Canary© model was also used to examine explosion impacts to 1 psi overpressure.

For thermal impacts due to a fire, the UL9540A testing and DNVGL 2019 testing results were utilized to estimate the distances to different hear flux values.

5.0 Environmental Consequences

The consequences associated with battery malfunctions are discussed below based on the methodology presented above.

5.1 Exposure Assessment

Project emissions to the air would consist of combustion and vent products from the burning and/or venting of the battery cells due to a battery cell malfunction under the reasonable worst-case scenario. Inhalation is the main pathway by which toxic air pollutants could potentially cause public health impacts.

Flammable impacts could be produced by vapor cloud deflagrations or explosions for the reasonable worst-case scenario, or from thermal exposure to fires.

5.2 Significance Criteria

A prioritization method was defined by the SBCAPCD guidelines (SBCAPCD 1990) and associated spreadsheet are utilized to assess the potential impacts associated with toxic emissions based on Total Score (TS) for acute impacts. A TS of below 1.0 is considered less than significant, with a TS of above 1.0 requiring additional analysis in order to determine significance.

For Canary© and AERMOD modeling assessments, impacts offsite would require additional analysis in order to determine significance utilizing a quantitative risk assessment (QRA) as discussed above for the CEQA thresholds. The QRA analysis is included below.

Flammable impacts are determined to be less than significant if vapor cloud fires or explosions do not impact sensitive areas, with additional analysis required to determine significance if flammable vapors could impact sensitive receptors (a QRA). If impacts do affect receptors, a more detailed analysis should be implemented utilizing a quantitative risk assessment as discussed above for the CEQA thresholds. The QRA analysis is included below.

5.3 Toxic Impacts

Potential human health impacts associated with the Project stem from exposure to air emissions from the battery cell malfunction reasonable worst-case scenario discussed above. The reasonable worst-case scenario would involve the battery malfunctions associated with off gassing and combustion. The battery manufacturer provided information on primary and toxic pollutants from the battery malfunction, and that information was utilized for the analysis.

Detailed calculations are provided in Exhibit F. Included in Exhibit E is a copy of the Emergency Response Guide provided by the battery vendor Tesla. The compounds and the associated mass emission rates were determined by proprietary testing performed by the battery vendor.

As per UL1973 tests, in the event of a single cell undergoing thermal runaway there was no propagation to surrounding cells. In addition, the tests showed that when an entire module was force-ignited, there was no propagation to surrounding modules. The entire BSS will be comprised of many modules, and the malfunction events discussed above are unlikely to occur. If such an event does occur, it will only likely occur within a single or limited number of battery cells as demonstrated per UL1973. Therefore, this analysis conservatively assumed that only 10 percent of the cells within a module would be affected as a reasonable worst-case analysis (i.e. a multicell malfunction). A lower frequency worst-case scenario was also included, which would be the thermal offgassing of all cells in a Megapack, as was described in the Fisher report. Note that manufacturer testing as part of UL1973 involving external punctures indicated that propagation of thermal runaway involved substantially fewer than 10% of cells within a module. Therefore, a 10 percent rate of cell involvement in thermal runaway is considered a reasonable worst-case for the multicell event.

Because the emissions would occur over a short period of time, only the public health impacts associated with acute exposure to short term releases were analyzed for the reasonable worst-case battery cell malfunction. The acute impact prioritization scores for the reasonable worst-case battery cell malfunction scenario is provided in Table 5, and detailed calculations can be found in Exhibit F. The single-cell and multi-cell scenarios scores are below a TS of 1.0, indicating that these modeled release scenarios receive a low priority classification. The megapack scenario indicates additional analysis is necessary, as discussed below.

Table 6 SBCAPCD Health Risk Screening Prioritization Results

Scenario	SBCAPCD Guidelines Total Score (TS)
Single Cell malfunction, reasonable worst case	0.0005
Multi-Cell malfunction (10% of cells), reasonable worst case	0.69
Full Megapack malfunction, reasonable worst case	33.5

Modeling conducted utilizing the Canary© software indicated that the plume centerline rapidly rises due to the elevated temperature of the off gassed materials, with ERPG and IDLH values remaining either onsite or elevated. AERMOD modeling indicated that the maximum exposed concentration offsite of toxic materials would remain below the ERPG-2 and the IDLH levels as well at receptor heights that would be experienced near ground level, such as at the M-Special brewery parking lot area.

Therefore, the public health impacts from toxic pollutants associated with the reasonable worst-case multicell malfunction would be less than significant for those receptors located near the site that are not elevated such as at the M-Special location.

Because some receptors would be elevated, such as the proposed Cortona Apartments, which could be 3 stories high, or vehicles along Storke Road, which is at a higher elevation, the impacts of toxic pollutants could extend offsite to these receptors. Additional modeling for elevated sources was conducted to assess the potential impact at the proposed elevated apartments and roadways. The elevated plume associated with carbon monoxide produced the greatest plume length and could impact elevated receptors offsite. Table 7 shows the results of this elevated-receptor analysis.

Table 7 Modeling Toxic Materials Results for Elevated Receptors

Pollutant	IDLH Downwind Distance, feet	ERPG-3 Downwind Distance, feet	ERPG-2 Downwind Distance, feet
Multicell Event			
Carbon monoxide (CO)	86	145	178
Hydrogen Chloride (HCL)	6	14	26
Hydrogen Cyanide (HCN)	20	32	60
Hydrogen Fluoride (HF)	8	12	16
Toluene	3	6	9
Megapack Event			
Carbon monoxide (CO)	139	237	292
Hydrogen Chloride (HCL)	10	22	42
Hydrogen Cyanide (HCN)	31	51	96
Hydrogen Fluoride (HF)	14	20	26
Toluene	6	10	15

Notes: based on Canary© modeling. See Exhibit F. Plume centerline heights are 15 feet at the farthest distance. Based on Table 3 Tesla Studies, Styrene and Methanol are low concentrations and do not generate offsite impacts.

The impacts from the combustion phase from combustion products is assumed to be incorporated into the potential for CO exposure, as generally CO exposure produces the greatest impacts from combustion products (NRC 2004).

Because these impacts could affect elevated offsite receptors, a detailed quantitative risk analysis was conducted. See below.

5.4 Flammable Vapor Impacts

The off gassed materials could generate a flammable vapor cloud and may produce a flammable gas mixture (see above). The Canary© computer model was utilized to estimate the distance that the flammable vapor cloud could reach (see Exhibit F for the Canary© model outputs and assumptions). The lower flammability limit (LFL) and the ½ LFL are used as an estimate of the potential impacts from flammable vapors. Distances for the LFL and the ½ LFL are estimated to be 9 and 15 feet, respectively, with a Megapack event extending to 15-25 feet. Explosion distances to a 1 psi overpressure assumed a high level of material reactivity (due to the presence of hydrogen) and a high obstacle density (due to the location of multiple cabinets together), thereby increasing the potential for an explosion, under a conservative scenario. The 1 psi overpressure levels are those at which building glass would shatter or light injuries occur due to fragments (NFPA 2014). Vapor cloud explosion impacts are estimated to be less than the ½ LFL distance.

5.5 Thermal Impacts

Impacts from a fire could produce thermal radiation which could affect areas near the fire and areas offsite. During the UL9540A testing, thermal radiation impacts were measured at both 20 and 30 feet from the Megapack. The Fisher Report indicated that the Megapack produced a fire for a peak period of about 10 minutes (from minutes 38-43 and minutes 53-58 of the test). Peak levels at 20 feet during that period were 28.8 kW/m2 and averaged 19.1 kW/m2. Peak levels at 30 feet during that period were 9.8 kW/m2 and averaged 4.9 kW/m2.

In order to estimate the thermal radiation at different distances from the Megapack during a fire event, a point source model for thermal radiation was utilized (CCPS 2003). The point source model uses the following equation:

$$q = \frac{x\,Q}{4\,\pi\,R}$$

Where

q = heat flux in kW/m2

Q = heat release rate, kW

R = distance from the flame center, meters

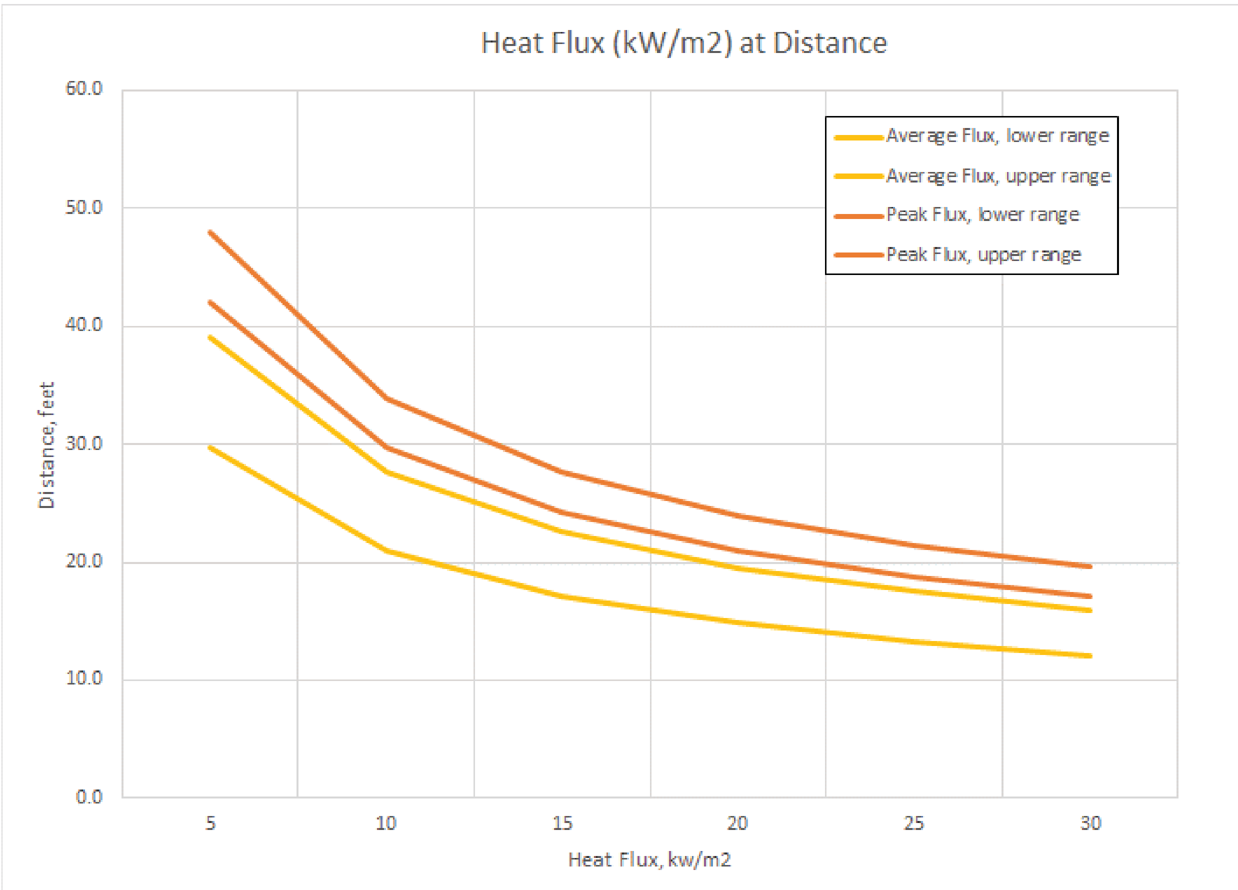
x = radiative fraction, energy fraction released as thermal radiation, with the fraction of energy released as radiation between 0.10 and 0.40 with a value of 0.35 conservatively assumed (as per SFPE 1999 and FMGlobal 2019).

Using the above point source approach, the Figure 2 was produced showing the thermal flux at different distances from a Megapack fire. Note this is a conservative assumption as no impacts due to the atmosphere or smoke effects are assumed and a high fraction of heat to radiation is also assumed. The Fisher report examined heat flux at two different distances, which provide an estimate of the range of heat release rate generated from the fire. The figure shows the range of peak heat flux and the range of average heat flux for different heat flux levels and distance.

In general, when estimating the potential impacts of thermal radiation, both the level of heat flux and the duration are used to estimate the thermal dose or amount of heat transferred or the "thermal load". Probit equations demonstrate this effect, as higher heat flux impacts to humans and materials can be substantially more tolerated at shorter durations (Lees 2014). Table 8 below shows different heat flux levels and associated impacts on humans and materials.

Note that heat flux impacts to humans can generally be tolerated below 5 kw/m2 and below 10 kw/m2 if sufficient time to escape is feasible. Heat flux levels that can produce spontaneous ignition in building materials generally does not occur below 12.5 – 20 kw/m2.

Figure 2 Fisher Analysis Estimated Heat Flux at Distance



Notes: using the point source model and the Fisher results for peak and average heat flux at 20 and 30 feet, to define the ranges of impacts.

Table 8 Potential Thermal Impacts from Heat Flux Exposure and Duration

Incident Flux, kW/m2	Duration	Impact
Impacts on Humans		
4.7	Multiple minutes	Emergency actions lasting several minutes can be performed without shielding
6.3	1 minute	Emergency actions lasting several minutes can be performed without shielding
10.0	20 seconds	Time to threshold of pain for bare skin Threshold for thermal Class IV
12.5	1 minute 10 seconds	1% fatalities First degree burns
15.8	1 minute 10 seconds	100% fatalities Significant injury from burns
25.0	10 seconds	1% fatality
Impacts on Materials		
12.5	Long exposure	Threshold for ignition of combustible materials (plastics and wood).
12.5 - 25	Long exposure	Wood ignites
20	< 30 seconds	Paper spontaneously ignites
20	250 seconds	Wood particle board ignites
27	Long exposure	Threshold for damage to non-combustible materials
35.0	1 minute	Cellulosic material will spontaneously ignite
35.0	< 30 seconds	Cloth spontaneously ignites
37.5	13 minutes	7mm steel plate failure
40.0	< 30 seconds	Wood spontaneously ignites

Notes: from CCPS 2003, NRC 2004, NIOSH 2017, SFPE 1999 and 2020, FMGlobal 2019

Note that as per the Fisher analysis, heat flux levels could extend outside of the project site boundaries if a thermal event were to occur at one of the Megapacks located near the site boundary. Thermal effects on the apartments to the north would range from 2.0 to 2.6 kW/m2 as a peak value, with the average ranging from 1.0 – 1.7 kW/m2. Therefore, thermal impacts to the apartments would not be sufficient to produce impacts. See Figure 3 for a site map showing the average heat flux values, which best represents the potential for damage due to heat flux impacts.

Because the distances for flammable vapors and thermal radiation could extend outside of the Project site boundaries, a detailed QRA was conducted. See below.

Although the thermal impacts extend offsite, the battery installation would comply with the NFPA 855 section 4.4.3.3, setback requirement of 10 feet from lot lines and public ways (see recommendations section below). In addition, although the installation of a fire wall along the perimeter of the site is feasible, it is not considered necessary due to the following issues:

1. The battery fire in the UL9540A tests took 38 minutes to develop, which, along with the detection systems proposed for the site, would allow for ample time to notify the fire department and evacuate persons from the areas near the Megapack installations.

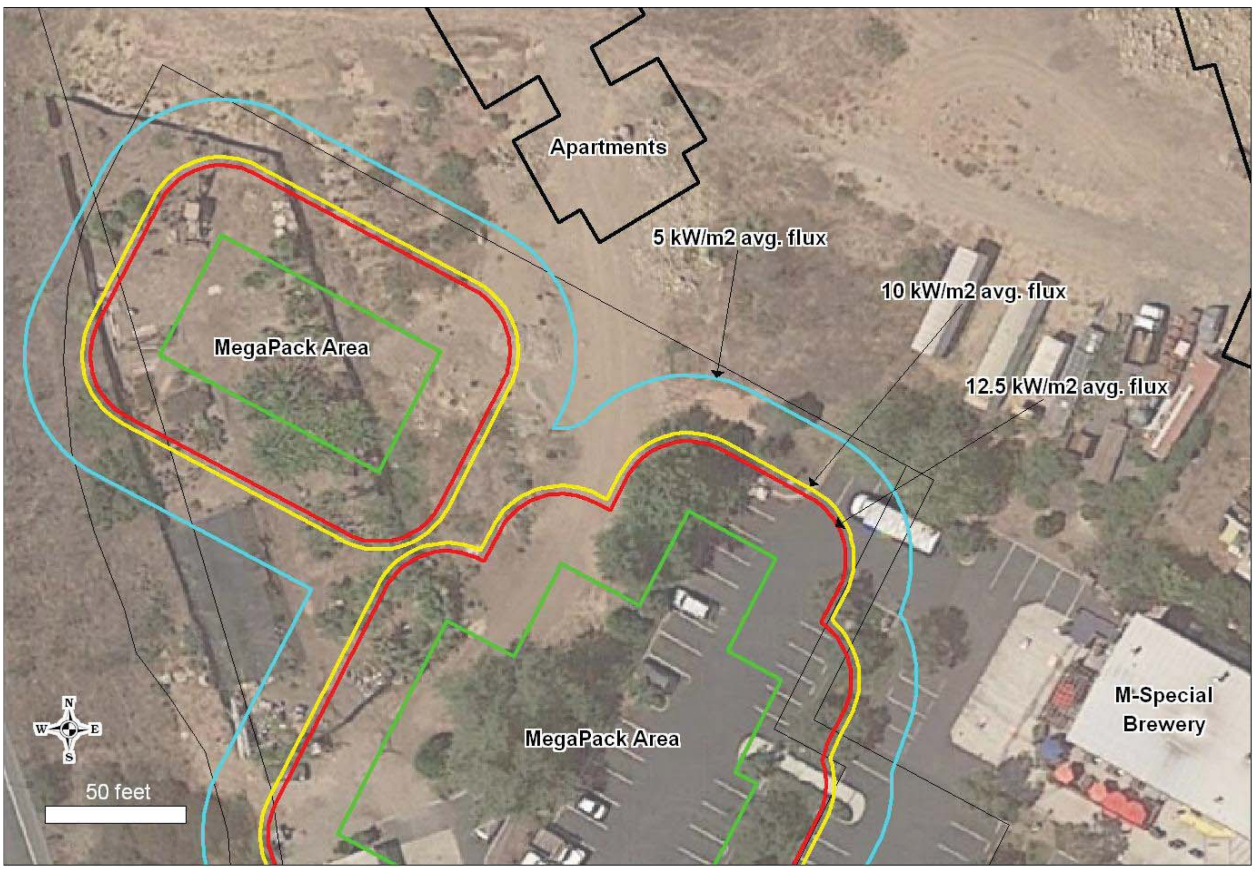
2. The areas along the fence lines are protectable space, meaning the authorities would have access to these spaces for fire water applications and evacuations.

3. The intense fire period was of short duration (10 minutes) during the UL9540A tests during a 3.5 hour test including off gassing.

4. The areas immediately around the project site and within the 10 kw/m2 areas are all parking lots and do not include buildings or other structures, which could be subject to damage a higher thermal flux levels.

Therefore, the installation of fire walls is not considered necessary.

Figure 3 Site Map with Thermal Flux Estimates



Notes: using the point source model and the Fisher results for average heat flux at 20 and 30 feet, to define the ranges of impacts.

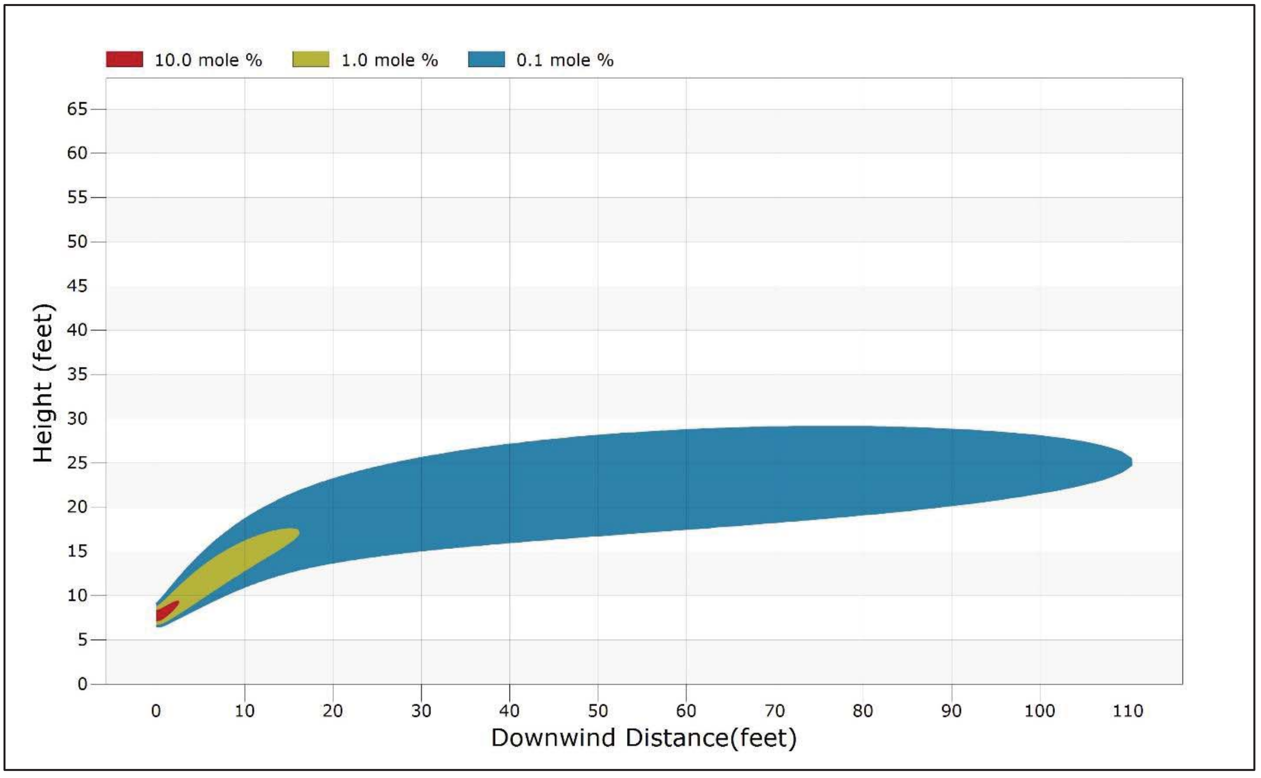
5.6 Combustion Products

Combustion products can include a number components that can be toxic: particles, vapors, toxic gases including carbon monoxide (CO), hydrogen cyanide from the burning of plastics, phosgene from vinyl materials. Fire can also reduce oxygen levels, either by consuming the oxygen, or by displacing it with other gases.

The Fisher report described some of the combustion products as part of the fire testing. Monitoring indicated low levels of carbon monoxide and carbon dioxide (83 – 680 ppm) and low levels of toxins (HF less than 1.0 ppm).

The dispersion and downwind impacts of smoke is highly complex, due to the influence of the flame and fire-induced turbulence as well as the effect of building and meteorological parameters. In order to estimate the dispersion of smoke, the Canary© model was utilized assuming stoichiometric combustion of the off gassed materials along with an assumed flame temperature of 900 ºC (FMGlobal 2019). Figure 4 shows the horizontal profile of the combustion products plume at low wind speeds and stable condition, the most advantageous for downwind impacts.

Figure 4 Combustion Products Downwind Impacts



Notes: Analysis using the Canary© model with stoichiometric combustion and 900 ºC combustion products temperature, F/1.5 m/s meteorological conditions.

5.7 Fire Water Flows and Contamination

In the event of a fire and/or off gassing at the facility, the fire department may apply water to the Megapacks both to knock down smoke and/or off gassed materials and also to cool the surrounding Megapacks. The fire water requirements could be substantial. Fire water also could become contaminated from off gassed materials.

A few studies address both contamination of fire water and the expected durations and application rates associated with responding to BESS emergency situations. The primary study was conducted by the company DNVGL in 2016 in part for the Fire Department of New York to help prepare them for potential response activities at ESS facilities. Additional studies included some fire water testing from vehicle battery incidents, sprinkler design studies for BESS, NFPA 855 sprinkler requirements, other code requirements and the results of large-scale fire testing conducted for Tesla. These studies are summarized as:

1. In general, fire water should be expected to pick up some contaminants and have some changes in pH, but these changes would not be different than a normal industrial or building fire where plastics may be combusting, picking up some fluorides, chloride and other contaminants.
2. Fire application rates are estimated to be between 250 – 750 GPM for a Megapack.
3. Durations could range as high as 4 hours based on large scale fire testing of the Megapacks and code requirements for other industries.

With a 4-hour application at the range of rates of 250 - 750 GPM, total water applied would range from 60,000 to 180,000 gallons. Fire department equipment typically utilized for a fire may increase this applied amount up to 1,500 gpm. The project has a proposed storm water management plan with a bioretention basin that will take all water that runs off the site before leaving the site. The square footage of this is 1300 square feet with the total gallons that this basin can hold approximately 28,000 gallons. Therefore, a 4-hour water application related to an incident at the BESS would exceed the capacity of the bioretention basin and water would overflow into the storm drain system.

The water that could enter the storm drain system, based on the studies discussed below, would not have contaminants that would exceed those encountered at an industrial, commercial or residential fire situation and is therefore considered to be with the range of normal fire water runoff from response situations.

Summaries of Fire Water Studies:

DNV 2016: Considerations for ESS Fire Safety: This study conducted a fire and extinguisher testing program that evaluated a broad range of battery chemistries. The testing was conducted for the New York State Energy Research & Development Authority (NYSERDA) and Consolidated Edison, as they engaged the New York City Fire Department (FDNY) and the New York City Department of Buildings (NYDOB) to address code and training issues. The study forced 6 different battery chemistry arrangements into thermal runaway, then then tested 5 different extinguishing agents. For water, water quality tests were conducted. Large scale testing was conducted within a shipping container.

- All batteries tested emitted toxic fumes, the toxicity being similar to a plastics fire and therefore a precedent exists.
- Water application rates of 0.10 GPM/kg of battery cells are estimated.
- Water application rates of 250 GPM is more than sufficient for typical battery systems on the market, provided that cascading protections and external fire rating requirements are also met.
- Based on calculations for a 1,000 kWH system, water requirements for an entire Megapack would total 358 GPM (report Table 10, assuming 1,200 kg/Megapack module, 17 modules per Megapack)).
- The pH of runoff water from the module burn tests was measured to be anywhere from pH 6 to pH 11 (with pH 11 being from a submerged batter arrangement). However, many of the same contaminants found from plastics fires were common to those found from battery fires.
- Suppression of large, fully involved systems may take more time than fires of similar size with different fuels. It is recommended fire service personnel continue to suppress with water for as long as required and then ensure the system is fully cooled throughout once suppression appears complete.
- While extinguishing was accomplished with all extinguishers, water demonstrated the best ability to cool and maintain cool temperatures on the battery.

BLUM 2016: Review of Battery Accidents

- water samples collected after extinguishing Li-ion batteries on vehicles showed concentrations of fluoride and chloride.

Tesla large scale fire test: Powerpack

- Duration of fire test – 3 hours 19 minutes.

Tesla Large Scale Fire Test: Megapack, Fisher Engineering

- Duration of test – 3 hours 30 minutes.

Fire Water Durations: Various codes and standards for industry require a duration for fire water, ranging from 2 – 4 hours (NFPA, API, IRI, CCPS, CFC).

Fire Water Contamination

Normal operational and stormwater discharges from facilities are governed by the National Pollution Discharge Elimination System (NPDES). Fire water is not included in NPDES permits as it is an emergency use. The City of Goleta Stormwater Management Plan exempts "emergency firefighting discharges". Furthermore, the failure rate of battery systems (described in greater detail later in this report) is extraordinarily low; failures that produce outgassing that would likely be addressed with application of fire water by the Fire Department are estimated to be once every 10,989 years. As indicated by NFPA 855 Annex C.7 as well as DNVGL studies (DNVGL 2017), pollutants are not expected to be present in battery fire water in large quantities or in quantities larger than any other similar fire (see below). Because it would be an extremely rare event and is not covered by current regulations regarding water discharges (NPDES) and would be similar to fire events associated with other development projects, contaminants in fire water are not considered a significant issue and are not expected to be analyzed pursuant to CEQA.

However, in order to give an indication of the level of contaminants that might be expected in fire water from a battery fire, and to provide information and full disclosure, this report examines the potential peak levels of water contamination that could occur if all of the cell-level off gassed materials are absorbed by the fire water and compares this to a range of NPDES requirements.

NPDES requirements generally only cover a short list of pollutants or pollutant inducing conditions, including biological oxygen demand (BOD), total suspended solids (TSS), chemical oxygen demand (COD), oil and grease, phenolic compounds, total chromium and hexavalent chrome (as per the EPA NPDES requirements section 419.53). None of these would be considered an issue associated with Megapacks and none of these pollutants were indicated in any of the historical monitoring reports associated with lithium battery events (see Table 2 above). Additionally, NPDES permits can have additional compound-specific limits in a facility's permits. For example, the Goleta Wastewater Treatment Plant (NPDES NO. CA0048160) has a large range of pollutants that are examined related to effluent discharges to the ocean. These include a range of pollutants such as arsenic, lead, mercury, cyanide, acrolein, etc. In addition, NPDES permits for industrial stormwater and for "low threat" facilities also have pollutant specific limits. The intention of listing a range of NPDES levels is to indicate the relative severity of the discharge concentrations.

Studies on fire water contamination associated with battery fires are limited. A few studies related to battery fire water contamination include studies conducted by DNVGL and NFPA 855. DNVGL (DNVGL 2017) conducted tests on batteries examining the most effective firefighting measures, and concluded that:

> *"for most tests the water runoff was slightly acidic measuring pH 6 - 7. In one case, however, the water became alkaline climbing to pH 10-11 after a few hours of submersion. This case was observed for a battery that was highly consumed in the fire".*

The application of water directly on the Megapack would not allow for direct contact of the water with the lithium-ion battery cells. The cells are protected by the Megapack enclosure and their module shells. This protection effectively limits the extent to which the water could become contaminated with battery elements. Changes to water quality or pH will therefore be limited under the scenarios associated with Megapack fire response activities. Although the DNVGL testing indicates high pH levels for one case, that one case was for a submerged battery in a static tub of water and is not representative of firefighting measures that would be employed at a site with a Megapack. (See Tesla letter in Exhibit H).

NFPA 855 Annex C.7 also indicates that:

> "*Though trace amounts of heavy metals such as nickel and cobalt [depending on battery type] can be deposited from combustion of the batteries, these elements are not expected to be present in large quantities or in quantities larger than any other similar fire. In most instances, water exposed to the batteries shows very mild acidity, with an approximate pH of 6*".

Therefore, water pH would not be expected to exceed a range of 6 – 7 and trace levels of contaminants are expected to be similar to fires associated with other industries and fires.

A battery fire would generate pollutants in the off gassed materials due to both the battery cells themselves, and from materials that would be associated with any facility fire, industrial, commercial or residential, such as the combustion of plastics, electrical components, etc. Each of these is discussed below.

Battery Cell Pollutants Only

Tesla has conducted toxic material off gassing sampling associated with both cell level tests and with the entire module or Megapack tests. Table 9 lists pollutants identified from only the cell level tests. Table 2 and Table 3 lists pollutants identified from entire module or Megapack tests. These pollutants that have been identified in the off gassed materials for only the battery cells, and therefore related to the battery off gassing only, and are associated with NPDES allowable limits, are listed in Table 9 along with the estimated fire water concentration given a 1,500 gpm water flowrate (a level confirmed by the Fire Department) and assuming 100% of the off gassed pollutant is absorbed by the water for a Megapack off gassing event (a very conservative assumption).

Even though NPDES standards do not apply to the battery storage project since it is not a discharge facility, Table 9 identifies the NPDES standards for the applicable pollutants for a range of discharge facility permit types to demonstrate that the battery storage fire water potential contamination level would be below the levels of other discharge facilities and their applicable NPDES allowable concentrations. For pollutants related to the battery cells, all concentrations would be below any of the NPDES limits indicating that a battery fire would not produce any unusual pollutant discharges if a fire were to occur.

Table 9 Potential Fire Water Contaminants from Battery Cell-Level Testing

Pollutant	Potential Fire Water Contaminant Level	NPDES Allowable Concentrations: WWTP Discharge Levels	NPDES Allowable Concentrations: Industrial Stormwater	NPDES Allowable Concentrations: Low Threat Facilities
Toluene	103 ug/l [3]	10 million ug/l [2]	*	150 ug/l [5]
Styrene	5.1 ug/l [3]	***	*	**
Methanol	278 ug/l [3]	75,000 ug/l [1]	15,000 ug/l [4]	**
pH	6 – 7 [6]	6 – 9 [7]	6 - 9 [7]	6 - 9 [7]

Notes: 1) instantaneous maximum from GWWTP NPDES permit. Methanol based on oil/grease levels. 2) Goleta Wastewater Treatment Plant (NPDES NO. CA0048160) permit average monthly. Instantaneous not available. 3) Peak levels identified in cell battery fire studies by Tesla. 4) General Permit For Storm Water Discharges Associated With Industrial Activities order NPDES no. cas000001, average annual (no instantaneous value listed) Table 2. Methanol based on oil/grease levels. 5) National Pollutant Discharge Elimination System (NPDES) General Permit For Discharges with Low Threat To Water Quality ORDER NO. R3-2017-0042 NPDES NO. CAG993001, effluent to inland surface waters, bays and estuaries Table 4. 6) estimates of pH range based on DNVGL 2017 and NFPA 855. 7) NPDES pH allowable limits.
* Industrial stormwater NPDES permit only addresses metals and not volatile organics. ** Not addressed in low threat listing Table 4. *** not addressed in WWTP NPDES permit.
Does not include volatile hydrocarbons (methane, propane, acetylene) which can also be produced by combustion of cells but are not NPDES pollutants.
Source: Tesla cell level testing indicates NPDES pollutants/conditions (toluene, styrene, methanol, pH) as well as non-NPDES pollutants (methane, propane, acetylene, CO, CO2).

Other Industrial Related Pollutants

For any residential, commercial, or industrial fire, there could be a number of pollutants released from a fire that could contaminate fire water. For this project, these pollutants are not directly related to the battery cell and are therefore pollutants that could be realized during a fire at any development project. During the high heat of the combustion process, the plastics and other materials that are used in the Megapacks will combust, thereby producing pollutants related to combustion. As indicated above, the NFPA 855 Annex C.7 indicates that, for lithium-ion batteries, in fire water, "*elements are not expected to be present in large quantities or in quantities larger than any other similar fire*" and DNVGL (DNVGL 2017) indicates that "*many of the same contaminants found from plastics fires were common to those found from battery fires*".

As discussed below under the scenario frequencies, the Megapacks have a number of design features that ensure a low frequency of failures, including redundant safety controls; venting system; a battery management system; remote monitoring of the battery operations; design and testing as per UL standards to ensure minimal potential for propagation to nearby cells; and monitoring through the use of fire detection. All of these measures ensure that the frequency of a battery malfunction requiring the application of water for a fire is very low.

5.8 Isolation and Protective Action Distances

In the event of a fire and/or off gassing at the facility, the USDOT Emergency Response Guide provides estimates of the initial isolation and protective action distances recommended for small and large spills (defined as less than or more than 55 gallons). The isolation and protective action distances for lithium ion batteries (Guide 147) is as follows:

- Isolate spill or leak area for at least 25 meters (75 feet) in all directions.
- Large Spill: Consider initial downwind evacuation for at least 100 meters (330 feet).
- Fire: If rail car or trailer is involved in a fire, isolate for 500 meters (1/3 mile) in all directions; also initiate evacuation including emergency responders for 500 meters (1/3 mile) in all directions.

6.0 Quantitative Risk Analysis

A quantitative risk analysis (QRA) involves assessing the potential impacts of exposing the public to flammable and toxic materials, in terms of fatalities and serious injuries, and then assessing the frequency that these scenarios could occur. The results are plotted on a frequency-cumulative number of occurrences plot (an FN curve). The County thresholds define areas on the FN curve that are considered acceptable and those area which are considered unacceptable. Any areas in the "Green" region are considered acceptable and less than significant. The County thresholds FN curves are shown in Figure 5.

The County's FN curves were originally developed based upon the United Kingdom and the Netherlands research and guidance on societal risk associated with facilities handling hazardous materials. The societal risk criteria developed by the United Kingdom Health and Safety Executive (UKHSE) for facilities handling hazardous materials is discussed in a guidance document titled *Reducing Risks, Protecting People* (UKHSE 2001). The UKHSE Hazardous Installation Directorate (HID) also developed an annex to this document titled *Societal Risk and Societal Concern* that specifically addresses societal concerns and societal risk and defines a set of acceptable and unacceptable societal risk areas for specific projects. The determinations of acceptable and unacceptable social risk outlined in the aforementioned document emulate the green, amber, and red zones that are currently used by Santa Barbara County.

Occupational safety or risk is governed by State and Federal Occupational Safety and Health Administration (OSHA) standards and is considered to be 'voluntary' risk. Voluntary risk addresses exposure to potential hazards associated with an activity, such as driving a car, work activities and others, that is consciously undertaken by an individual and is evaluated according to different standards than those applied in assessing involuntary exposure. The public safety thresholds addressed under this analysis do not apply to occupational safety.

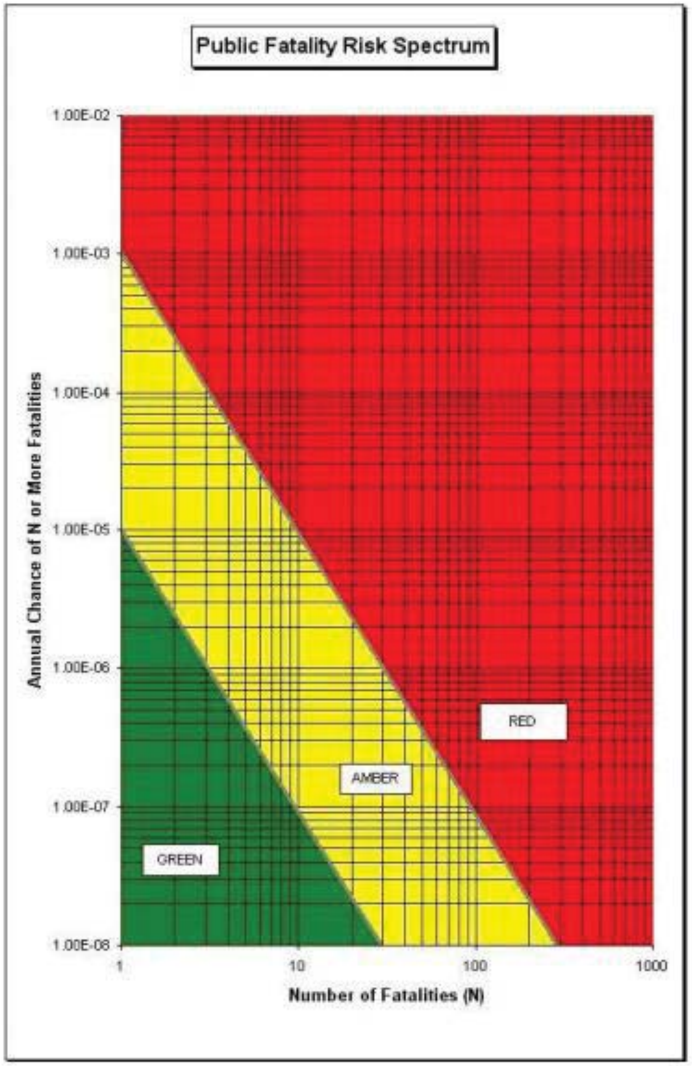
The development of a hazards assessment typically involves four major tasks that include the following:

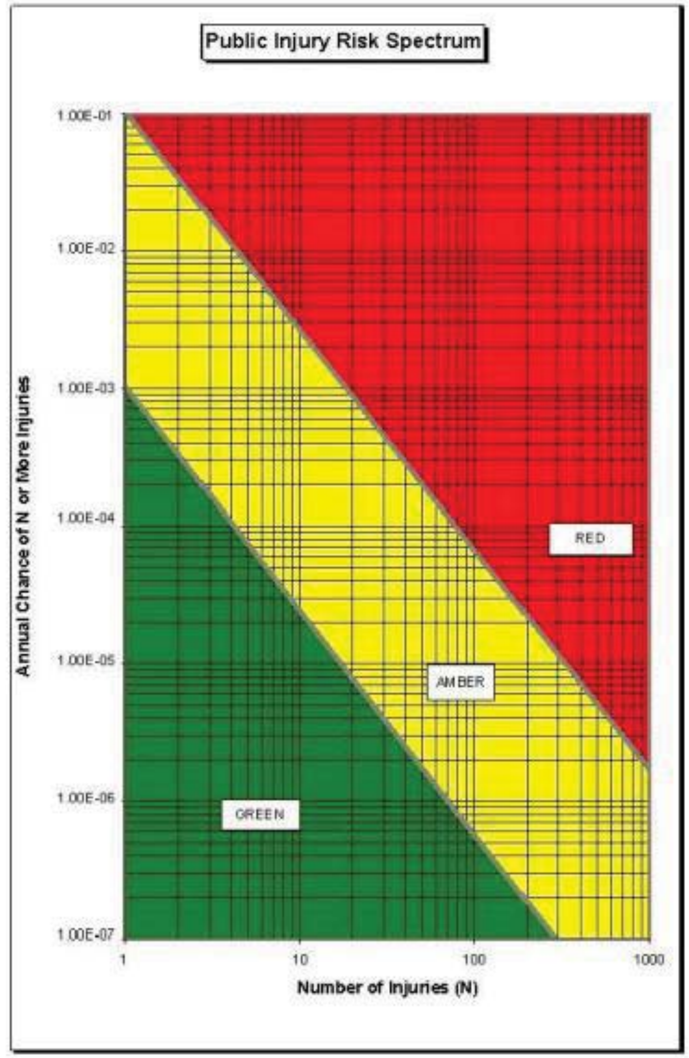
- Identification of release scenarios,

- Determine the consequences of each release scenario,
- Development of probabilities of occurrence for each release scenario that could impact the public, and
- Development of risk estimates (risk profiles, risk contours, risk matrix, etc.).

The inter-relationship and specific elements for each of these tasks are shown in Figure 6.

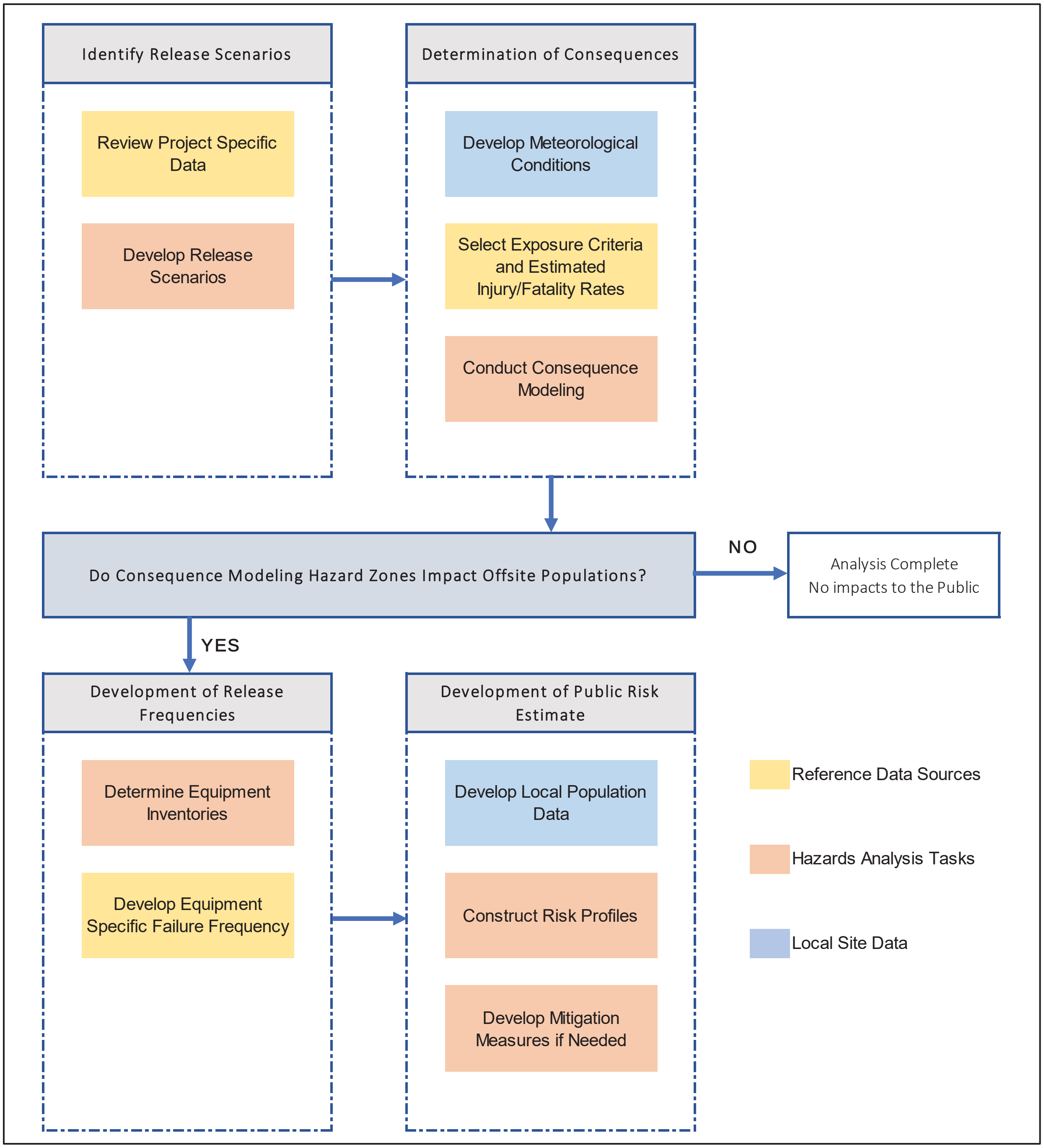
Figure 5 Santa Barbara County Project Specific Fatality and Injury Risk Thresholds





Source: Santa Barbra Environmental Threshold and Guidelines Manual, Revised 2018

Figure 6 Steps Involved in Developing a Quantitative Risk Assessment



Impacts and Levels of Concern

Modeling, as discussed above, was performed to estimate the distances at which impacts could be experienced at different concentrations (levels of concern). The ERPG values are used to estimate the extent of fatality impacts (ERPG-3) and serious injury impacts (ERPG-2). Fatality rates are assumed to be 2.75% for persons exposed to these levels based on an average of the IDLH and ERPG-3 fatality rates using the probit method (CCPS 1989). Serious injury rates are assumed to be 10% of persons exposed to the ERPG-2 levels.

For flammable impacts, exposure to vapor clouds and flash fires above the LFL, are assumed to produce 100% fatalities if the cloud ignites, with a 10% rate of serious injury within the ½ LFL if the cloud ignites. These levels are based on experiments done by Texas A&M Engineering Extension Service (TEEX) on flash fires for propane found that the peak heat flux was around 200 kW/m^2 and the duration was between 2 and 3 seconds (Child, 2016). This level of thermal dosage would result in a fatality. People outside of the LFL area could experience thermal radiation exposure for about three seconds. Exposure to 50 kW/m^2 for three seconds can result in second degree burns (Lee 2012). The distance to 50 kW/m^2 was taken as the ½ LFL value, which is conservative.

Ignition probabilities offsite are based on light industrial areas with a 10% rate of vapor cloud ignition.

For exposure to thermal impacts from fires, the exposure assumes 10% fatalities with radiation levels above 10 kw/m2 and 10% injuries with thermal radiation levels above 5 kw/m2. These levels are based on several probit functions that have been developed to estimate the potential for fatalities from exposure to various thermal radiation levels. These probit functions are based upon results from experiments carried out on animals and humans and are commonly used in this type of hazards assessment. The most commonly used are probits developed by Eisenberg, Lees, Tsao & Perry and TNO (HSE 2001).

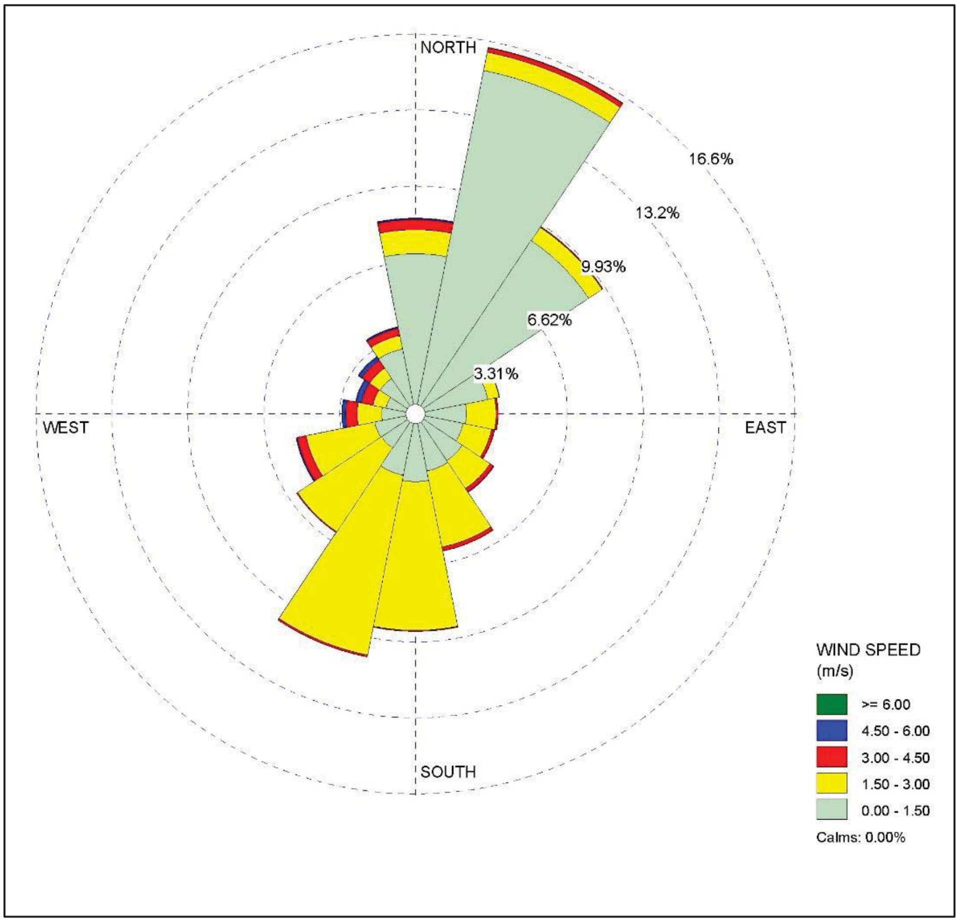
Populations

Populations that could be exposed include the areas at the M-Special brewing company, the parking lot areas to the south, the proposed Cortuna Apartments to the north and vehicles along Storke Road. The Cortona Apartments are assumed to be 3 stories, with an estimated 20 units in the closest apartment building. An estimated 2.5 persons per unit is assumed, based on 2010 census data for Santa Barbara County persons per housing unit.

Meteorological Data

The meteorological data shown in Figure 7 represents the meteorological conditions at the site and are from the APCD Goleta monitoring station for the years 2012-2016. The wind rose shows the predominant wind is from the north and the south.

Figure 7 Meteorological Wind Rose



Note: For the Goleta Monitoring Station 2012-2016. Wind Rose shows the wind based on the direction the wind is from.

Scenario Frequencies

Megapacks have not been installed at any facilities at this time as they are a recent iteration of the Tesla product line. However, the same components (battery cells, control systems, etc.) are utilized in other Tesla products, particularly the Tesla PowerPacks, which have an extensive installation base. Testing and operations of the PowerPacks is considered to be representative of the Megapacks as the battery cells are identical and any thermal runaway scenario would produce the same pollutant concentrations and emissions rate per battery cell. The Megapacks have a number of design features that ensure a low frequency of failures, including:

- A parallel battery module architecture that provides redundant safety controls with isolated architecture that reduces events such as architectural faults;
- Dedicated venting system to direct any off gases vertically with sparkers to ensure combustion and prevent deflagration;

- Pre-assembled and pre-tested systems with a single operator interface ensures minimal installation and commissioning interfaces;
- Weatherproof enclosures built to IP66 requirements minimizes the potential for environmental and physical exposures;
- A battery management system that monitors and ensures the cells are operated within appropriate limits;
- Remote monitoring of the battery operations, including temperatures, by Tesla and the battery operator;
- Testing as per UL standards to ensure that batteries will perform in a safe manner with minimal potential for propagation to nearby cells;
- Monitoring through the use of fire detection to ensure rapid response in the event of problems.

Since 2015, 17 schools in California have had Tesla Stationary Energy Storage Projects installed and according to Tesla, the total installed base of stationary energy storage products totals over 5,000 MWh (5 GWh) at over 61,000 sites, including over 1,000 industrial sites, with almost half a billion operating hours without any recorded thermal runaway events (note this includes a range of battery sizes and configurations). Therefore, in order to conservatively estimate the failure rates of battery systems, the failure rate is based on the replacement rate of similar battery systems. Tesla indicates that there is a replacement rate of the PowerPacks of about 0.007%. This replacement rate was conservatively scaled upward to account for the greater number of battery cells located in a Megapack as opposed to a PowerPack (about 13 times more cells) with a conservative estimated 10% of replacement failures generating outgassing of flammable and toxic materials from a multicell event and 1.0% of replacement failures producing a Megapack event. The base failure rate for a single Megapack was therefore estimated to be 9.1×10^{-5} failures per year (once every 10,989 years) that produce outgassing (as a multicell event). Note that the site is proposing the installation of multiple Megapacks, although only a subset number of Megapacks are close enough to the site boundaries to cause impacts to receptors.

Although the nationwide experience with battery installations is not as extensive as oil and gas, for example, there is some experience to be able to estimate failure rates. In order to provide some perspective and additional substantial evidence of the failure rates of battery systems and the extent of battery installations, a review of the battery installations across the U.S. is provided. The Energy Information Agency conducts surveys through the EIA-860 form for all industrial-sized electricity generators nationwide. As per the most recent data (EIA 2020), 188 battery installations are currently operating nationwide ranging in size up to 250 MW. In California, there are currently 55 installations averaging about 10 MW in size. There are an additional 144 installations in the planning stages nationwide, and 45 in California. In 2019, 92% of the battery installations utilized lithium-ion technology nationwide. The EIA database includes battery installations back to 2012, with a total installed operating experience of 4,606 MW-years.

The only thermal off gassing incident (utilizing lithium-ion technology) identified was an April 2019 incident at the Arizona Public Services facility (DNVGL 2020). In this incident, a single LG Chem battery rack located in a container system thermally off gassed and caught fire and, after 3 hours, the container was opened, resulting in an explosion of the flammable gasses causing injuries to fire fighters. The thermal off gassing and fire did not spread to the other 27 racks in the container. Based on a single event with the operating experience defined above, the failure rate for a single rack system is estimated at 1.6×10^{-5} failures per year, which is lower than the estimate based on the replacement rate above. The higher failure rate is utilized in this analysis to be conservative.

Quantitative Risk Assessment Results

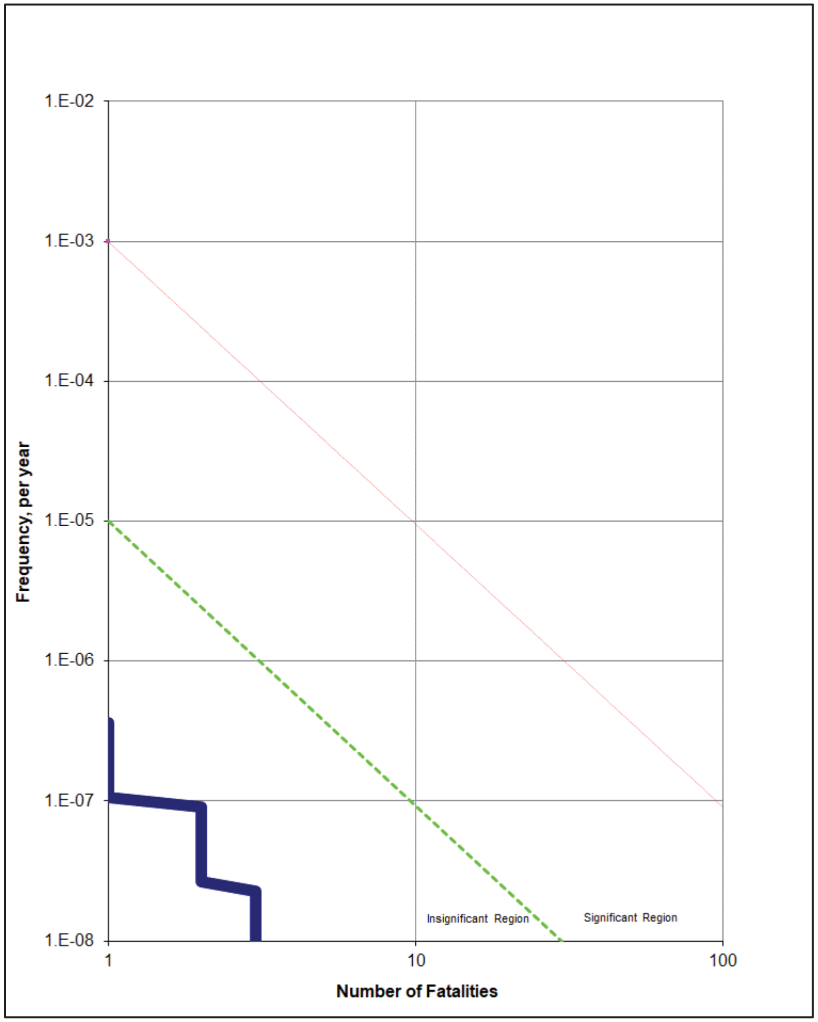
The impact zones, the levels of concern and the vulnerability criteria, the scenario frequencies, the population densities, and the wind direction frequencies are combined to produce the FN curves shown in Figure 8. The results of the risk assessment shown in Figure 8 indicate that the risk levels would be in the green "acceptable" region and impacts would be less than significant. The FN curves indicate that the risk of realizing a fatality would be less than 1 in a million years, and the risks of realizing a serious injury would be less than 1 in 200,000 years. The FN curves show the frequency (along the y-axis) plotted against the number of fatalities/injuries (along the x-axis). The frequency and fatalities/injuries are listed in scientific notation on a logarithmic scale.

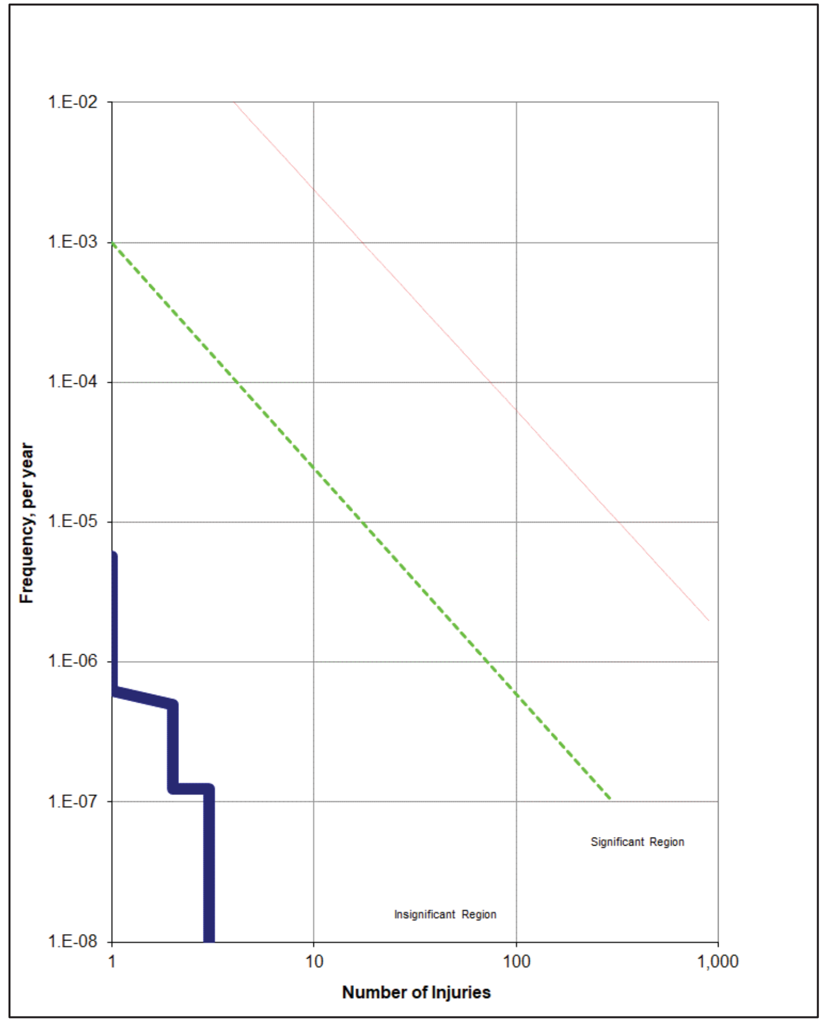
7.0 Recommendations

Recommendations related to siting and megapack installation would help to ensure that the potential for significant events are minimized. These would include the following:

1. All batteries shall be discharged to below 30% state of charge (SOC) during the construction/installation phases.
2. Any replacement or maintenance of batteries requiring the use of heavy construction equipment, such as cranes or forklifts, shall be conducted only on batteries discharged to below 30% SOC and nearby batteries that could be affected shall also be discharged to below 30% SOC.
3. Vehicle impact bollards or equivalent shall be installed to reduce the potential for vehicle impacts (as per NFPA 855 section 4.3.7).
4. Install detection systems for both flame and gas detection, being equal to or similar to the Det-Tronics x3302 flame and the Det-Tronic CGS gas detectors.
5. Monitoring and detection systems shall alarm locally and both visually and audibly, shall be monitored by a 24-hour system and shall notify the local Fire Department. Indication shall be provided to responders indicating which Megapack is experiencing issues.

Figure 8 Project FN Curves





Notes: 1E-05 is the Excel form of scientific notation and is the same as 1 x 10^{-5} frequency per year, or one in 100,000 years.

6. Develop an Emergency Operations Plan in compliance with sections of NFPA 855, including

    a. procedures for safe shutdown, de-energizing and isolation of equipment under emergency situations;

    b. procedures for inspection and testing of alarms, interlocks, detection systems and controls including recordkeeping;

    c. procedures to be followed in response to notification from the storage systems that could signify dangerous situations, including shutting down equipment and notification to the local fire department; and

    d. procedures and schedules for conducting drills of the procedures.

7. Develop a Site Safety Plan prior to startup, that identifies and summarizes the design safety features identified in the Project description and measures required pursuant to the measures above. Measures required by the Fire Department shall be included in the Site Safety Plan. The Plan shall include a graphic depiction of Project safety features and equipment onsite, including but not limited to, the following:

    a. Fire prevention, detection, and suppression features, including

        i. a description of the BMS and the monitoring of alarms and battery cell conditions and thresholds for alarms;

        ii. flame and gas detection systems, including the location of detection, type of detection and the monitoring of alarms (NFPA 855 Section 4.10);

        iii. availability of water for fire fighting and compliance with Fire Department requirements for flow and availability (NFPA 855 Section 4.13);

    b. Emergency response procedures, including notification of local responders;

    c. Personnel safety training;

    d. Fire suppression and other safety features/equipment located at the site;

    e. Type and placement of warning signs;

    f. Emergency ingress and egress routes;

    g. Special safety measures to be implemented for battery installation and replacement, including disposal of replaced (discarded) equipment;

    h. Provisions and timing for updating the Plan to incorporate new or changed requirements;

i. Control of vegetation (NFPA 855 Section 4.4.3.6);

j. Security of installations (NFPA 855 Section 4.3.8);

k. Access roads design (NFPA Section 4.3.8);

l. Signage (NFPA Section 4.3.5); and

m. Remediation measures (NFPA 855 Section 4.16) including authorized service personnel and fire mitigation personnel.

8. Provide a copy of an NFPA 855 compliance audit report to verify that the system is designed and built to comply with the NFPA 855 requirements prior to system startup.

9. Provide documentation indicating that batteries are listed in accordance with UL 1973 and listed in accordance with UL 9540.

10. Ensure that Megapack batteries are located at least 10 feet from lot lines as per NFPA 855.

Studies have shown (Golubkov 2015) that the potential for thermal runaway is a strong function of the level of charge of the batteries, with batteries that are charged below 50% exhibiting a lower potential for runaway and lower levels of offgassed volume given an external accident scenario. Therefore, when construction equipment is operating onsite, batteries that could be affected should be discharged to less than 30% SOC in order to reduce the potential for thermal-runaway accidents.

In addition, ensuring all batteries are protected from vehicle impacts would reduce the potential for accident scenarios associated with vehicle impacts.

Detection systems allow for efficient response coordination and rapid detection of potential issues of concern. Both flame detection and gas detection are recommended to ensure detection of a range of scenarios, with local and remote notifications.

An Emergency Operations Plan ensures procedures are in place to respond to emergency scenarios including notification to the local responders.

A Site Safety plan and associated audit would ensure that descriptions of detection systems and testing as well as training and a range of other issues are addressed and to ensure compliance with existing codes and standards.

8.0 NFPA 855 Hazard Mitigation Analysis Requirements

NFPA 855 Section 4.1.4 requires a hazard mitigation analysis under the following circumstances:

1. *When technologies are specifically not addressed in Table 1.3*

2. *More than one ESS technology is provided in a room or indoor area where adverse interaction between the technologies is possible*

3. *When allowed as a basis for increasing the maximum stored energy as specified in 4.8.1 and 4.8.2.*

The lithium technology is specifically listed in NFPA 855 Table 1.3 and the technology is not located inside of a room. Therefore, numbers 1 and 2 are not applicable.

NFPA 855 Section 4.8.1 is applicable to areas in non-dedicated use buildings and is not applicable to this project as this project would be located entirely outside with no buildings.

NFPA 855 Section 4.8.2 allows for approval of an outdoor ESS installation that exceed 600 kWH if a hazard mitigation analysis in accordance with section 4.1.4 and large scale fire testing as per 4.1.5.

NFPA 855 Section 4.8(2) indicates that "*Outdoor ESS installations in locations near exposures as described in 4.4.3.1(2) [within 100 feet of buildings] shall not exceed the maximum stored energy values in Table 4.8 [600 kWH] except as permitted by 4.8.3.*"

NFPA 855 Section 4.1.4 addresses the requirements for a hazard mitigation analysis. Section 4.1.4.2 specifies:

4.1.4.2 The analysis shall evaluate the consequences of the following failure modes and other deemed necessary:

1. *Thermal runaway condition in a single module, array or unit*
2. *Failure of an energy storage management system*
3. *Failure of a required ventilation or exhaust system*
4. *Failure of a required smoke detection, fire detection, fire suppression or gas detection system.*

In addition, NFPA 855 Section 4.1.4.3 indicates that a hazard mitigation analysis should demonstrate the following:

1. *Fire will be contained within unoccupied ESS rooms for the minimum duration of the fire resistance rate specified in 4.3.6*
2. *Suitable deflagration protection is provided where required*
3. *ESS cabinets in occupied work centers allow occupants to safely evacuate in fire conditions*
4. *Toxic and highly toxic gases released during normal charging, discharging, and operation with not exceed the PEL in the area where the ESS is contained.*
5. *Toxic and highly toxic gases released during fires and other fault conditions will not reach IDLH concentrations in the building or adjacent means of egress routes during the time deemed necessary to evacuate from that area*

6. *Flammable gases released during charging, discharging and normal operations will not exceed 25 percent of the LFL*

This report documents the reasonable worst-case failure that could lead to a release of toxic and flammable materials, and documents that the levels of toxic and flammable materials do not exceed the risk thresholds required under CEQA for the City of Goleta. This report indicates that the primary focus is on the worst-case reasonable scenario which could produce the largest impacts. This report also indicates that it is assumed that the control systems fail and do not control the battery cell malfunction in line with the requirements for a hazard mitigation analysis under NFPA 855, Section 4.1.4.2.

The analysis in this report demonstrates, in response to the above listings from NFPA 855 Section 4.1.4.3, that:

1. The process would be located outside, so containment of fire within rooms is not applicable.
2. Deflagration protection is provided in the form of over-pressure ventilation and sparkers to ensure combustion of gasses as well as the facilities would be installed outside, thereby reducing the potential for deflagration.
3. There would not be any occupied work centers as all cabinets would be located outside.
4. During normal charging, discharging, and operation operations, no discharges of toxic materials would occur.
5. Reasonable worst-case fault conditions would release flammable and toxic materials, but the risk levels are determined to be acceptable by the CEQA and City of Goleta guidelines. Multiple egress routes (to the east and to the south) are available and detection systems, including the flame detection and gas detection systems, would allow for egress routes to be utilized during the time necessary to evacuate from the area.
6. During normal charging, discharging operations, no discharges of flammable materials would occur and therefore the 25 percent of the LFL levels would not be exceeded.

NFPA 855 Section 4.1.5 requires large scale fire testing, which was conducted by Tesla and TUV and is included as Exhibit A in this report.

Therefore, this report could be used to satisfy the NFPA 855 requirements for a hazard mitigation analysis.

The concerns in NFPA 855 related to the 100 foot distances from nearby buildings (NFPA 855 Section 4.8(2) and 4.8.2 and 4.4.3.1) is related to exposures of nearby buildings and nearby receptors to potential off gassing events. This report addresses this concern by utilizing the Santa Barbara County and City of Goleta Risk Assessment Guidelines and CEQA thresholds to determine the acceptability of placing the systems within 100 feet of buildings and having buildings potentially be exposed to toxic or flammable materials above levels of concern given a reasonable worst case scenarios (as per NFPA 855 Section 4.8 (2), 4.1.4, 4.1.5 and 4.4.3.1). Using the detailed quantitative risk analysis approach detailed in this report demonstrates that the risks are acceptable.

In addition, the 2019 CFC Section 1206.2.3 states that:

A failure modes and effects analysis (FMEA) or other approved hazard mitigation analysis shall be provided in accordance with Section 104.7.2 under any of the following conditions:

1. *Battery technologies not specifically identified in Table 1206.2 are provided.*
2. *More than one stationary storage battery technology is provided in a room or indoor area where there is a potential for adverse interaction between technologies.*
3. *Where allowed as a basis for increasing maximum allowable quantities in accordance with Section 1206.2.9.*

And, as per 1206.2.9, Maximum Allowable Quantities:

Fire areas within buildings containing stationary storage battery systems exceeding the maximum allowable quantities in Table 1206.2.9 (600 kWH for Lithium) shall comply with all applicable Group H occupancy requirements in this code and the California Building Code.

The proposed battery storage system is a lithium system, as listed in Table 1206.2, does not utilize more than one stationary battery technology, and is not located within a building. Note that Table 1206.2.9 is related to occupancy issues. There are no occupancy issues at the site as everything is located outside. The installation therefore does not qualify for a FMEA analysis requirement under the 2019 CFC Section 1206.2.3, although a hazards mitigation analysis as an alternative approach meeting the requirements under NFPA 855 has been conducted in the form of this report as discussed above.

The California Fire Code section CFC 1206.10.1 requires that battery systems be listed in accordance with UL 1973. The Tesla battery systems have been tested and certified to comply with UL 1973 and UL 9540 by the certification and testing company TUVRheinland, which is a part of the OSHA NRTL Program. These certifications are included in Exhibit B and C.

9.0 Summary of Impacts and Conclusions

Results from the analysis indicate that the reasonable worst-case battery cell malfunction scenarios would result in risk impacts below the significant thresholds. Recommendations would help to ensure that the battery systems do not suffer malfunctions from external events and appropriate planning and audits have been implemented. Therefore, the risk impacts for the battery facility are considered less than significant.

10.0 References

Anderson 2013, Investigation of fire emissions from Li-ion batteries

Blum 2016, Lithium Ion Battery Energy Storage System Fires

CAPCOA 2016, CAPCOA Air Toxic "Hot Spots" Program Facility Prioritization Guidelines

CCPS. 1989, Guidelines for Chemical Process Quantitative Risk Analysis. American Institute of Chemical Engineers Center for Chemical Process Safety, New, York, 1989.

Child, Drew. 2016. Duration and Energy of Hydrocarbon Flash Fires. AATCC Flammability in Textile Applications Symposium. September 21, 2016.

CPUC 2017, SED Safety Inspection Items for Energy Storage Ratified by D.17-04-039, April 27, 2017 (Finding of Fact #24)

DNVGL 2017, Considerations for ESS Fire Safety

DNVGL 2019, Live Fire Test of Tesla Powerpacks Tesla, Inc. DNV GL Doc. No.: 10118434-HOU-R-02-D Issue: D; Status: Release Issue Date: April 17th, 2019

DNVGL 2020, McMicken Battery Energy Storage System Event Technical Analysis and Recommendations, Arizona Public Service, Document No.: 10209302-HOU-R-01, July 18, 2020

EIA 2020, Energy Information Administration, October 2020 form EIA-860 database, https://www.eia.gov/electricity/data/eia860/

ESN 2019, Energy Storage News, Korea's ESS fires: Batteries not to blame but industry takes hit anyway, 19 June, 2019

FDNY 2015, Workshop on Energy Storage Systems and the Built Environment

Fent 2004, Airborne Contaminants During Controlled Residential Fires, Journal of Occupational and Environmental Hygiene

Fisher Engineering 2020, Tesla Megapack UL 9540A Test Results: Interpretive Report and FPE Code Narrative, August 7, 2020

FMGlobal 2019, Development of Sprinkler Protection Guidance for Lithium Ion Based Energy Storage Systems

Fowels 2001, Fire Research The Ecotoxicity of Fire-Water Runoff Part II: Analytical Results -

Golubkov 2015, Thermal Runaway of Commercial 18650 Li-Ion Batteries With LFP And NCA Cathodes – Impact Of State Of Charge And Overcharge

Hopper 2017, Energy Storage Systems – Fire Safety Concepts in the 2018 International Fire and Residential Codes

Health and Safety Executive (HSE). 2001. Methods for Approximation and Determination of Human Vulnerability for Offshore Major Accident Hazard Assessment. 2001.

Lees, Frank. 2012. Lees' Loss Prevention in the Process Industries 4th Edition. 2012.

Larsson 2017, Toxic Fluoride Gas Emissions from Lithium-Ion Battery Fires

NFPA 2014, Separation Distances in NFPA Codes, The Fire Protection research Foundation.

NFPA 2017, Technical Committee on Stationary Energy Storage Systems Minutes of Meeting

NIOSH 2017, Maximum allowable exposure to different heat radiation levels in three types of heat protective clothing

NIOSH 2019, The National Institute for Occupational Safety and Health (NIOSH), Immediately Dangerous To Life or Health (IDLH) Values: Table of IDLH Values, https://www.cdc.gov/niosh/idlh/intridl4.html

NRC 2004, Nuclear Regulatory Commission, Fire Dynamics Tools (FDT): Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program

OEHHA 2019, REL listing, https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary

Rincon 2017, NRG Ellwood Battery Storage Project Final Initial Study – Mitigated Negative Declaration Case #15-145-CUP (LG Chem batteries)

Ronken 2017, Lithium-Ion Batteries – A New Fire Risk

SBC 2008, Environmental Thresholds and Guidelines Manual, 2008

SBCAPCD 1990, Santa Barbara County Air Pollution Control District Procedures For Prioritizing Facilities Pursuant To The Air Toxics “Hot Spots” Information And Assessment Act Of 1987

SPFE 1999, Society of Fire Protection Engineers, Engineering Guide: Assessing Flame Radiation to External Targets from Pool Fires

SPFE 2020, Sprinkler Design in ESS Installations, Fire Protection Engineering Magazine

Tesla 2019, Tesla "Cell and unit level assessment of gas release composition from Tesla ESS"

UKHSE 2001, Reducing Risks, Protecting People

USDOT, 2020 Emergency Response Guidebook

Exhibit A

9540A Unit Level Test Report

TEST REPORT

ANSI/CAN/UL 9540A:2019
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Report Number .... :	32072059.001
Date of issue .... :	June 17, 2020
Total number of pages .... :	25
Name of Testing Laboratory preparing the Report .... :	**TÜV Rheinland of North America, Inc.** 1279 Quarry Lane, Suite A, Pleasanton, CA 94566
Applicant's name .... :	**Tesla, Inc.**
Address .... :	3500 Deer Creek Road, Palo Alto, CA 94304
Test specification:	
Standard .... :	ANSI/CAN/UL 9540A:2019
Test procedure .... :	Report
Non-standard test method .... :	N/A
Test Report Form No. .... :	N/A
Test Report Form(s) Originator .... :	N/A
Master TRF .... :	Dated 2019-01-17

General disclaimer:

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the Issuing Testing Laboratory. The authenticity of this Test Report and its contents can be verified by contacting the CB, responsible for this Test Report.

Test item description ....:	Battery Energy Storage System
Trade Mark ....:	Tesla
Manufacturer....................................:	Tesla, Inc, (new # 1210368) 3500 Deer Creek Rd, Palo Alto, CA 94304
Model/Type reference ....:	1462965-XX-Y Megapack XX – can be any number from 00 to 99. XX – represents style codes used for different variants of the same part, having no impact on the safety and functionality of the entire product. Y – can be any upper case letter from A to Z. Y – represents pedigree and is used for tracking changes to parts that have already been released to suppliers or production, having no impact on the safety and functionality of the entire product
Ratings ....:	1) 480Vac, 1264.5 kW, 1573 kVA 2) 505Vac, 1264.5 kW, 1654.9 kVA (3 phase 3 wire or 3 phase 4 wire) Battery capacity 4hr: 2964.8kWh Battery capacity 2hr: 2529kWh

Responsible Testing Laboratory (as applicable), testing procedure and testing location(s):

☒	**Testing Laboratory:**	**TÜV Rheinland of North America, Inc.** 1279 Quarry Lane, Suite A, Pleasanton, CA 94566	
Testing location/ address .... :			
Tested by (name, function, signature) .... :			
Approved by (name, function, signature) .. :			
☒	**Testing procedure: CTF Stage 1/TMP:**	**Tesla, Inc.**	
Testing location/ address .... :		3500 Deer Creek Road, Palo Alto, CA 94304	
Tested by (name, function, signature) .... :		Justin Goh/ Himanshu Vaidya	
Approved by (name, function, signature) .. :		Howard Liu	
☐	**Testing procedure: CTF Stage 2/WMT:**		
Testing location/ address .... :			
Tested by (name + signature) .... :			
Witnessed by (name, function, signature) . :			
Approved by (name, function, signature) .. :			
☐	**Testing procedure: CTF Stage 3/SMT:**		
☐	**Testing procedure: CTF Stage 4:**		
Testing location/ address .... :			
Tested by (name, function, signature) .... :			
Witnessed by (name, function, signature) . :			
Approved by (name, function, signature) .. :			
Supervised by (name, function, signature) :			

List of Attachments (including a total number of pages in each attachment):

1. Test package with testing equipment list
2. Photo documentation

Summary of testing:

Tests performed (name of test and test clause):	**Testing location:**
9540A cl 9 – Unit Level	Tesla, Inc. Tesla Battery Test Facility Fernley, Nevada

Summary of compliance with National Differences (List of countries addressed): N/A

☐ **The product fulfils the requirements of _________ (insert standard number and edition and delete the text in parenthesis, leave it blank or delete the whole sentence, if not applicable)**

Possible test case verdicts:	
- test case does not apply to the test object ....:	N/A
- test object does meet the requirement...........:	P (Pass)
- test object does not meet the requirement ....:	F (Fail)
Testing:	
Date of receipt of test item ....:	May 10, 2020
Date (s) of performance of tests ....:	May 13, 2020
General remarks:	
"(See Enclosure #)" refers to additional information appended to the report. "(See appended table)" refers to a table appended to the report. **Throughout this report a ☐ comma / ☒ point is used as the decimal separator.**	
Name and address of factory (ies) .... :	
Copy of marking plate: Use – "Only for use with Tesla Products" "The artwork below may be only a draft. The use of certification marks on a product must be authorized by the respective NCB' s that own these marks"	
General product information and other remarks:	

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
CONSTRUCTION			--
5	**General**		--
5.1	**Cell**		P
5.1.1	The cells associated with the BESS that were tested shall be documented in the test report	Panasonic Model NCR2170D LiNiCoAlO2 Cylindrical Lithium ion battery Rated capacity (Ah): 3930mAh Nominal voltage (V): 3.6V Upper limit charging voltage (V) : 4.2V Nominal mass (g): 70.6g or less (68.1g typ) External dimensions (mm): 21+/-0.12mm diameter 70+/-0.25mm height	P
5.1.2	The cell documentation included in the test report shall indicate if the cells associated with the BESS comply with UL 1973	Battery module is compliant with UL 1973. Cell is compliant with UL 1642.	P
5.1.3	Refer to 7.6.1 for further details	See 7.6.1	N/A
5.2	**Module**		P

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
5.2.1	The modules associated with the BESS that were tested shall be documented in the test report	Battery module (12 modules in series): Rated Voltage MV (before DCDC converter) nominal voltage: 400V MV max. charge voltage: 470 V(operational) (460 V full power) MV min. discharge voltage: 216 V (operational) (324 V full power) Rated Current Max. HV charge/discharge current: 116 A (2 hr), 58 A (4 hr) Max. MV charge/discharge current: 280.8 A (2 hr), 143.8 A (4 hr) Max. HV charge and discharge power: 125 kW (2 hr), 52 kW (4 hr) Battery module: Nominal voltage: 33.3 V Max charge voltage: 38.75 V(operational) (37.75 V full power) Min. discharge voltage: 18 V (operational) (27 V full power)	P
5.2.2	The module documentation included in the test report shall indicate if the modules associated with the BESS comply with UL 1973	Battery module is compliant with UL 1973	P
5.2.3	Refer to 8.3 for further details	See 8.3	N/A
5.3	**Battery energy storage system unit**		P
5.3.1	The BESS unit documentation included in the test report shall indicate the units that comply with UL 9540	UL 9540 compliant	P
5.3.2	For BESS units for which UL 9540 compliance cannot be determined,	See above	N/A
5.3.3	If applicable, the details of any fire detection and suppression systems that are an integral part of the BESS shall be noted in the test report	No fire detection and suppression systems used	N/A
5.3.4	Refer to 9.7, 10.4 and 10.7 for further details	See 9.7	P
5.4	**Flow Batteries**		N/A
5.4.1	For flow batteries, the report will cover the chemistry, as well as the electrical rating in capacity and nominal voltage of the cell stack	Not flow batteries	N/A
5.4.2	The flow battery documentation included in the test report shall indicate if the flow battery system complies with UL 1973		N/A

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
5.4.3	See 7.6.2 for further details		N/A
PERFORMANCE			--
6	**General**		N/A
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices that can result in fires		N/A
6.2	At the conclusion of testing, samples shall be discharged in accordance with the manufacturer's specifications		N/A
9	**Unit Level**		--
9.1	**Sample and test configuration**		--
9.1.1	The unit level test shall be conducted with BESS units installed as described in the manufacturer's instructions and this section. Test configurations include the following:		P
	a) Indoor floor mounted non-residential use BESS; b) Indoor floor mounted residential use BESS; c) Outdoor ground mounted non-residential use BESS; d) Outdoor ground mounted residential use BESS; e) Indoor wall mounted non-residential use BESS; f) Indoor wall mounted residential use BESS; g) Outdoor wall mounted non-residential use BESS; h) Outdoor wall mounted residential use BESS; and i) Rooftop and open garage non-residential use BESS installations.	Outdoor ground mounted non-residential use BESS	P
9.1.2	The unit level test requires one initiating BESS unit in which an internal fire condition in accordance with the module level test is initiated and target adjacent BESS units representative of an installation	One initiating BESS and two target adjacent BESS	P
	Exception: Testing can be conducted outdoors for outdoor only installations if there are the following controls and environmental conditions in place:	Testing can be conducted outdoors for outdoor only installations See Figure 1	P

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
	a) Wind screens are utilized with a maximum wind speed maintained at ≤ 12 mph; b) The temperature range is within 10°C to 40°C (50°F to 104°F); c) The humidity is < 90% RH; d) There is sufficient light to observe the testing; e) There is no precipitation during the testing; f) There is control of vegetation and combustibles in the test area to prevent any impact on the testing and to prevent inadvertent fire spread from the test area; and g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area and to prevent exposure of persons to any hazards as a result of testing.	This was an outdoor installation test. The ambient temperature was varied between 10°C and 27°C and humidity less than 90% RH, and wind was under 12 mph.	P
9.1.3	Depending upon the configuration and design of the BESS (e.g. the BESS is composed of multiple separate parts within separate enclosures), this testing to determine fire characterization can be done at the battery system level	Testing performed at BESS level	N/A
9.1.4	The initiating BESS unit shall contain components representative of a BESS unit in a complete installation.	Complete unit in the testing	P
9.1.5	Target BESS units shall include the outer cabinet (if part of the design), racking, module enclosures, and components		P
9.1.6	The initiating BESS unit shall be at the maximum operating state of charge (MOSOC),	100% SOC	P
9.1.7	If a BESS unit includes an integral fire suppression system, there is an option of providing this with the DUT	No integral fire suppression system	N/A
9.1.8	Electronics and software controls such as the battery management system (BMS) in the BESS are not relied upon for this testing.		P
9.2	**Test method – Indoor floor mounted BESS units**	Outdoor ground mounted units. Used the test method described in the Section 9.2 except conflicted with Section 9.3.	--
9.2.1	Samples and test configurations are in accordance with 9.1.	Testing conducted outdoor	N/A
9.2.2	Any access door(s) or panels on the initiating BESS unit and adjacent target BESS units shall be closed,	Doors closed	P
9.2.3	The initiating BESS unit shall be positioned adjacent to two instrumented wall sections	No instrumented wall sections	N/A
9.2.4	Instrumented wall sections shall extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of the target BESS units.	No instrumented wall sections	N/A
9.2.5	Instrumented wall sections shall be at least 0.61-m (2-ft) taller than the BESS unit height	No instrumented wall sections	N/A
9.2.6	The surface of the instrumented wall sections shall be covered with 16-mm (5/8-in) gypsum wall board and painted flat black	No instrumented wall sections	N/A

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Clause	Requirement – Test	Result – Remark	Verdict
9.2.7	The initiating BESS unit shall be centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter	Testing conducted outdoor	N/A
9.2.8	The light transmission in the calorimeter's exhaust duct shall be measured using a white light source and photo detector for the duration of the test	Testing conducted outdoor	N/A
9.2.9	The chemical and convective heat release rates shall be measured for the duration of the test, using the methodologies specified in 8.2.11 and 9.2.12, respectively	Testing conducted outdoor	N/A
9.2.10	With reference to 9.2.9, the heat release rate measurement system shall be calibrated	Testing conducted outdoor	N/A
9.2.11	With reference to 9.2.9, the convective heat release rate shall be measured using thermopile	Testing conducted outdoor	N/A
9.2.12	With reference to 9.2.9, the convective heat release rate shall be calculated using the following equation: $HRR_c = V_e A \frac{353.22}{T_e} \int_{T_0}^{T} C_p dT$	Testing conducted outdoor	N/A
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation	No instrumented wall sections	N/A
9.2.14	Separation distances shall be specified by the manufacturer for distance between:		P
	a) The BESS units and the instrumented wall sections; and b) Adjacent BESS units.	a) No wall b) 6 inches from ISO knuckle of Initiating unit to Target unit. 4 inches from surface of initiating unit to target unit surface.	P
9.2.15	Wall surface temperature measurements shall be collected for BESS intended for installation in locations with combustible construction.	No instrumented wall sections	N/A
9.2.16	Wall surface temperatures shall be measured in vertical array(s) at 152-mm (6-in) intervals for the full height of the instrumented wall sections using No. 24-gauge or smaller,	No instrumented wall sections	N/A
9.2.17	Thermocouples shall be secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires	No instrumented wall sections	N/A
9.2.18	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall:	No instrumented wall sections	N/A
	a) Both are collinear with the vertical thermocouple array;		N/A
	b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and		N/A

Clause	Requirement – Test	Result – Remark	Verdict
	c) One is positioned at the elevation estimated to receive the greatest heat flux during potential propagation of thermal runaway within the initiating BESS unit.		N/A
9.2.19	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit:	No target facing the initiating BESS	N/A
	a) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating BESS; and		N/A
	b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.		N/A
9.2.20	For non-residential use BESS, heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge	Testing conducted outdoor	N/A
9.2.21	No. 24-gauge or smaller, Type-K exposed junction thermocouples shall be installed to measure the temperature of the surface	No. 24-gauge, Type-K used	P
9.2.22	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth	Non-residential	N/A
9.2.23	An internal fire condition in accordance with the module level test shall be created within a single module in the initiating BESS unit:	See Figure 2 Megapack can consist up to 17 Battery Module assemblies. Each module assembly contains 6 trays of 2 Modules each which is a total of 204 modules. The module that was set to initiate was located at location 72 and on Tray III. Two sections of heaters with 29 and 27 heater were setup to force thermal runaway.	P
	a) The position of the module shall be selected to present the greatest thermal exposure		P
	b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module shall be the same as that used to initiate and propagate thermal runaway within the module level test		P
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases shall be measured within the calorimeter's exhaust duct	Testing conducted outdoor	N/A
9.2.25	The hydrocarbon content of the vent gas shall be measured using flame ionization detection	Testing conducted outdoor	N/A
9.2.26	The test shall be terminated if:		P
	a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;	Appilcable	P
	b) The fire propagates to adjacent units or to adjacent walls; or		N/A
	c) A condition hazardous to test staff or the test facility requires mitigation		N/A

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Clause	Requirement – Test	Result – Remark	Verdict
9.2.27	For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation	Non-residential	N/A
9.3	**Test method – Outdoor ground mounted units**		--
9.3.1	Outdoor ground mounted non-residential use BESS being evaluated for installation in close proximity to buildings shall use the test method described in Section 9.2	See 9.2	P
9.3.2	except as noted in 9.3.3 and 9.3.4. Heat flux measurements for the accessible means of egress shall be measured in accordance with 9.2.20.	See 9.2	P
9.3.3	Test samples shall be installed as shown in Figure 9.2 in proximity to an instrumented wall section that is 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit	No instrumented wall sections	N/A
	Exception: If the manufacturer requires installation against non-flammable material, the test setup may include manufacturer recommended backing material between the unit and plywood wall		N/A
9.3.4	Target BESS shall be installed on each side of the initiating BESS in accordance with the manufacturer's installation specifications	No target unit on the front side	N/A
9.4	**Test Method – Indoor wall mounted units**	Testing conducted outdoor	N/A
9.4.1	Testing of indoor wall mounted BESS shall be in accordance with Section 9.2, except as modified in this section. See Figure 9.3.		N/A
9.4.2	The test shall be conducted in a standard NFPA 286 fire test room, 3.66 × 2.44 × 2.44-m (12 × 8 × 8-ft) high, with a 0.76 × 2.13-m (2-1/2 × 7-ft) high opening.		N/A
9.4.3	The initiating BESS unit shall be positioned on the wall opposite of the door opening		N/A
9.4.4	Target BESS shall be installed on the wall on each side of the initiating BESS		N/A
9.4.5	The wall on which the initiating and target BESS units are mounted shall be instrumented in accordance with Section 9.2.		N/A
9.4.6	The gas collection methods shall be in accordance with 9.2		N/A
9.4.7	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator.		N/A
9.5	**Test Method – Outdoor wall mounted units**	Testing conducted outdoor, ground mounted	N/A
9.5.1	Testing of outdoor wall mounted BESS shall be in accordance with Section 9.2, except as modified in this section. See Figure 9.4.		N/A
9.5.2	Test samples shall be mounted on an instrumented wall section that is 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit (undersurface of the eave shown in Figure 9.4).		N/A

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Clause	Requirement – Test	Result – Remark	Verdict
9.5.3	The initiating BESS unit shall be positioned on the instrumented wall, with its center located 1.22-m (4-ft) above the floor,		N/A
9.5.4	Target BESS shall be installed on the wall on each side of the initiating BESS, at the same height		N/A
9.5.5	The wall on which the initiating and target BESS units are mounted shall be instrumented in accordance with Section 9.2.		N/A
9.5.6	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth		N/A
9.6	**Rooftop and open garage installations**	Testing conducted outdoor, ground mounted	N/A
9.6.1	Testing of BESS intended for non-residential use rooftop or open garage installations shall be in accordance with 9.2.		N/A
9.6.2	If intended for rooftop and open garage use only installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured		N/A
9.7	**Unit level test report**		--
9.7.1	The report on the unit level testing shall identify the type of installation being tested, as follows:		P
	a) Indoor floor mounted non-residential use BESS; b) Indoor floor mounted residential use BESS; c) Outdoor ground mounted non-residential use BESS; d) Outdoor ground mounted residential use BESS; e) Indoor wall mounted non-residential use BESS f) Indoor wall mounted residential use BESS; g) Outdoor wall mounted non-residential use BESS; h) Outdoor wall mounted residential use BESS; i) Rooftop installed non-residential use BESS; or j) Open garage installed non-residential use BESS.	Outdoor ground mounted non-residential use BESS;	P
9.7.2	With reference to 9.7.1, if testing is intended to represent more than one installation type, this shall be noted in the report	One installation type	N/A
9.7.3	The report shall include the following, as applicable:	See Table 1	P

	a) Unit manufacturer name and model number (and whether UL 9540 compliant); b) Number of modules in the initiating BESS unit; c) The construction of the initiating BESS unit per 5.3; d) Fire protection features/detection/suppression systems within unit; e) Module voltage(s) corresponding to the tested SOC; f) The thermal runaway initiation method used; g) Location of the initiating module within the BESS unit; h) Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits; i) Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension; j) Chemical and convective heat release rate versus time data; k) Separation distances from the initiating BESS unit to target walls (e. g. distances A and C in Figure 9.1); l) Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1); m) The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple; n) The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple; o) The maximum incident heat flux on target wall surfaces and target BESS units; p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test; q) Gas generation and composition data; r) Peak smoke release rate and total smoke release data; at which activation occurred; t) Observation of flying debris or explosive discharge of gases; u) Observation of re-ignition(s) from thermal runaway events; v) Observation(s) of sparks, electrical arcs, or other electrical events; w) Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units;		

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Clause	Requirement – Test	Result – Remark	Verdict
	3) Adjacent walls, ceilings, or soffits; and x) Photos and video of the test.		
9.8	**Performance at unit level testing**		--
9.8.1	Installation level testing in Section 10 is not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.	a) Peak flame extension was observed to be at about 10-12 ft upwards and 8-10 ft in front of the unit. b) Surface temperatures of the modules within the target BESS remained below 140.2C (cell vent temperature). Maximum temperature measured was 44.5C. c) Not intended for installation near exposures, no measurements taken to walls. d) No explosion hazards observed (no deflagration, detonation, or accumulation of battery vent gases) e) Maximum incident heat flux was 17.5kW/m^2 at 3 ft from the left of the initiating cabinet enclosure (Note: Megapack is not designed to be installed near accessible means of egress. Refer to Figure 10. Heat Flux results for more information on heat flux around the product).	--
10	**Installation Level**	Unit level testing only	N/A
10.1	General		N/A
10.1.1	The installation level test method assesses the effectiveness of the fire and explosion mitigation methods for the BESS in its intended installation		N/A
	a) Test Method 1 – "Effectiveness of sprinklers" is used		N/A
	b) Test Method 2 – "Effectiveness of fire protection plan" is used		N/A
10.1.2	Installation level testing is not appropriate for units only intended for outdoor use or residential use.	Outdoor use only	P
10.2	Sample		N/A
10.2.1	The samples (initiating BESS and target BESS) and their preparation for testing		N/A
10.2.2	A flame indicator consisting of a cable tray with fire rated cables that complies with UL 1685 and representative of the installation per the anufacturer's specifications		N/A
10.3	Test method 1 – Effectiveness of sprinklers		N/A
10.3.1	For BESS units with a height of 2.44 m (8 ft) or less, the test shall be conducted in a 6.10 × 6.10 × 3.05-m (20 × 20 × 10-ft) high test room		N/A

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Clause	Requirement – Test	Result – Remark	Verdict
10.3.2	The test room shall be fitted with four sprinklers at 3.05-m (10-ft) spacing in the center		N/A
10.3.3	Walls shall be constructed with 16-mm (5/8-in) gypsum wall board		N/A
10.3.4	The initiating BESS unit shall be positioned at manufacturer specified distances		N/A
10.3.5	Temperature measurements at the ceiling locations directly above the initiating and target BESS unit shall be collected by an array of thermocouples		N/A
10.3.6	Instrumented wall surface temperature measurements shall be collected in a vertical array at 152-mm (6-in) intervals		N/A
10.3.7	Thermocouples for wall surface temperature measurements shall be secured to gypsum surfaces by the use of staples		N/A
10.3.8	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall:		N/A
	a) Both are collinear with the vertical thermocouple array;		N/A
	b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and		N/A
	c) One is positioned at the elevation estimated to receive the greatest heat flux during potential propagation of thermal runaway within the initiating BESS unit.		N/A
10.3.9	Heat flux shall be measured with at least two sensing water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit:		N/A
	a) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating BESS; and		N/A
	b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.		N/A
10.3.10	The heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge		N/A
10.3.11	No. 24-gauge or smaller Type-K exposed junction thermocouples shall be installed		N/A
10.3.12	An internal fire condition in accordance with the module level test shall be created		N/A
	a) The position of the module shall be selected to present the greatest thermal exposure		N/A
	b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module shall be the same		N/A
10.3.13	The composition of BESS unit vent gases shall be measured		N/A
10.3.14	The test shall be terminated if:		N/A

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Clause	Requirement – Test	Result – Remark	Verdict
	a) Temperatures measured inside each module of the initiating BESS return to below the cell vent temperature;		N/A
	b) The fire propagates to adjacent units or to adjacent walls; or		N/A
	c) A condition hazardous to test staff or the test facility requires mitigation.		N/A
10.3.15	The initiating unit shall be under observation for 24 h after conclusion of the installation test		N/A
10.4	Installation level test report – Test method 1 – Effectiveness of sprinklers		N/A
10.4.1	The report on installation level testing shall include the following:		N/A

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Clause	Requirement – Test	Result – Remark	Verdict
	a) Unit manufacturer name and model number (and whether compliant with UL 9540); b) Number of modules in the initiating BESS unit; c) The construction of the initiating BESS unit per 5.3; d) Module voltage(s) of initiating BESS corresponding to the tested SOC; e) The thermal runaway initiation method used; f) Diagram and dimensions of the test setup including location of the initiating and target BESS units, and the locations of walls and ceilings; g) Location of initiating module within the BESS unit; h) Separation distances from the initiating BESS unit to (e.g. distances A and C in Figure 10.1); i) Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and E in Figure 10.1); j) Distances of the flame indicator (if used) with respect to the BESS (e. g. distances A and B in Figure 10.2); k) Maximum temperature at the ceiling; l) Distance of fire spread within the flame indicator; m) The maximum wall surface and target BESS unit temperatures achieved during the test and the location of the measuring thermocouple; n) The maximum incident heat flux on target wall surfaces and target BESS units; o) Voltages of initiating BESS; p) Total number of sprinklers that operated and length of time the sprinklers operated during the test; q) Gas generation and composition data, if measured; r) Observation of flaming outside of the test room s) Observation of flying debris or explosive discharge of gases; t) Observation of re-ignition(s) from thermal runaway events; u) Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; and 3) Adjacent walls; v) Photos and video of the test; w) Fire protection features/detection/suppression systems within unit; and x) Sprinkler K-factor, RTI, manufacturer and model, number of sprinklers and layout		N/A
10.5	Performance – Test method 1 – Effectiveness of sprinklers		N/A

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Clause	Requirement – Test	Result – Remark	Verdict

10.5.1	For BESS units intended for installation in locations with combustible construction, surface temperature measurements along instrumented wall surfaces shall not exceed a temperature rise of 97°C		N/A
10.5.2	The surface temperature of modules within the BESS units adjacent to the initiating BESS unit shall not exceed the temperature at which thermally initiated cell venting occurs		N/A
10.5.3	The fire spread on the cables in the flame indicator shall not extend horizontally beyond the initiating BESS enclosure dimensions		N/A
10.5.4	There shall be no flaming outside the test room.		N/A
10.5.5	There is no observation of detonation.		N/A
10.5.6	Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m2.		N/A
10.5.7	There shall be no observation of re-ignition within the initiating unit after the installation test		N/A
10.5.8	An installation level test that does not meet the applicable performance criteria noted above is considered noncompliant and would need to be revised and retested		N/A
10.6	Test method 2 – Effectiveness of fire protection plan		N/A
10.6.1	The test method 2 test set-up and test procedures are identical to that in 10.3, except instead of the sprinkler system set up of 10.3.2, the room shall be fitted with the specified fire protection		N/A
10.7	Installation level test report – Test method 2 – Effectiveness of fire protection plan		N/A
10.7.1	The report on installation level testing shall include the following:		N/A
	a) The report information in 10.4.1 items (a) – (u), and (v) if applicable; b) Fire protection features/detection/suppression systems within installation; and c) Length of time of operation of the clean agent, or other suppression system in addition to any sprinklers used.		N/A
10.8	Performance – Test method 2 – Effectiveness of fire protection plan		N/A
10.8.1	See 10.5 for performance criteria		N/A

ANNEX A	**Test Concepts And Application Of Test Results To Installations**	INFORMATIVE	
ANNEX B	**Safety Recommendations for Testing**	INFORMATIVE	

Figure 1. Site layout

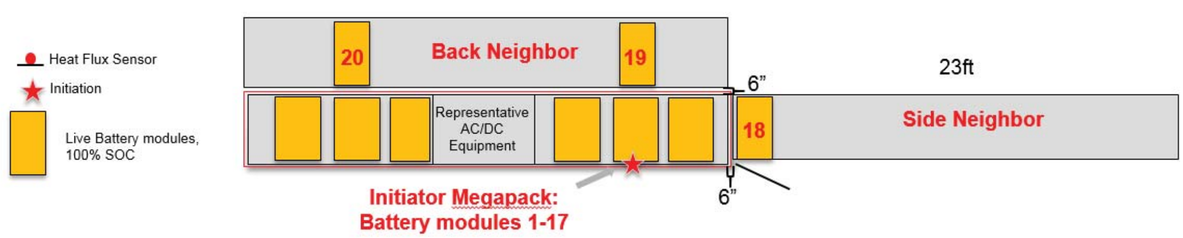


Figure 2. Test enclosure layout

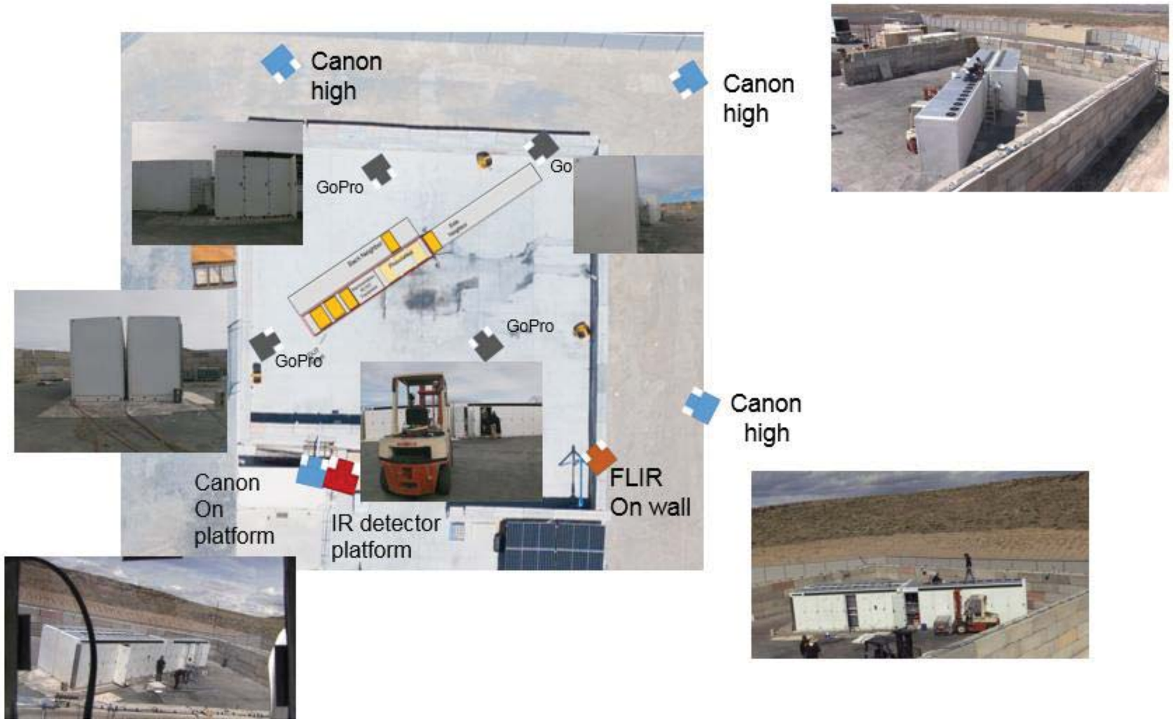
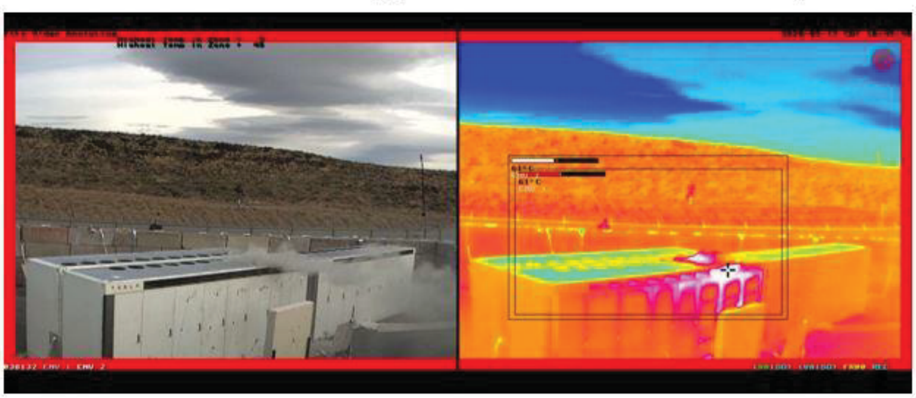


Figure 3. Camera and IR detector layout and view

Figure 4. White smoke indication

First alarm - 60 C trigger 38 seconds after first runaway



Second alarm - 60 C trigger 7 minutes 47 seconds after first alarm

Figure 5. IR detector alarm

Figure 6. Peak reaction rate site photo

Figure 7. End of test site photo

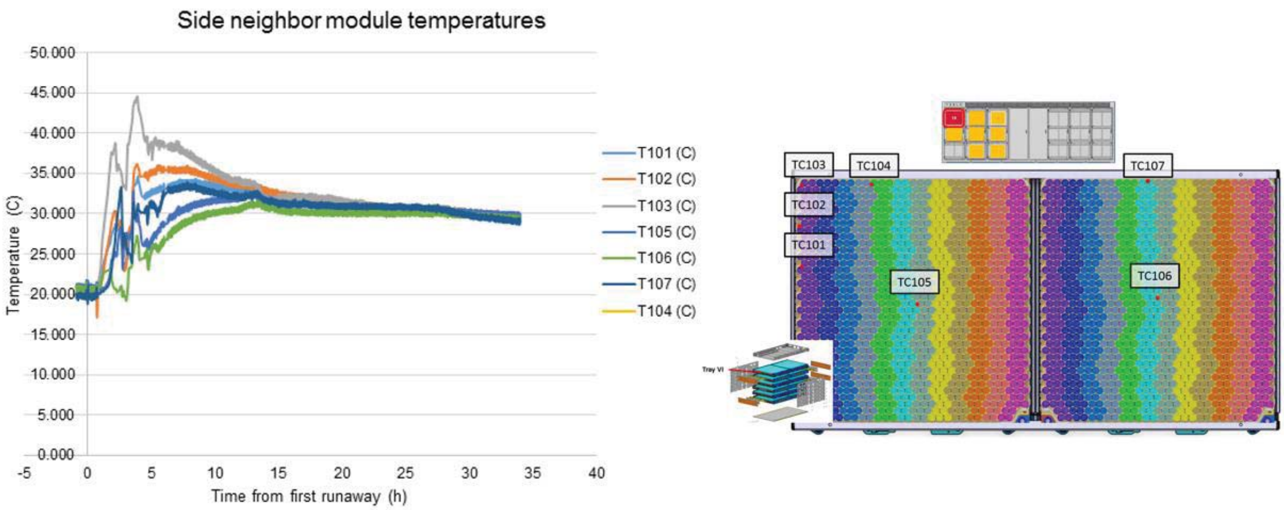


Figure 8. Side neighbor temperature result

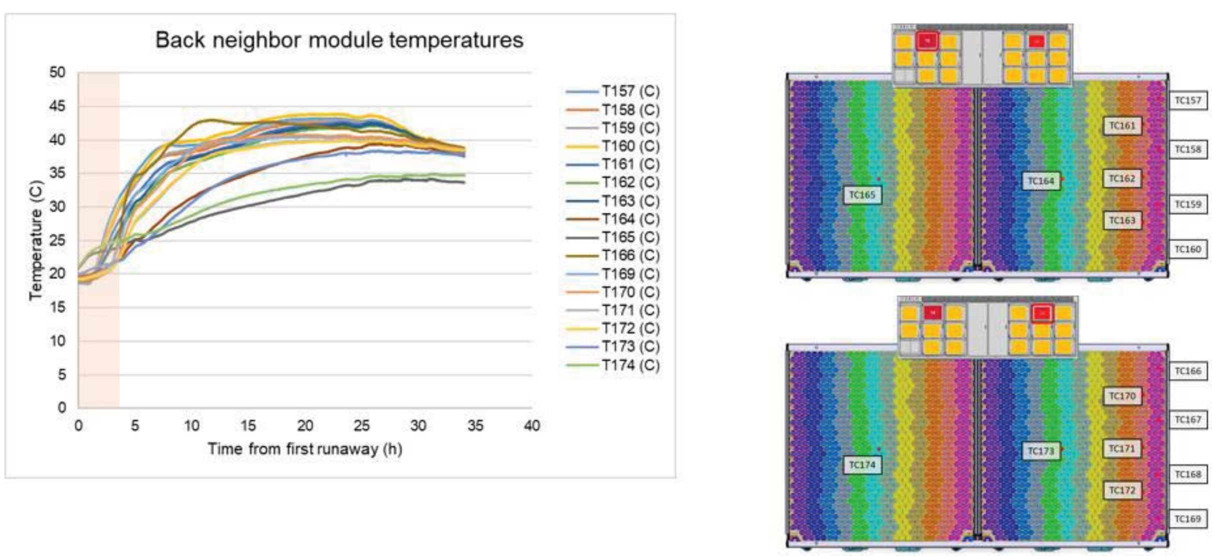


Figure 9. Back neighbor temperature result

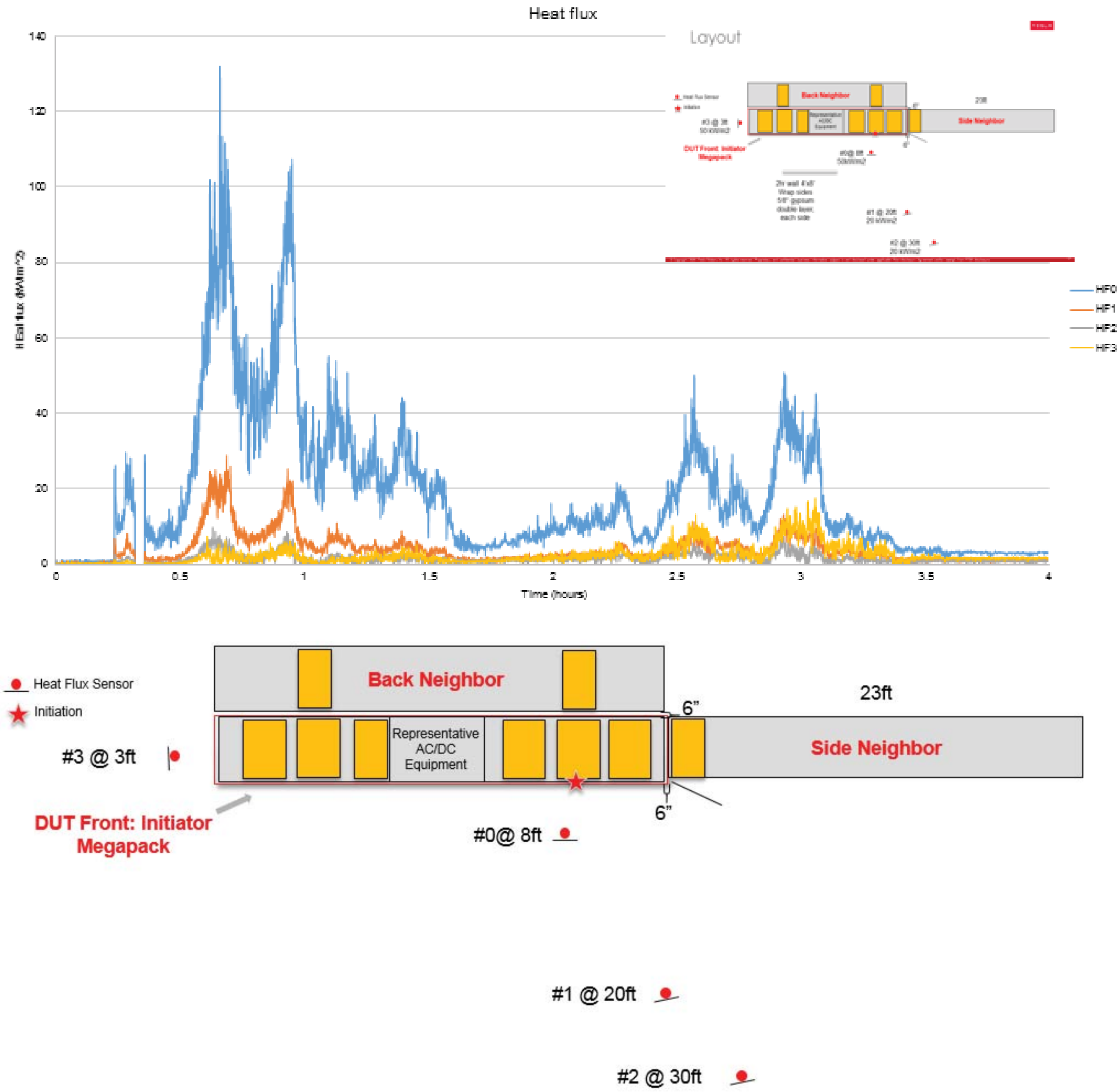


Figure 10. Heat flux results

Table 1. Test results per Clause 9.7

#	Items	Description
a)	Unit manufacturer name and model number (and whether UL 9540 compliant);	Tesla Megapack - 1462965
b)	Number of modules in the initiating BESS unit;	12 modules in a Battery assembly. Maximum 17 Battery assemblies in Megapack. 12 X 17 = 204
c)	The critical construction of the initiating BESS unit per 5.3;	UL 9540 compliant. Refer to TUV certificate CU 72200868
d)	Fire protection features/detection/suppression systems within unit;	Optional signal
e)	Module voltage(s) corresponding to the tested SOC;	100% SOC measured 4.1 V per brick (parallel connection of cells). 9 bricks in series in a module. 9 X 4.1V = 36.9V
f)	The thermal runaway initiation method used;	Heating of 27 cells simultaneously.
g)	Location of the initiating module within the BESS unit;	Initiator Megapack Battery assembly 72
h)	Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits;	6 inches from ISO knuckle of Initiating unit to Target unit. 4 inches from surface of initiating unit to target unit surface; wall – N/A
i)	Observation of any flaming outside the initiating BESS enclosure;	Yes. 10-12 ft upwards and 8-10 ft in front of the unit.
j)	Chemical and convective heat release rate versus time data;	N/A
k)	Separation distances from the initiating BESS unit to target walls (e.g. distances A and C in Figure 9.1);	N/A
l)	Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1);	6 inches from ISO knuckle of Initiating unit to Target unit. 4 inches from surface of initiating unit to target unit surface
m)	The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	Back neighbor Module: 43.9 C at location 19 Side neighbor module:44.5 C at location 18 Wall surface: N/A
n)	The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple;	N/A
o)	The maximum incident heat flux on target wall surfaces and target BESS units;	17.5 kW/m^2 at 3 ft to left
p)	The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;	N/A
q)	Gas generation and composition data;	N/A
r)	Peak smoke release rate and total smoke release data;	N/A
s)	Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;	N/A
t)	Observation of flying debris or explosive discharge of gases;	None observed

u)	Observation of re-ignition(s) from thermal runaway events;	None observed
v)	Observation(s) of sparks, electrical arcs, or other electrical events;	None observed
w)	Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; and 3) Adjacent walls	1. Initiator internally fully consumed. All damage contained within the enclosure. 2. Back neighbor had some signs of fans and paint degradation. Side neighbor had some aesthetic degradation on the top left corner. 3. N/A
x)	Photos and video of the test	Attached

- End of Report -

Exhibit B

UL 1973 Listing

Certificate

TÜVRheinland®

Certificate no. CU 72202325 01

License Holder:
Tesla, Inc.
3500 Deer Creek Road
Palo Alto CA 94304
USA

Manufacturing Plant:
Tesla, Inc.
Electric Avenue
Sparks NV 89434
USA

Test report no.: USA-LL 32070986 004

Client Reference: Jonathan McCormick

Tested to: ANSI/CAN/UL 1973:2018
UL 1998:2013 R9.18

Certified Product: Battery Module

License Fee - Units

Model Designation: 1465144-X-Y
(X = 00-99; Y = A-Z)

Rated Voltage: DC 470V 7
Battery Power: 125kW
Protection Class: I
Rated Ambient Temperature: -30°C to 50°C

Special Remarks: To be installed according to the licensee's installation instructions. Replaces Certificate CU72201344.

7

Appendix: 1, 1-6

Licensed Test mark:

TÜVRheinland C US

Date of Issue (day/mo/yr)
25/06/2020

TUV Rheinland of North America, Inc., 12 Commerce Road, Newtown, CT 06470, Tel (203) 426-0888 Fax (203) 426-4009

Exhibit C

UL9540 Listing

Certificate

TÜVRheinland

Certificate no. CU 72202327 01

License Holder:
Tesla, Inc.
3500 Deer Creek Road
Palo Alto CA 94304
USA

Manufacturing Plant:
Tesla, Inc.
Electric Avenue
Sparks NV 89434
USA

Test report no.: USA-LL 32070994 004

Client Reference: Jonathan McCormick

Tested to: ANSI/CAN/UL 9540:2016
UL 1741:2010 R2.18
UL 1998:2013 R9.18

Certified Product: Battery Energy Storage System

License Fee - Units

Model Designation: 1462965-X-Y
(XX = 00-99; Y = A-Z) — 7

Rated Voltage: AC 480V, 50/60Hz
Rated Power: 1264.5kW (1573kVA)
Battery Capacity: 4hr: 2964.8kWh, 2hr: 2529kWh
Output Ratings: AC 480V, 50/60Hz; 1264.5kW, 1573kVA
Protection Class: I

Special Remarks: To be installed according to the licensee's installation instructions. Software evaluated to UL1998:2013 R9.18. Replaces Certificate CU72201818.

7

Appendix: 1, 1-24

Licensed Test mark:

TÜVRheinland
C US

Date of Issue (day/mo/yr)
26/06/2020

TUV Rheinland of North America, Inc., 12 Commerce Road, Newtown, CT 06470, Tel (203) 426-0888 Fax (203) 426-4009

Certificate

TÜVRheinland®

Certificate no. CU 72202327 02

License Holder:
Tesla, Inc.
3500 Deer Creek Road
Palo Alto CA 94304
USA

Manufacturing Plant:
Tesla, Inc.
Electric Avenue
Sparks NV 89434
USA

Test report no.: USA-LL 32070994 005

Client Reference: Jonathan McCormick

Tested to: ANSI/CAN/UL 9540:2016
UL 1741:2010 R2.18
UL 1998:2013 R9.18

Certified Product: Battery Energy Storage System

License Fee - Units

Addition:
Rated Voltage: AC 505V, 50/60Hz
Rated Power: 1264.5kW (1654.9kVA)
Output Ratings: AC 505V, 1264.5kW, 1654.9kVA

Appendix: 1, 1-24

Licensed Test mark:

TÜVRheinland
C US

Date of Issue (day/mo/yr)
28/07/2020

Exhibit D

Site Design Manual

Megapack Site Design Manual - Rev. 2.1

CONFIDENTIAL INFORMATION - SHARED UNDER NDA ONLY

PRODUCT SPECIFICATIONS

All specifications and descriptions contained in this document are verified to be accurate at the time of printing. However, because continuous improvement is a goal at Tesla, we reserve the right to make product or documentation modifications at any time, with or without notice.

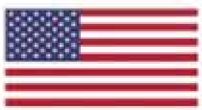
The images provided in this document are for demonstration purposes only. Depending on product version and market region, details may appear slightly different.

This document does not create contractual obligations for Tesla or its affiliates, except to the extent expressly agreed in a contract.

ERRORS OR OMISSIONS

To communicate any inaccuracies or omissions in this manual, please send an email to: *energy-pubs@tesla.com*.

MADE IN THE USA



Reference Documents

Visit the Tesla Partner Portal at *https://partners.tesla.com/* to find reference material referred to within this guide, including:

- Megapack Drawings - *https://partners.tesla.com/home/en-US/content/download/Megapack_Drawings.zip*
- Megapack Installation Manual - *https://partners.tesla.com/home/en-US/content/download/Megapack_Installation_Manual.pdf*
- Megapack Transportation and Storage Guidelines - *https://partners.tesla.com/home/en-US/content/download/Megapack_Transportation_and_Storage_Guidelines.pdf*
- Megapack Interconnection Datasheet - *https://partners.tesla.com/home/en-US/content/download/Megapack_Interconnection_Data.pdf*
- Megapack Option Codes Quick Reference Guide - *https://partners.tesla.com/home/en-US/content/download/Megapack_Option_Codes_Quick_Reference_Guide.pdf*
- Tesla Energy Controls and Communications Manual - *https://partners.tesla.com/home/en-US/content/download/Tesla_Energy_Controls_and_Communications_Manual.pdf*
- Microgrid Controller Owner's Manual - *https://partners.tesla.com/home/en-us/content/download/microgridcontroller_manual_owners.pdf*
- Megapack Compliance Packet - *https://partners.tesla.com/home/en-US/content/download/Megapack_Compliance_Packet.zip*
- Lithium-Ion Battery Emergency Response Guide - *https://www.tesla.com/firstresponders*
- Megapack Construction Checklist - *https://partners.tesla.com/home/en-US/content/download/megapack-construction-checklist.pdf*
- Megapack Design Review Checklist - *https://partners.tesla.com/home/en-US/content/download/Megapack_Design_Review_Checklist.pdf*

Important Safety Information

Save these instructions.

This manual contains important information that must be read, understood, and followed while designing and preparing the Megapack installation site.

SYMBOLS

This manual uses the following symbols to highlight important information:

DANGER: Indicates a hazardous situation which, if not avoided, could result in severe injury or death.

WARNING: Indicates a hazardous situation which, if not avoided, could result in injury.

CAUTION: Indicates a hazardous situation which, if not avoided, could result in minor injury or damage to the equipment.

NOTE: Indicates an important step or tip that leads to best results but is not safety or damage related.

PRODUCT WARNINGS

WARNING: In order to operate, Megapack requires a solidly grounded circuit such that the line-to-Ground voltage does not exceed 300 V.

WARNING: All installations must conform to the laws, regulations, codes, and standards applicable in the jurisdiction of installation, such as National Electric Code (NEC) ANSI/NFPA 70 or the Canadian Electrical Code CSA C22.1.

WARNING: Do not install adjacent to or expose to any external heat source. The battery used in this device may present a risk of fire or chemical burn if mistreated. Do not operate above 50°C (122°F).

CAUTION: Do not paint any part of Megapack other than external white metal surfaces, using only Tesla-provided touch-up paint. Internal or external components such as exterior cabinets or grilles should not be painted.

CAUTION: Do not use cleaning solvents to clean the Megapack system or expose the system to flammable or harsh chemicals or vapors.

CAUTION: Do not use fluids, parts, or accessories other than those specified in Tesla manuals, including use of non-genuine Tesla parts or accessories, or parts or accessories not purchased directly from Tesla or a Tesla-approved party.

Refer to the *Lithium-Ion Battery Emergency Response Guide* for detailed hazard information specific to the lithium-ion battery.

Voltage Classification

This section defines voltage classification as used in this document.

The table below represents Tesla's standard voltage ranges. The defined ranges, comparable to global codes and standards, help categorize potential electrical hazards where applicable.

NOTE: Any voltage referred to in this document is low voltage unless otherwise specified.

Table 1. Voltage Classifications

Classification	Acronym	Alternating Current (AC) Range	Direct Current (DC) Range
Ultra-Low Voltage	ULV	0-48 V	0-48 V

Classification	Acronym	Alternating Current (AC) Range	Direct Current (DC) Range
Low Voltage	LV	50-1,000 V	50-2,000 V
Medium Voltage	MV	1,000-35,000 V (1kV-35kV)	2,000-35,000 V (2kV-35kV)
Sub-Transmission Medium Voltage	STMV	35,000-69,000 V (35kV-69kV)	35,000-69,000 V (35kV-69kV)
High Voltage	HV	Above 69,000 V (>69kV)	Above 69,000 V (>69kV)

1 Megapack Overview

1.1 Introduction

Tesla Megapack is a modular, fully integrated, AC-coupled industrial battery energy storage system (BESS). This document consists of information required during pre-installation of the Megapack system while preparing the installation site and is intended as a prerequisite to the *Megapack Installation Manual*.

You may use the *Megapack Design Review Checklist* in tandem with this guide to assist you in verifying your site design.

NOTE: Any deviation from what is specified in this manual must be submitted to Tesla in writing in advance for approval.

1.2 Megapack Component Overview

A Megapack system consists of two types of enclosures:

- **Megapack:** Rechargeable lithium-ion battery modules housed in an enclosure with integrated bi-directional power conversion system
- **Standard Site Controller Enclosure:** Vertically mounted enclosure that contains Tesla Site Controller for sites up to 18 MW (see *Tesla Site Controller* on page 11)

This document applies to systems with the following part numbers:

- Megapack
  - 1462965-XX-Y[1]
- Standard Site Controller Enclosure
  - 1471208-XX-Y[1]

[1]Where X is a number between 0 and 9, and Y is a letter.

Megapack is bi-directional, supporting charge and discharge. It converts power for storage in rechargeable lithium-ion battery packs (battery modules) and is designed in a modular fashion in order to support a range of AC power.

NOTE: Individual Megapack specifications are detailed on the product label (see *Megapack Labels* on page 12).

Each Megapack contains up to 17 battery modules, up to 22 Powerstages, a thermal bay and associated thermal roof components, an AC circuit breaker, a set of customer interface terminals and internal controls circuit boards (see *Example Megapack* on page 7). An external auxiliary power supply is not required for Megapack; Megapack pulls auxiliary power for the control power and thermal management from the internal DC bus.

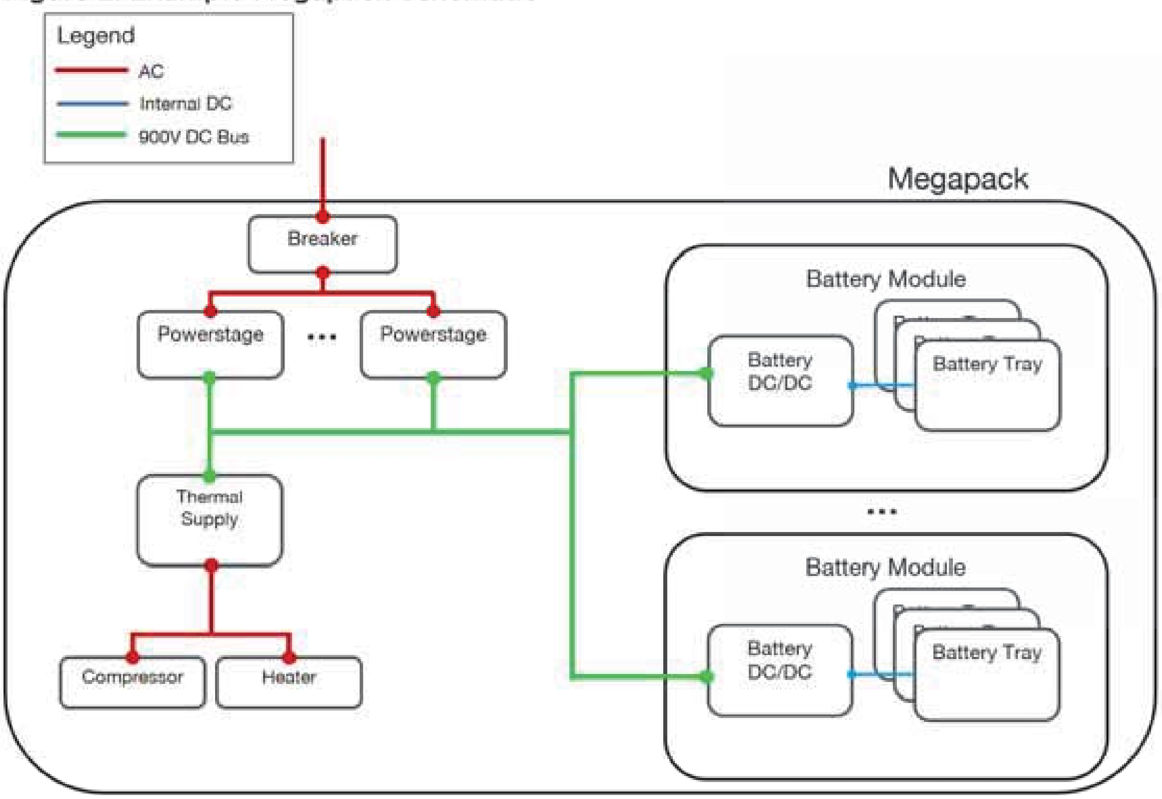
Depending on the system configuration (2-hour or 4-hour), a Megapack can be configured with different combinations of battery modules and Powerstages to optimize for either energy or power. The Megapack nominal power rating depends on the number of installed Powerstages and the site's grid voltage.

An example Megapack consists of the following components:

Figure 1. Example Megapack

1. Thermal bay (see *Thermal Components* on page 8)
2. Battery module bays (see *Battery Modules* on page 8)
3. Customer Interface Bay (see *Customer Interface Bay* on page 10)
4. Inverter bay (see *Powerstages* on page 8
5. Battery/inverter "flex" bay (contains battery modules or Powerstages depending on configuration)
6. IP66 enclosure (see *The Megapack IP66 Enclosure* on page 10)
7. Thermal roof (see *Thermal Components* on page 8)

Figure 2. Example Megapack Schematic



1.3 Battery Modules

Battery modules are factory-installed into Megapack bays and contain cylindrical lithium-ion battery cells, the smallest non-divisible energy storage components of the Megapack. A battery module in turn is the smallest field-replaceable battery unit. One Megapack contains up to 15 of these modules in the 2-hour system and up to 17 in the 4-hour system. Battery modules are connected in parallel, each with a DC and communications output connection. The modules do not require any field assembly or adjustments and may only be replaced by Tesla Service or approved third-party service provider.

Figure 3. Battery Module

1.4 Powerstages

Powerstages convert power between DC and AC and interact with the grid. Each Megapack contains up to 22 rack-mounted Powerstages which occupy one or two inverter bays next to the Customer Interface Bay (depending on Megapack configuration) and can be scaled for the needs of the site. Powerstages are factory-installed in the Megapack before shipment.

NOTE: There may be more than 22 visible objects, but there are only up to 22 grid-connected Powerstages.

Figure 4. Powerstage

1.5 Thermal Components

The thermal bay houses Megapack's thermal system. It contains a closed-loop thermal management system that circulates coolant and refrigerant through the batteries and power components to maintain thermal control. The thermal bay is accessible for servicing from ground level.

The thermal roof, or top cabinet of the enclosure, provides ventilation airspace and contains fans and radiators that cool the ethylene glycol-water coolant mix. The thermal roof is accessible for servicing with the help of a ladder or mechanical lift.

WARNING: The thermal management sections are locked during operation. The thermal bay and thermal roof are only serviceable when the system is not operating. Do not open the thermal enclosures while the unit is operational to avoid hazard from moving parts.

Figure 5. Thermal Bay and Roof

1. Thermal bay
2. Thermal roof

1.6 Megapack Numbering Key

A numbering key can help identify locations of Megapack enclosure components to assist you when referring to them during installation or service. Below are the numbering keys for **bay** (vertical tower) and **shelf** (horizontal row) locations:

Figure 6. Bay Numbering Key

Figure 7. Shelf Numbering Key

For example, as depicted in *Example Megapack* on page 7 above:

- The thermal bay is located in bay 1, shelf 3
- The Customer Interface Bay is bay 4
- A battery module under consideration might be located in bay 2, 3, 6, 7, or 8; shelves 1-3.

1.7 Customer Interface Bay

The Customer Interface Bay is a single bay that includes all the external connections needed for initial installation (the AC bus bars and customer I/O area) and the AC breaker.

For complete information on electrical design in the Customer Interface Bay, see *Customer I/O Wiring Detail* on page 42.

1.8 The Megapack IP66 Enclosure

Megapack's enclosure is rated according to the IP Code (Ingress Protection Code) to IP66. This means it affords a high protection against particle and water ingress in order to protect the enclosure contents.

This high protection rating must be maintained at all times. In particular, special precautions must be observed while installing or servicing Megapack in order to prevent particles or water from entering the enclosure.

At a minimum, this means the following conditions must be observed:

- **Megapack must remain sealed:** While actively working on Megapack, ensure that all Megapack doors are closed and conduit openings are sealed **before you leave the site each day** in order to keep the Megapack interior dry and clean.
  - IP66 sealing details should be considered during electrical design. See suggested products in the *Megapack Installation Manual*.
- **Megapack must remain dry:** Do not perform any work on Megapack that requires opening its doors when there is a possibility of moisture (from precipitation or excess humidity) entering the enclosure.
- **Megapack must remain protected from dust and debris:** At all times when doors are open, ensure that dust or debris of any kind does not enter the enclosure. For example, do not operate a leaf blower near an open door and ensure that doors are closed when wind may blow debris.

WARNING: Failure to properly seal the conduit openings and enclosure may violate the integrity of the IP66 enclosure and allow moisture, particles, rodents or other objects to enter the enclosure and cause significant damage to equipment.

CAUTION: Some foaming agents such as plumbing foam can degrade insulation and PVC conduit pipes. Ensure all sealants are compatible with site materials.

1.9 Tesla Site Controller

Megapack communicates with the overall system through the Tesla Site Controller, which controls the entire energy storage site. The Tesla Site Controller hosts the control algorithm that dictates the charge and discharge functions of the Megapack units. It is also the single point of interaction with external parties.

The Tesla Site Controller communicates with Megapack over a private TCP network, aggregating real-time information and using the information to optimize the commands sent to each individual battery unit. Based on the signal received from the Tesla Site Controller, the battery system triggers the charge or discharge of batteries connected via the DC bus.

There are two variants of the Tesla Site Controller:

- **Standard Site Controller** - used in sites up to 18 MW. Delivered in an enclosure called the Standard Site Controller Enclosure.
- **Large Site Controller** - for all sites larger than 18 MW. Delivered as the controller only.

Figure 8. Standard Site Controller in the Standard Site Controller Enclosure

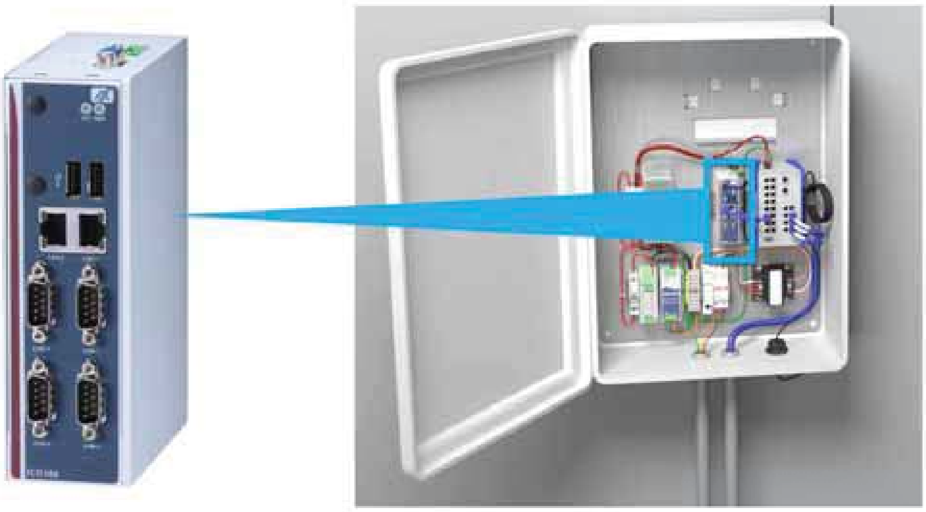


Figure 9. Large Site Controller

One Tesla Site Controller is typically required for each point of interconnection, however Tesla may choose to provide a second redundant Tesla Site Controller.

The Tesla Site Controller is the single point of interface for the Megapack system for customers to control and monitor the system. It provides an external communication interface over TCP (Modbus, DNP3, or REST) to the utility, network operator or customer SCADA systems. The Tesla Site Controller communicates with each Megapack over a private TCP network. Each Megapack is controlled by the inverter: based on the signal received from the Tesla Site Controller, the inverter triggers the charge or discharge of each battery module connected to the DC bus. All data values are updated at least once per second.

The Tesla Site Controller aggregates real-time information from all Megapacks and uses the information to optimize the commands sent to each Megapack.

For larger sites where Ethernet alone is not sufficient, standard fiber networking solutions can be used to connect every Megapack to the Tesla Site Controller.

Refer to *Tesla Site Controller Wiring* on page 49 for electrical design considerations.

NOTE: Refer to the *SCADA Design Manual* for additional, required information when designing an energy storage site larger than 18 MW.

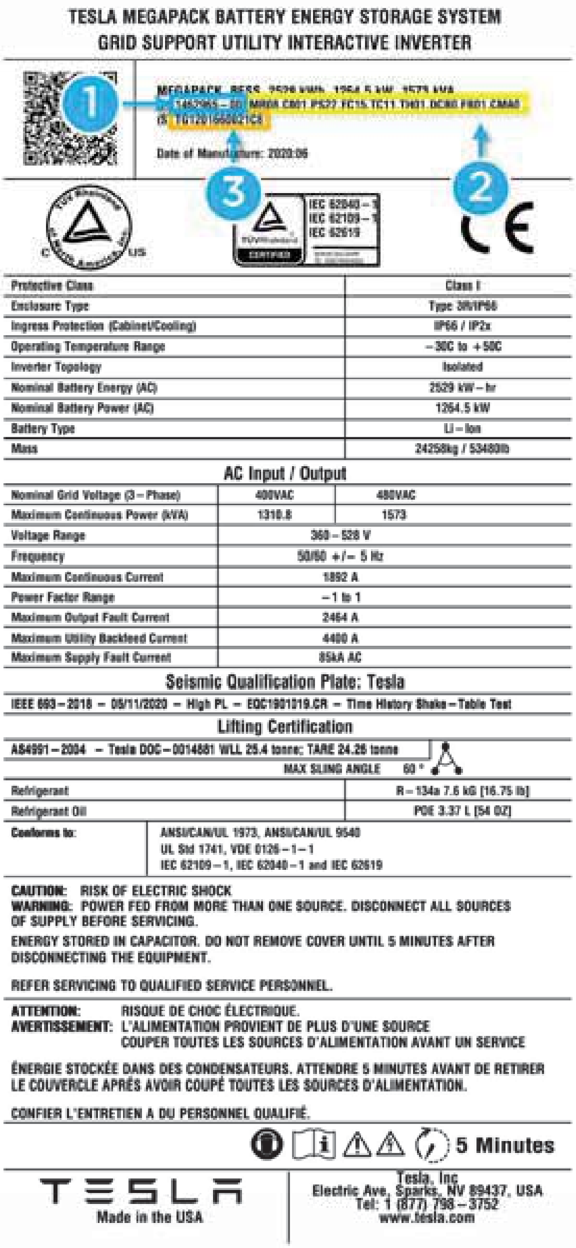
NOTE: Refer to the *Tesla Energy Controls and Communications Manual* for complete instructions on how to interface with the Tesla Site Controller.

1.10 Megapack Labels

The main Megapack label is a large sticker affixed to the inside of the Customer Interface Bay door. Megapack labels provide the reference for each specific Megapack including:

- AC input/output specifications including relevant power and energy ratings
- Part number followed by complete list of option codes
- Serial number
- Date of manufacture
- Weight (mass)
- Other detailed product specifics and compliance marks

Figure 10. Example Megapack Label


TESLA MEGAPACK BATTERY ENERGY STORAGE SYSTEM
GRID SUPPORT UTILITY INTERACTIVE INVERTER

Date of Manufacture: 2020:06

IEC 62040-1
IEC 62109-1
IEC 62619

Protective Class	Class I
Enclosure Type	Type 3R/IP66
Ingress Protection (Cabinet/Cooling)	IP66 / IP2x
Operating Temperature Range	-30C to +50C
Inverter Topology	Isolated
Nominal Battery Energy (AC)	2529 kW-hr
Nominal Battery Power (AC)	1264.5 kW
Battery Type	Li-Ion
Mass	24258kg / 53480lb

AC Input / Output

Nominal Grid Voltage (3-Phase)	400VAC	480VAC
Maximum Continuous Power (kVA)	1310.8	1573
Voltage Range	360-528 V	
Frequency	50/60 +/- 5 Hz	
Maximum Continuous Current	1892 A	
Power Factor Range	-1 to 1	
Maximum Output Fault Current	2464 A	
Maximum Utility Backfeed Current	4400 A	
Maximum Supply Fault Current	85kA AC	

Seismic Qualification Plate: Tesla

IEEE 693-2018 - 05/11/2020 - High PL - EQC1901319.CR - Time History Shake-Table Test

Lifting Certification

AS4991-2004 - Tesla DOC-0014881 WLL 25.4 tonne; TARE 24.26 tonne
MAX SLING ANGLE 60°

Refrigerant	R-134a 7.6 kG [16.75 lb]
Refrigerant Oil	POE 3.37 L [54 OZ]

Conforms to: ANSI/CAN/UL 1973, ANSI/CAN/UL 9540
UL Std 1741, VDE 0126-1-1
IEC 62109-1, IEC 62040-1 and IEC 62619

CAUTION: RISK OF ELECTRIC SHOCK
WARNING: POWER FED FROM MORE THAN ONE SOURCE. DISCONNECT ALL SOURCES OF SUPPLY BEFORE SERVICING.
ENERGY STORED IN CAPACITOR. DO NOT REMOVE COVER UNTIL 5 MINUTES AFTER DISCONNECTING THE EQUIPMENT.
REFER SERVICING TO QUALIFIED SERVICE PERSONNEL.

ATTENTION: RISQUE DE CHOC ÉLECTRIQUE.
AVERTISSEMENT: L'ALIMENTATION PROVIENT DE PLUS D'UNE SOURCE
COUPER TOUTES LES SOURCES D'ALIMENTATION AVANT UN SERVICE
ÉNERGIE STOCKÉE DANS DES CONDENSATEURS. ATTENDRE 5 MINUTES AVANT DE RETIRER LE COUVERCLE APRÈS AVOIR COUPÉ TOUTES LES SOURCES D'ALIMENTATION.
CONFIER L'ENTRETIEN A DU PERSONNEL QUALIFIÉ.

5 Minutes

TESLA
Made in the USA

Tesla, Inc
Electric Ave, Sparks, NV 89437, USA
Tel: 1 (877) 798-3752
www.tesla.com

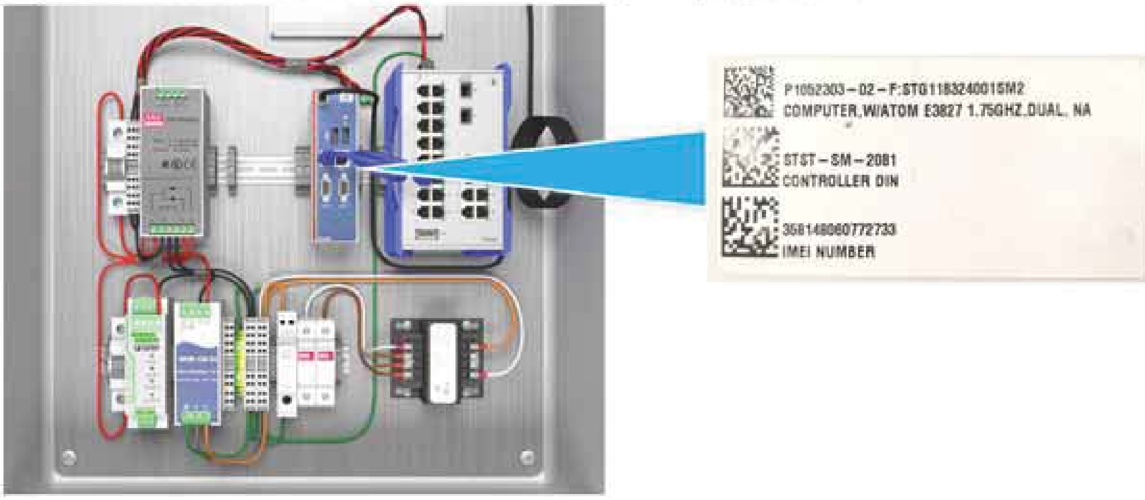
1. Part number
2. Option codes
3. Serial number

NOTE: The label pictured here is an example label. Refer to the actual Megapack label for applicable ratings and specifications per option codes.

For more information about option codes, refer to the *Megapack Option Codes Quick Reference Guide*.

Tesla Site Controller serial number and VIN are located on a label on the side of the Tesla Site Controller computer:

Figure 11. Tesla Site Controller Serial Number (Example) Location



The VIN is typically labeled *CONTROLLER DIN* and takes the format *STST-SM-####*.

2 Site Architecture

2.1 Overview of Site Components

In addition to one or more Megapacks and the Tesla Site Controller, a Megapack site may require other support equipment. Typical components include:

- Meters (battery meter required, other meters optional)
- Transformer
- Switchgear
- Customer communication network connection

Each of these components is described later in this section.

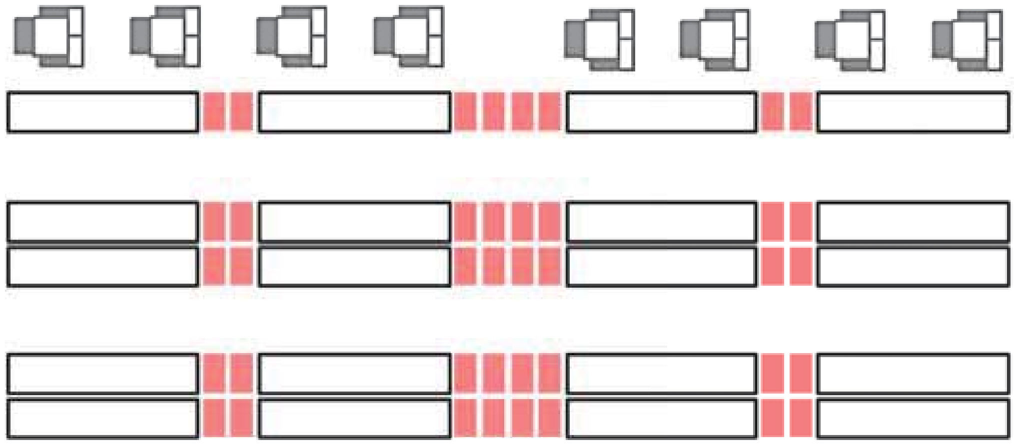
2.2 CMA Overview

A Capacity Maintenance Agreement (CMA) guarantees power and energy capacity over the life of the product. A capacity-maintained system adds units over time to maintain power and energy; therefore, the site and foundation designs and the electrical infrastructure must pre-allocate space for the additional units during initial construction. This prevents the need to re-permit the entire site later in its lifecycle. A CMA site is also designed with sufficient Megapack capacity to account for battery degradation, so that additional Megapacks are not required. A CMA must be contracted at the beginning of the project.

Guidance must be given to installation partners to ensure they understand the purpose of the space left for future CMA units, and they do not attempt to optimize layout during initial construction. Access must also be provided for a crane so that the supplementary CMA units can be added or removed as needed.

Upon request, Tesla can provide specifications for CMA lengths of 10, 15, or 20 years. If a site intends to use a CMA, contact Tesla for additional site design assistance.

Figure 12. Example CMA Layout



2.3 Product Configurations

Megapack may be configured to meet specific site and project requirements. A fully populated Megapack has the following nominal ratings at 480 V AC:

Table 2. Nominal Fully Populated Ratings

System Duration	AC Power (KWp)	AC Power (kVA)	AC Minimum Initial Energy (kWh)
2-hour	1341.0	1358.5	2682.0
4-hour	770.1	786.5	3080.4

2.4 Energy Meter Design

The Tesla Site Controller uses various meter inputs for different control functions, so energy metering, in various capacities as described in *Energy Meter Functions* on page 16 below, is required in order for the system to operate.

Energy meters must be provided, installed, and configured by the contractor. Tesla will confirm communication with these energy meters but is not responsible for their accuracy.

The Tesla Site Controller supports only the following meter hardware, using TCP/IP communication:

- Accuenergy Acuvim IIR/IIE/IIW - with additional AXM-WEB2 Ethernet module for Modbus TCP
- Schneider PowerLogic ION8650
- Schneider PowerLogic ION7550
- Nexus 1262
- SEL 735

NOTE: Projects with export limitation, or that require fast response times (less than 2 seconds), must use approved Acuvim meters communicating over a Modbus TCP interface. This is required for both the site and battery meters to meet system requirements.

NOTE: Tesla requires a specific firmware version on Acuvim meters. If the meter is not purchased through Tesla, inform Acuvim at the time of purchase that the meter is intended for a Tesla project.

NOTE: The system requires Ethernet to connect meters to the Tesla Site Controller. RS-485 is not supported.

NOTE: Tesla is not responsible for the accuracy of the energy meters provided, installed and configured by the customer. Please consult with the energy meter manufacturer in the event of faulty communications from energy meters.

NOTE: See the *Megapack Installation Manual* for instructions on connecting energy meters.

2.4.1 Energy Meter Functions

Meters can be used in several capacities, not all of which are required.

Every site requires a battery meter that measures the AC energy output of the battery system. Some meters, such as a site meter (which measures the net load of the site with the battery system included), solar meter, generation meter, or others, are optional depending on application.

If a meter is indicated as optional in this guide, it means the meter may not be required in order for the battery to receive and execute charge or discharge commands. However, depending on the use case, these meters may be required in order to send the correct commands. Therefore, **consider the intended operation of the system before deciding which meters to include in the design.**

For example:

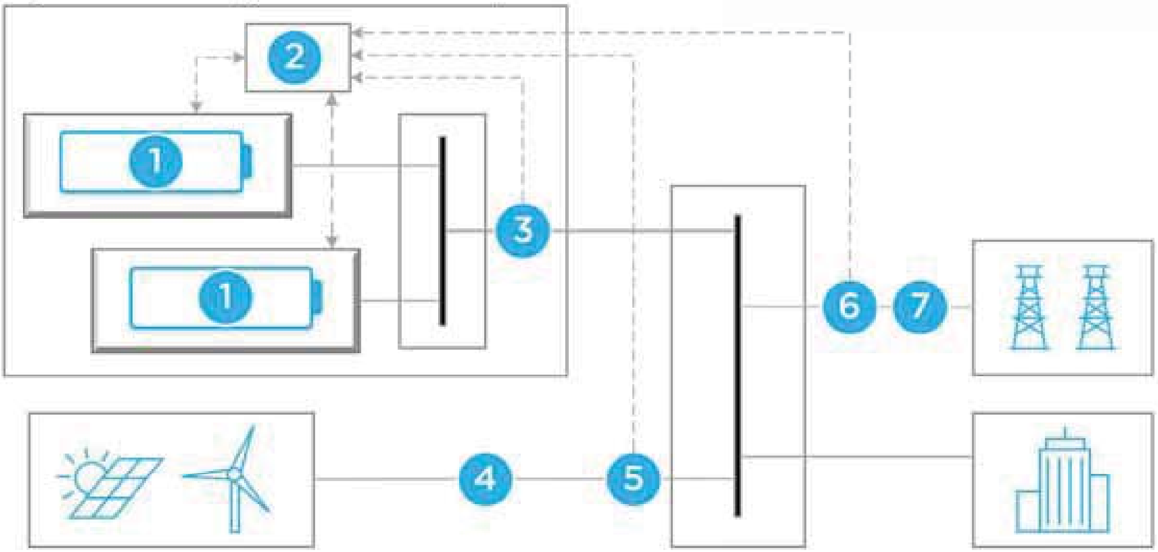
- Systems that intend to collect the Federal Investment Tax Credit for a combined PV and storage system may be required to charge only from the PV, in which case a revenue meter is required.
- Systems connected to a utility may be forbidden from exporting battery power to the grid, in which case a site meter, and possibly a solar meter (if there's onsite generation) may be required.
- Sites involving PV installations or wind or other power sources may require an additional generation meter.

Meters are required or optional as described below:

- Battery meter – required
- Site meter – required for certain applications
- Solar meter – required for certain applications
- Generator meter – optional
- Revenue / Utility meter - optional site-level requirement
- Bus meter – optional
- Load meter – calculated or optional

Your site may have additional meters as required per design. An example metering overview appears below:

Figure 13. Metering Overview - Example



(Dashed lines indicate communication with Tesla Site Controller)

1. Tesla battery system
2. Tesla Site Controller
3. Battery meter
4. Revenue meter
5. Solar (or wind) meter
6. Site meter
7. Utility meter

2.4.2 Battery Meter

All systems require a battery meter. The battery meter is bidirectional and is used to measure the AC power and energy charge and discharge of the system. The Tesla Site Controller uses the battery meter for closed-loop controls to ensure high accuracy on the power setpoint. The customer can either provide a single aggregated meter for the system or multiple battery meter inputs if the system is segregated. Check with Tesla for configuration options if more than one battery meter may be needed.

2.4.3 Site Meter

The site meter monitors the feed from the utility or the point of common coupling (PCC). It measures the site import (negative for any export). The site meter is required for the following control functions described in the *Tesla Energy Controls and Communications Manual*:

- *Site control*
- *Opticaster*
- *Voltage control* (where the voltage reference is the site voltage)
- *Non-export control* (where required by utilities)
- Powerhub UI/reporting (to show energy production in the Tesla Powerhub platform)

2.4.4 Solar Meter

A solar meter is required in order to configure the site to charge only from solar.

A solar meter is recommended for:

- Opticaster sites that have solar (to improve tariff optimization and forecasting)
- Microgrid sites (to aid in troubleshooting/diagnostics with waveform capture)
- Powerhub UI/reporting (to show energy production in the Tesla Powerhub platform)

2.4.5 Generator Meter

A generator meter is recommended for:

- Microgrid sites (to aid in troubleshooting/diagnostics with waveform capture)
- Powerhub UI/reporting (to show energy production in the Tesla Powerhub platform)

2.4.6 Bus Meter

The bus meter is optional and can be used to ensure that the battery system does not overload an intermediate bus or transformer on the system.

2.4.7 Load Meter

The load data provided by the Tesla Site Controller is a calculated value based on the site, battery, and generation values. The system cannot have both a load and site meter. If a system does not have a site meter (for example, in an off-grid microgrid), a load meter can be installed to provide a direct rather than a calculated value for load data.

2.4.8 UL 1741 PCS Requirements

UL 1741 PCS compliance may be required by the interconnecting utility or site host. If UL 1741 PCS compliance is required according to applicable site design, follow the guidance in this section.

The Tesla battery system is UL 1741 PCS-compliant with the following nominal voltages:

- 480 V
- 505 V
- 518 V

The Tesla battery system is certified to UL 1741 PCS for the energy storage system (ESS) operating mode of **import only**. Using this mode, the Tesla battery system will not export active power from the battery to the grid (Area EPS).

Compliance with UL 1741 PCS can be achieved for system sizes under 20 MW with an Accuenergy meter according to the requirements below.

2.4.8.1 Meters

The Tesla battery system's UL 1741 PCS compliance is only compatible with the following meters:

- Acuvim IIR-D-50-5A-P1
- Acuvim IIR-D-60-5A-P1
- Acuvim IIW-D-50-5A-P1
- Acuvim IIW-D-60-5A-P1

2.4.8.2 Current Transformers

The Tesla battery system is UL 1741 PCS-compliant when an Acuvim meter operating as a site meter is installed with UL 2808-compliant CTs with 5 A on the secondary and between 86 A and 24,000 A on the primary. The maximum battery system currently supported by our UL 1741 PCS certification is 24,000 A per phase. To improve safety, Tesla suggests using a CT with a burden resistor, such as the following Accuenergy AcuCT series models:

- AcuCT-3135R
- AcuCT-4161R
- AcuCT-5170R

CT Labeling Requirements

You must post the following label near the installation of the CTs:

> **WARNING: THIS SENSOR IS PART OF POWER CONTROL SYSTEM. DO NOT REMOVE. REPLACE ONLY WITH SAME TYPE AND RATING.**

2.4.8.3 Voltage Sensing Configurations

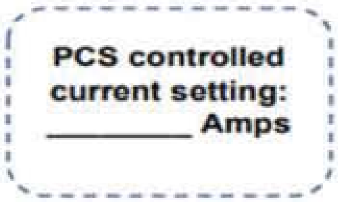
The Tesla battery system's UL 1741 PCS compliance requires that the voltage sensing configuration be one of the following:

- 3LN direct connection
- 3LN with 3PTs

2.4.8.4 Busbar Labeling Requirements

The PCS-controlled current setting for each busbar shall be indicated with a field-applied marking label on the conductor or in close proximity to the busbars. Refer to the label below, filling the blank with the following value: (Maximum Nameplate Current)x(Number of installed Tesla units per site):

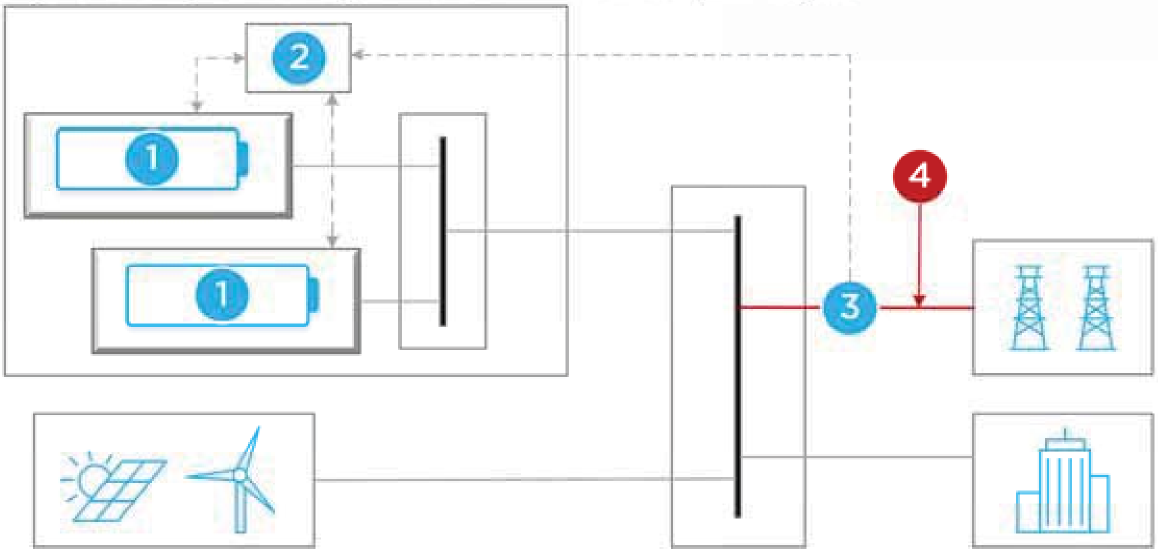
Figure 14. PCS Field Marking Label



2.4.8.5 Required UL 1741 PCS Compliance Information

> *This system is equipped with a power control system (PCS). All PCS controlled busbars or conductors shall be protected with suitably rated overcurrent devices appropriately sized for the busbar rating or conductor ampacity.*
>
> *Notice: The maximum operating currents in controlled busbars or conductors are limited by the settings of the power control system (PCS) and may be lower than the sum of the currents of the connected controlled power sources. The settings of the PCS controlled currents may be used for calculation of the design currents used in the relevant sections of NEC Article 690 and 705.*
>
> *Warning: Only qualified personnel shall be permitted to set or change the setting of the maximum operating current of the PCS. The maximum PCS operating current setting shall not exceed the busbar rating or conductor ampacity of any PCS controlled busbar or conductor.*
>
> *Maximum overcurrent protection rating per each PCS controlled conductor's location: 41,600 A.*

Figure 15. Single Line Diagram for UL 1741 PCS-Compliant System



(Dashed lines indicate communication with Tesla Site Controller)

1. Tesla battery system
2. Tesla Site Controller
3. Site meter
4. PCS controlled conductors

2.5 Transformer Design

In order to operate, Megapack requires a solidly grounded circuit (IEC 60364 TN-S) to ensure that the line-to-ground voltage does not exceed 300 V AC during steady-state conditions. The circuit is solidly grounded by connecting the Megapack terminals to the wye side of a transformer. The transformer may be:

- A step-up/step-down transformer
- A grounding transformer
- An isolation transformer

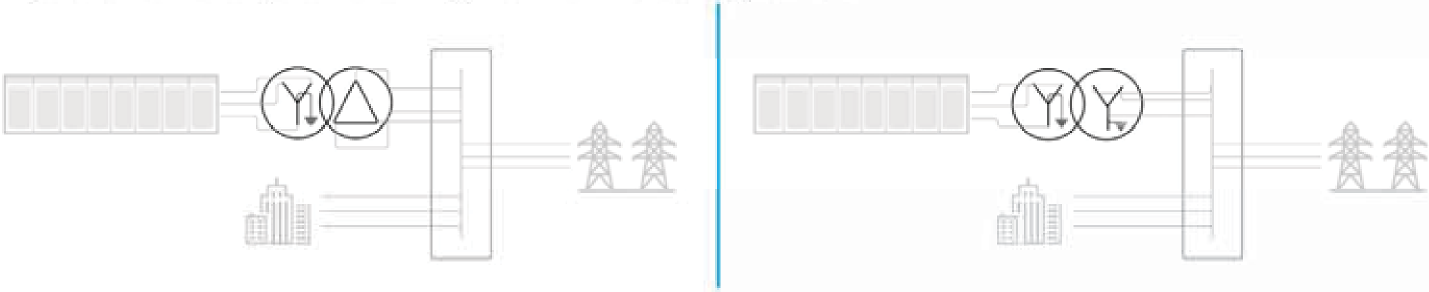
The customer's engineer should ensure that the requirements listed here are met alongside other technical considerations such as utility compliance, protection, maintenance, certification and load requirements. See the approved transformer configurations below. For alternative transformer configurations, contact Tesla for review.

NOTE: For detailed information about islanding and the Islanding Controller, refer to the *Microgrid Islanding Controller Specification* and the *Tesla Energy Controls and Communications Manual*.

2.5.1 Approved On-Grid (Grid-Following) Configurations

The side of the transformer connected to Megapack must be a wye-grounded connection. The other side of the transformer may be a delta or wye connection for on-grid (grid-following) applications.

Figure 16. On-Grid (Grid-Following) Transformer Configurations

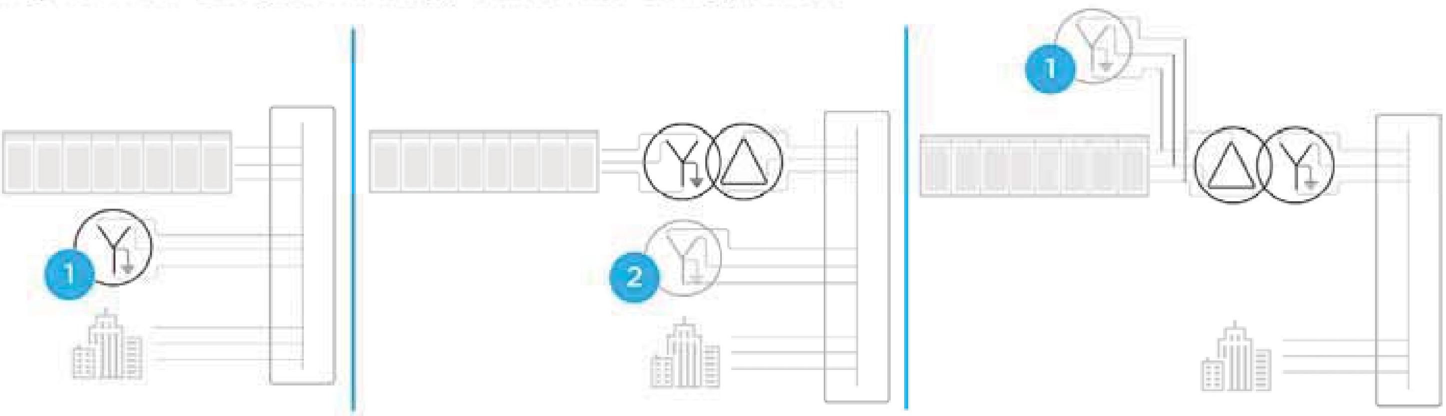


NOTE: For grid-following applications, the solidly grounded circuit may be provided by the utility transformer.

2.5.2 Approved Off-Grid (Grid-Forming) Configurations

The side of the transformer connected to Megapack must be a wye-grounded connection. The other side of the transformer must be a delta connection for off-grid (grid-forming) applications.

Figure 17. Off-Grid (Grid-Forming) Transformer Configurations

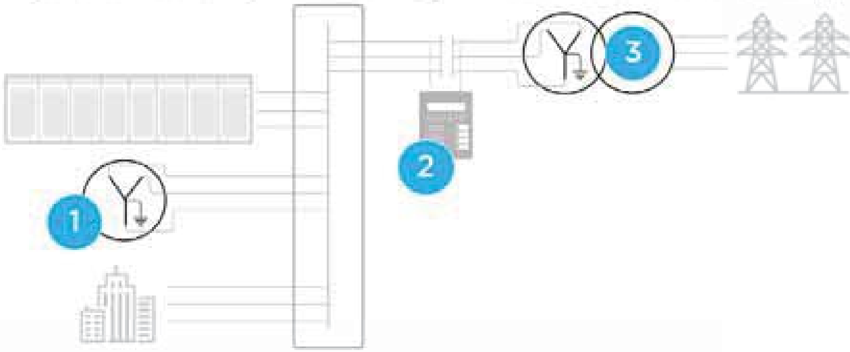


1. Grounding Transformer
2. Optional Grounding Transformer: An example of a potential system ground source and neutral source for line-to-neutral loads if present. This is not required for Megapack's proper operation in this example.

2.5.3 Approved Islanding Configurations

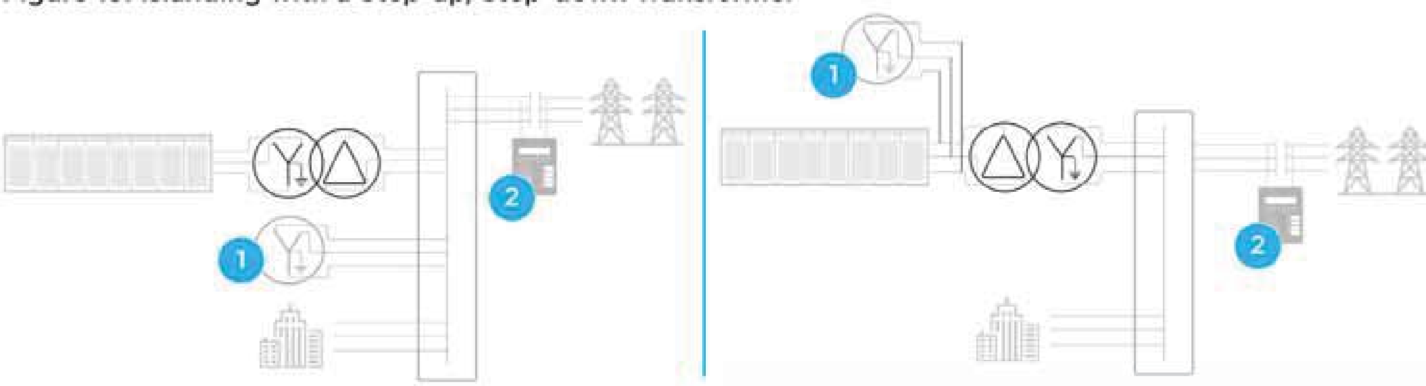
For islanding applications, ensure that a solidly grounded circuit exists during both on-grid and off-grid operation, as shown in the figures below. Depending on the project requirements, the grounding transformer may require disconnection when on-grid.

Figure 18. Islanding with a Utility Transformer and a Grounding Transformer



1. Grounding Transformer
2. Islanding Controller
3. Delta or wye

Figure 19. Islanding with a Step-up/Step-down Transformer



1. Optional Grounding Transformer: An example of a potential system ground source and neutral source for line-to-neutral loads if present. This is not required for Megapack's proper operation in this example.
2. Islanding Controller

2.5.4 Transformer Rating

The total short-circuit withstand rating of the Megapack is 85 kAIC. Ensure that your transformer is designed to provide less than this fault current at inverter terminals.

Customers can parallel multiple Megapacks on a single secondary (low voltage side) winding. One transformer grouped with several Megapacks is called a "transformer block."

Megapacks do not require galvanic isolation from each other; therefore, a standard single winding primary single winding secondary transformer is sufficient for connecting multiple Megapacks. Megapack also does not require any additional transformer features such as k-factor or shielding requirements.

For operations and maintenance needs the line side bus bars and cables within the Megapack must be able to be isolated and locked out from the secondary of the transformer. This can be generally performed with a no-load disconnecting means at the secondary of the transformer (due to the circuit breaker in the Megapack performing the load break functionality), or via a load break disconnect at the primary winding. Arc flash, personal safety and operational procedures should be considered when selecting the means of disconnection.

For more information or with specific questions, contact your Tesla representative.

2.6 Network and Internet Considerations

The Tesla Site Controller and meters communicate using Modbus TCP/IP, therefore, connectivity requirements must be part of the design.

Tesla requires communication between the Tesla Site Controller and all meters and Megapacks onsite. Every Megapack requires a wired Ethernet connection to the Tesla Site Controller. In multi-Megapack sites, this often requires the use of customer-supplied Ethernet switches and may require the use of fiber. Refer to the Controls and Communication Manual for further control details.

The Tesla Site Controller requires an internet connection. It has a built-in cellular connection that can provide a communication link between the Tesla Site Controller and Tesla via the internet. If the cellular network is not sufficient, a hardwired internet connection is mandatory. Refer to the Controls and Communication Manual for further control details. Additionally, if the customer wants a network connection for a control interface, the Tesla Site Controller is also the customer point of connection to the Megapack.

For more information or with specific questions, contact your Tesla representative.

The Tesla Site Controller requires network connectivity to control the Megapack. Ensure adequate connectivity by installing a permanent external antenna at sites where the Tesla Site Controller is installed inside metal enclosures such as switchgear cabinets, in concrete buildings such as parking structures, or in areas with poor coverage. See the *Megapack Installation Manual* for additional instruction on external antenna installation.

NOTE: Some projects may use external cell antennas different from the included external antenna. The standard Tesla Site Controller computer has an RP-SMA female connector (outer threading and pin) and requires an antenna with an RP-SMA male connector (inner threading and hole).

NOTE: Removing any component from the Tesla Site Controller enclosure other than the antenna (for example, to mount the backplane in a different enclosure or control room) must meet the environmental requirements on the Tesla datasheet and is not covered in the certified installation configuration. Discuss any modifications with Tesla prior to installation.

2.7 SCADA

For many applications, Megapack can be operated as a standalone system as detailed in the *Tesla Energy Controls and Communications Manual*. However, for custom solutions, Megapack can be integrated with a supervisory control and data acquisition (SCADA) system to expand its functionality.

The *SCADA Design Manual* further outlines what items to consider when designing a SCADA system, what additional features may be supported by Tesla, and how to integrate them with the Tesla Site Controller.

3 Civil Design

3.1 Site Safety

Ensure that you bear the listed *Important Safety Information* on page 4 and all safety considerations in mind while designing your site, including:

- Do not install batteries in areas where temperatures routinely approach or exceed 50°C (122°F).
- Do not install batteries near heating equipment or heat sources.
- Protect the installation area from flooding or more than 15 cm (6 in) of standing water for more than 30 minutes.
- Ensure that all installations comply with the appropriate local fire, electrical, and building code requirements.

3.2 Mechanical Specifications

Table 3. Megapack Dimensions and Mass (Weight)

Width	Depth	Height	Max. Shipping Mass (Light)	Max. Shipping Mass (Standard)
7168 mm (282 ¼ in)	1659 mm (65 ¼ in)	2522 mm (99 ¼ in)	20400 kg (44970 lb)	25400 kg (56000 lb)

NOTE:

- Mass (weight) as listed is maximum shipping mass. Mass changes depending on product configuration and can be configured lighter based on project-specific requirements.
- Dimensions as listed are as measured for the enclosure envelope exclusive of anchor feet.
- Do not use the dimensions above as anchoring specifications. For structural and anchoring details, see the *Megapack Layout* drawing in *Megapack Drawings* on the Partner Portal.

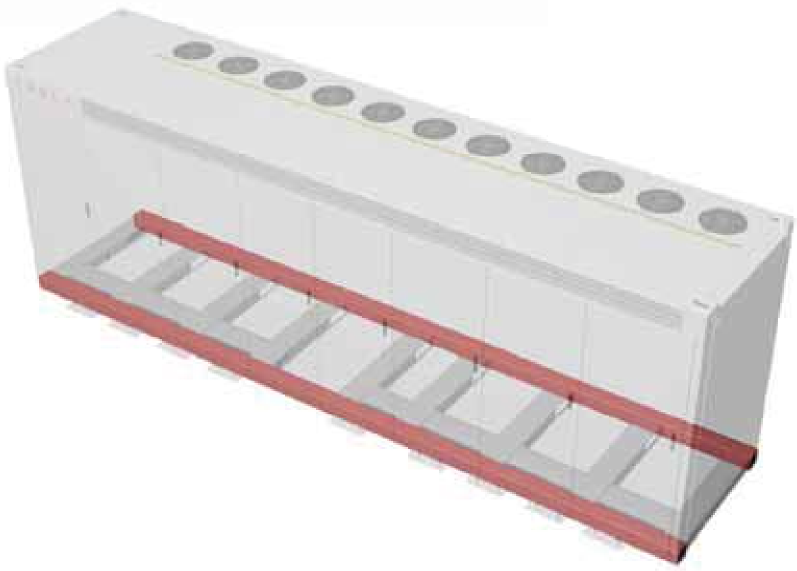
Table 4. Standard Site Controller Enclosure Dimensions and Mass

Width	Depth	Height	Max. Mass (Weight)
255 mm (10 in)	560 mm (22 in)	724 mm (29.2 in)	21.4 kg (47.2 lb)

3.3 Equipment Bearing Areas and Anchoring

Megapack requires support along the length of the long sides to a width of 200 mm (8 in.). The foundational sections that must be supported are shown below:

Figure 20. Megapack Ground Support



Megapacks must be anchored to their foundations using their anchor brackets. For single Megapack installations, anchors are required to be installed at the front and rear of the Megapack. For installations with two or more Megapacks installed back-to-back (at the distance specified in *Observing Clearances* on page 32), anchors are required at the front of each Megapack only, and Megapacks are secured together using coupling at the ISO corner fittings of each Megapack.

NOTE: For anchor locations per Megapack installation type and complete anchor installation instructions, refer to the *Megapack Installation Manual*.

Figure 21. Megapack Anchor Brackets

Table 5. Anchor Bracket Dimensions

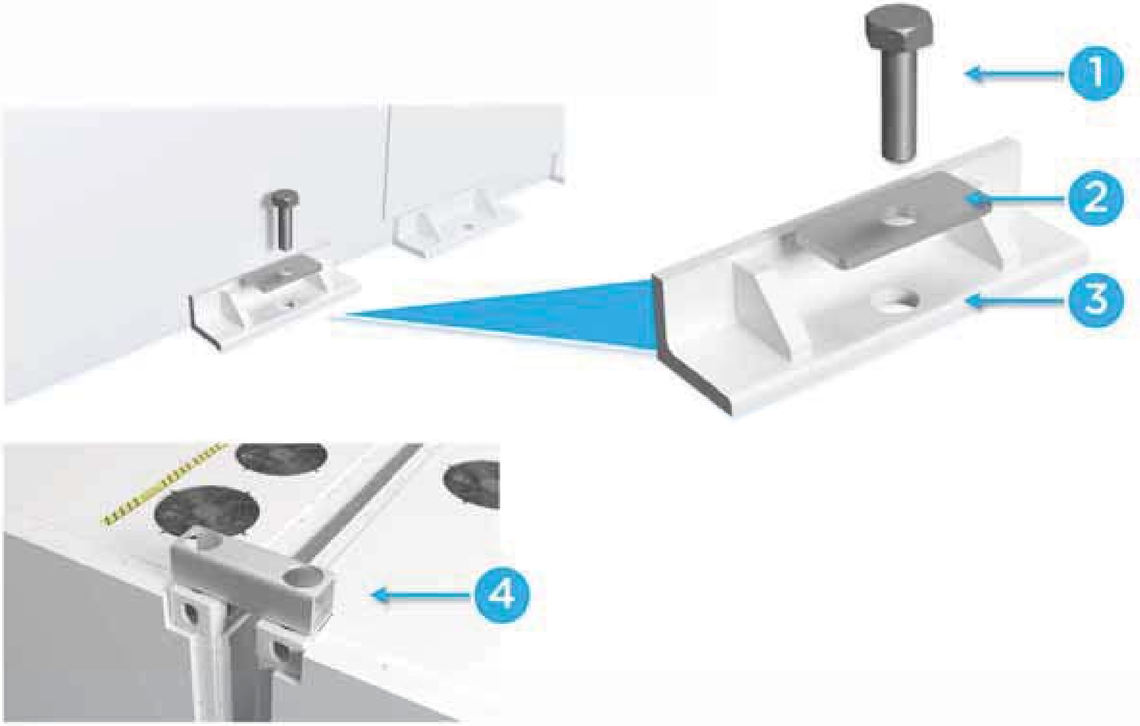
Description	Length	Depth
Anchor bracket	360 mm (14 in)	102 mm (4 in)

3.3.1 Anchor Requirements

Anchors must be provisioned by the customer as selected by the structural engineer of record per site- and foundation-specific requirements according to the guidelines in this section.

NOTE: For complete anchor installation instructions, refer to the *Megapack Installation Manual*.

Figure 22. Anchoring Equipment



1. Anchor - customer-provided; customer- and site-specific
2. Washer - delivered with Megapack
3. Bracket - welded on to Megapack
4. Coupling (required for back-to-back installations only)

When provisioning anchor hardware for Megapack, consider the following requirements:

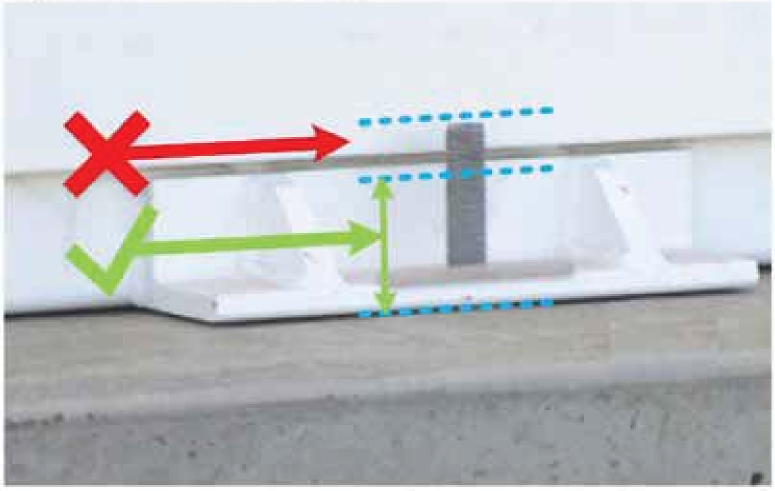
Table 6. Anchor Specifications

Specification	Requirement
Quantity - Single	10 (5 in front; 5 in rear)
Quantity - Back-to-back	9 (in front)
Material	Stainless steel
Max allowable anchor diameter	27 mm (1 in)
Anchor hole diameter	30 mm (1.125 in)
Anchor position tolerance	± 11 mm (7/16 in)

CAUTION: If using a concrete foundation, the structural engineer must provide the minimum allowable distance from the installed anchor to the edge of the foundation.

In addition, note that anchor hardware must not protrude greater than 76 mm (3 in) above the foundation surface:

Figure 23. Anchor Protrusion



⚠ **CAUTION:** Modification of anchor brackets is not permitted in any way.

Additional anchoring considerations:

- Stainless steel is required for anchor hardware in all installations
- Hilti KB-TZ 5/8" SS wedge anchors or 5/8" Dia HAS-R 304/316 SS and Hilti HIT-HY 200 epoxy anchor system are recommended
- The final anchor selection must be made by the structural engineer of record.
- Refer to the seismic and wind specification values in *Environmental Specifications* on page 29.

3.3.1.1 Additional Considerations for Concrete

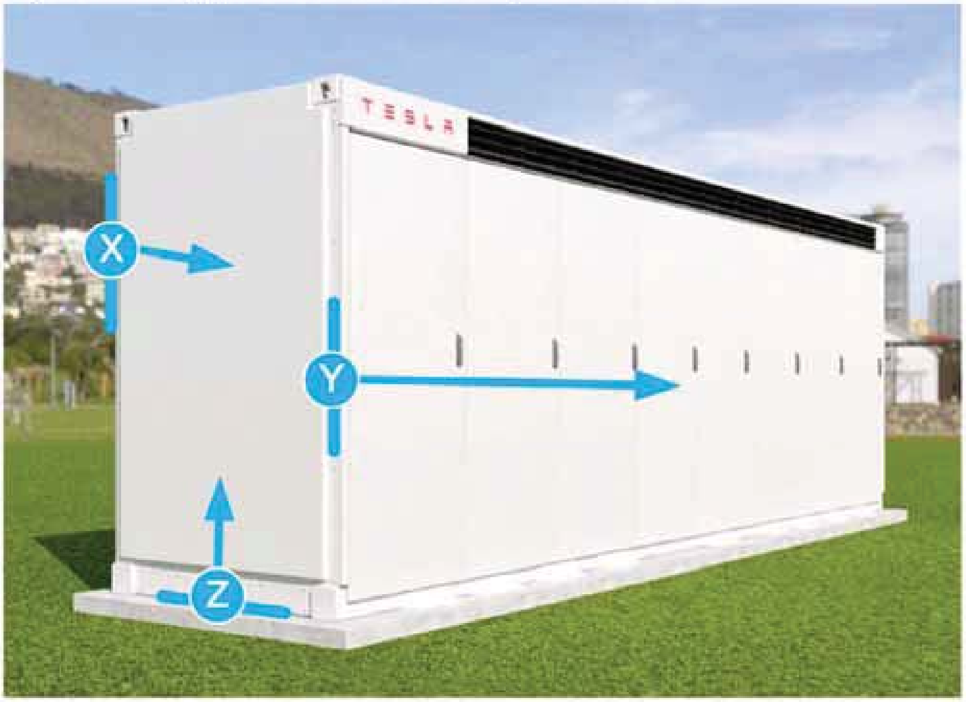
If using concrete foundations, follow these guidelines in addition to the above:

- Concrete rebar reinforcement location must be coordinated with equipment anchor locations to avoid overlap.
- The pad thickness and size shall be sufficient to accommodate Megapack anchoring as required per ACI 318 or equivalent local standards.
- Specify rebar with a minimum and maximum allowed spacing, to allow the contractor to adjust rebar spacing to avoid conflicts with equipment anchoring
- Alternately, the minimum concrete cover over the rebar can be increased to exceed anchor embedment depth, to avoid rebar conflicts with equipment anchoring.

3.4 Center of Gravity

The Megapack center of gravity varies depending on the option code, notably its energy ratings (EC##). Other option codes, including the number of Powerstages or PS##, should have little impact on the unit's center of gravity. Contact your Tesla representative for more information.

Figure 24. Megapack Center of Gravity Dimensions



- X = Distance from rear panel
- Y = Distance from left panel
- Z = Distance from base

Table 7. Megapack Center of Gravity

X	Y	Z
849 mm (33 ½ in)	3500 mm (138 in)	960 mm (38 in)

3.5 Environmental Specifications

Table 8. Environmental Specifications

Operating Temperature*	-30°C to 50°C (-22ºF to 122ºF)
Humidity	Up to 100% condensing
Storage	-40°C to 60°C (-40ºF to 140ºF)**
Maximum Altitude	3000 m (9840 ft) above sea level
Wind	Category 5 hurricane sustained wind speeds of up to 157 mph (252 km/h)
Ingress Rating	IP66/ NEMA 3R (Main enclosure) IP20 (Thermal system) IP67/ NEMA 3R (Standard Site Controller Enclosure)
Impact Rating	IK09

Noise	<75 dBA SPL at a 10-meter distance from any side surface of the enclosure, at full thermal system performance***
Seismic Rating	IEEE 693-2018 High PL: *ZPA*=1.0 g 5% damping IEEE 693-2005 High PL: *ZPA*=1.0 g 2% damping ICC-ES AC 156-2018 S_{DS}=2.50 g z/h=0 I_p=1.5

**Installation in full sun raises the temperature inside the enclosure above ambient temperature. This temperature rise is not a safety risk but can impact the performance of the batteries. A canopy to shield the installation from direct sun exposure is permitted, as long as the canopy does not impact the ability to operate fans, or to service, remove, or replace the equipment and is outside the top clearance distance.*

*** Megapack may not be stored for more than 24 hours at these temperatures. Always refer and adhere to the* Megapack Transportation and Storage Guidelines *for all shipping and storage of Megapack.*

****This noise level assumes a 2-hour Megapack configuration with the maximum number of fans (11), all running at 100% duty cycle. In practicality, the system is designed to remain well under this noise level with a reduced fan duty cycle, and fans operating at 100% will not be common in most climates. In many cases, based on the expected operating profile and ambient temperatures of most locations, we expect noise levels closer to 60 dBA SPL at 10 m. For more information on noise levels, please contact Tesla.*

NOTE: Each Megapack contains approximately 540 L / 140 gal of 50-50 ethylene glycol-water mix and approximately 7.6 kg of R-134a in the coolant system. Depending on the number of Megapacks installed on a site storage, use and handling of these substances may require reporting, hazard management plans, or containment procedures as required by local codes and regulations. Refer to the *Megapack Operations and Maintenance Manual* for details.

3.6 Foundation Design

Observe the foundation design requirements noted below, including construction, clearance, and installation requirements.

3.6.1 Foundation Construction

Megapacks must be installed on a foundation or base strong enough to support the weight of the equipment listed in the sections above and to resist all anchor loads. Observe equipment clearances per *Observing Clearances* on page 32.

Foundation or base examples include, but are not limited to, concrete pad, grade beams, structural steel deck or skid. The foundation and anchoring design must be performed by a civil or structural engineer registered in the jurisdiction where the system is being installed in accordance with local building codes. Consult the site geotechnical report for the geotechnical design requirements.

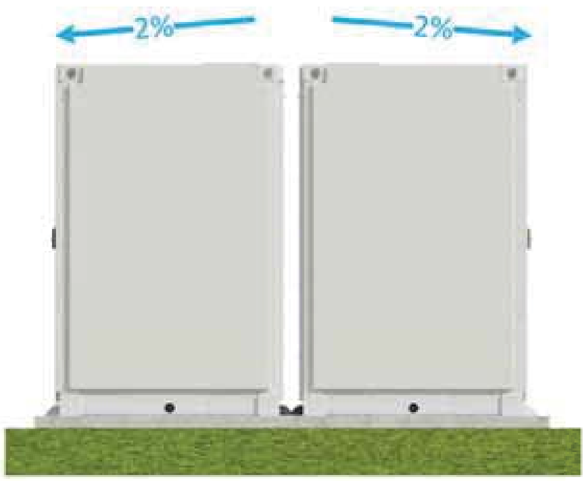
For installations that do not use a concrete pad, such as a steel skid, the following considerations must be respected:

- Equipment must all be installed on a single level surface
- AC, control and communications conduit must stub up from below grade (skid) into the enclosure. All non-concrete pad designs must be approved by Tesla before work begins.

3.6.2 Foundation Installation Requirements

- Foundation finish must have a smooth, even surface of uniform texture and appearance, free from bulges, depressions, and other imperfections that would impact equipment anchorage or foundation/ base drainage.
  - If the foundation top surface is concrete, it must have a Class B finish.
- The top of the foundation must be above adjacent grade, 305 mm (12 in) maximum, with the edge of the foundation a maximum of 305 mm (12 in) from the front of Megapack. If the site does not allow this foundation height, contact Tesla. The foundation may not be below grade and must conform to local construction standards and regulations.
- A maximum of 13 mm (0.5 in) differential settlement is permitted.
- Foundation must be sloped 2% (+/- 0.5%) downwards from back of Megapack to front to allow positive drainage toward the front.
  - For example, given a Megapack depth of 1,659 mm (65 ¼ in), the 2% (1.15°) slope means that the front of the Megapack is 33 mm (1 ¼ in) lower in elevation than the back.
  - If you are installing Megapacks back-to-back, the foundation must be sloped downwards 2% towards the front of each Megapack:

Figure 25. 2% (1.15°) Foundation Slope Towards Front



NOTE: If you are unable to provide for this slope, contact your Tesla representative.

- The area around the foundation must be designed to prevent standing water.
  - Any walls must be designed with sufficient clearance and be provisioned with features such as drains or weep holes to allow for proper drainage.
  - Megapack can withstand no more than 15 cm (6 in) of standing water for up to 30 minutes.
- Ensure that the foundation observes all clearance requirements as listed in *Observing Clearances* on page 32.
  - This includes designing for door clearance. Ensure that the doors of each Megapack are not constrained by any adjacent cabinet or structure. Refer to specific dimensions for door swing in *Door Clearance and Maximum Door Swing Requirements* on page 35.
- For anchoring requirements, see *Anchor Requirements* on page 27.
  - Concrete pad and equipment anchorage design shall meet ACI 318 and ASCE 7 requirements or the local building code requirements as required by the Authority Having Jurisdiction (AHJ).

- Post-installed anchors (anchors installed into existing hardened concrete) must be approved to resist seismic loads in the installation jurisdiction and have a current ICC-ES or IAPMO report. Where anchoring conditions require an engineered design, it must be performed in accordance with the ICC-ES or IAPMO report and the cracked concrete provisions of ACI 318-11, Appendix D.

CAUTION: Modification of anchor brackets is not permitted in any way.

3.7 Inspecting Fencing

Megapack shall be installed in a manner that deters access by persons who are not qualified. When deterring access, fences, screens, walls, or barriers no shorter than 2.1 m (7 ft) in height are suggested. The distance from any fence to the equipment shall match the clearance requirements listed in *Observing Clearances on page 32*, or as noted per the exceptions below. Fencing shall be locked and posted with a placard stating "Authorized Users Only," or similar. If applicable, see 2018 IFC 1206.2.8.7.3.

Exception: If the installation is located within a property that already contains perimeter fencing to prevent unauthorized public access, additional fencing might not be required.

3.8 Observing Clearances

Observe the following clearance requirements referring to the appropriate diagrams.

NOTE: The clearances listed are as required by the product. Additional clearances to non-Megapack equipment may be required per local codes and regulations.

3.8.1 Equipment Clearances

NOTE: All clearances listed must be observed from Megapack to any equipment including other Tesla-provided components such as Tesla Site Controller.

Figure 26. Equipment Clearance Requirements - Side View / Front View

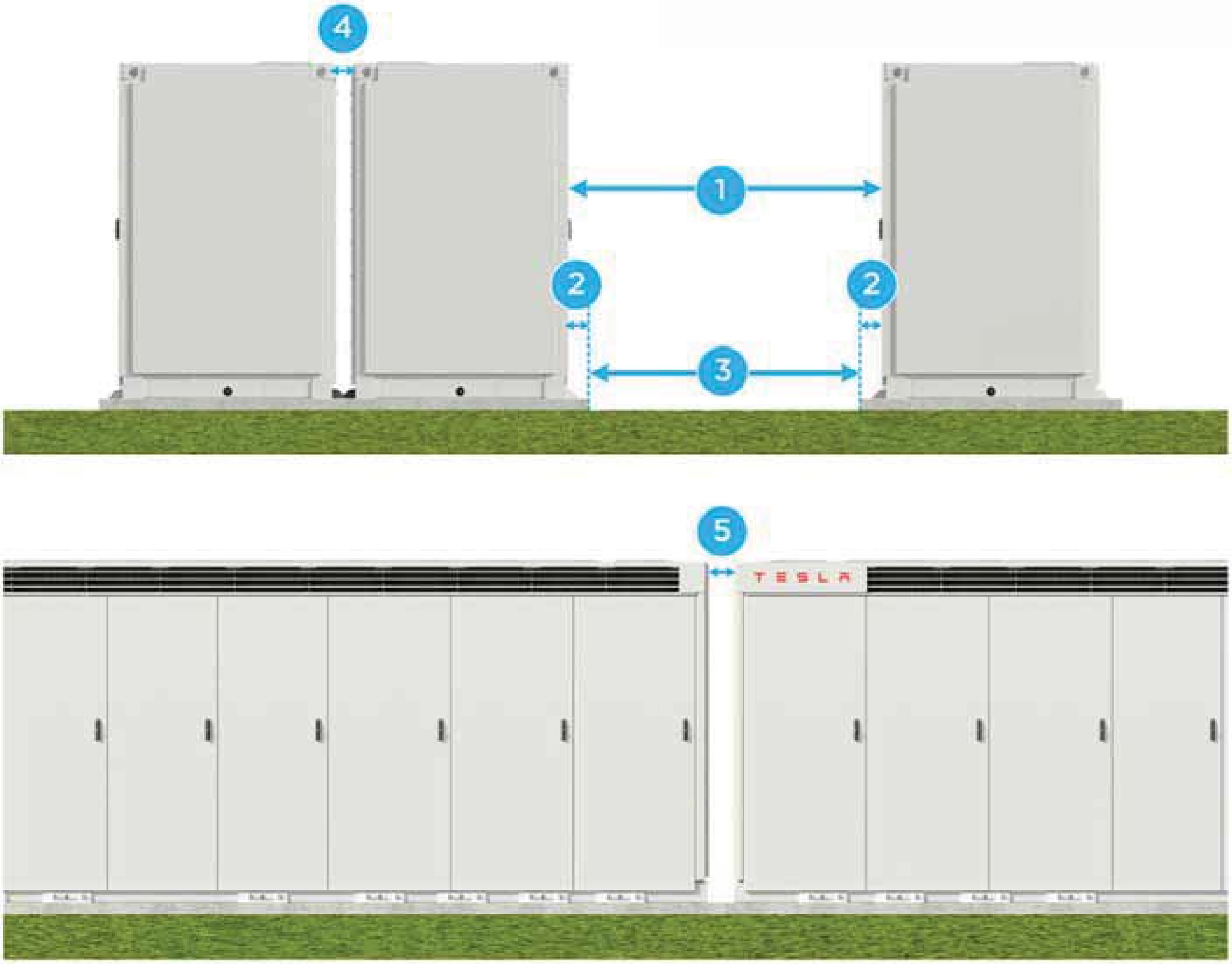


Table 9. Equipment Clearance Requirements

Callout	Type	Minimum	Maximum	Notes
1	Front	8 ft (2.5 m)	None	Measured from face of doors. Tesla-required clearance for maintenance access.
2	Foundation overhang	4 in (102 mm)	12 in (305 mm)	Varies depending on anchor and site design but must fall within this range. See *Equipment Bearing Areas and Anchoring* on page 25 for more information.
3	Drive aisle	6 ft 5 in (2 m)	None	Measured from foundation. Tesla-required clearance for maintenance access.
4	Back-to-back coupling	6 in (150 mm)	7-1/2 in (200 mm)	Measured from the outside faces of the ISO corners at top of Megapack. Any spacing at back of adjacent Megapacks greater than 8 inches (203 mm) is considered stand-alone and such Megapacks must be installed accordingly (using rear anchors).

Callout	Type	Minimum	Maximum	Notes
				Once installed, minimum absolute clearance between Megapacks is approximately 4 in (100 mm) due to Megapack's thermal insulation on the back surfaces.
5	Side	6 in (150 mm)	None	Measured from the outside faces of the ISO corners at top of Megapack. Once installed, minimum absolute clearance between Megapacks is approximately 4 in (100 mm) due to Megapack's thermal insulation on the side surfaces.

3.8.2 Exposures and Fire Clearances

Figure 27. Exposure Clearances - Isometric View / Side View

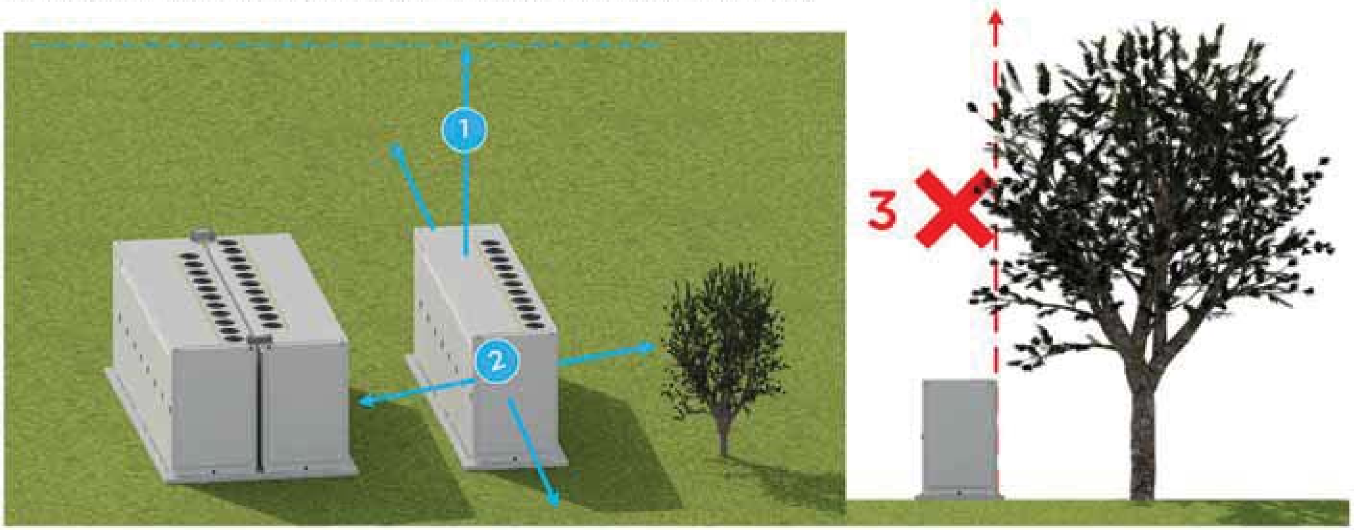


Table 10. Exposure Clearance Requirements

Callout	Type	Minimum	Maximum	Notes
1	Vertical	8 ft (2.5 m)	None	Must extend the entire area of the service clearance. Some service equipment extends beyond the roof of the enclosure. Megapack may only be installed by a crane, thus actual clearance during installation will be greater.
2	Combustible	5 ft (1.5 m) *Do not install Megapack under combustible objects.*	None	Minimum clearance as noted is required on all sides from combustible objects including trees, wooden fences, and other combustible structures. Megapack must not be installed under combustible objects. **NOTE: For Megapacks with option code C008 (see *Megapack Labels* on page 12), 915 mm (3 ft) of non-combustible surface (for example dirt, gravel, concrete) must extend beyond the perimeter of the Megapack enclosure.**

Callout	Type	Minimum	Maximum	Notes
3	Vertical combustible	NA	NA	**Do not install Megapack under combustible objects, at any distance.**

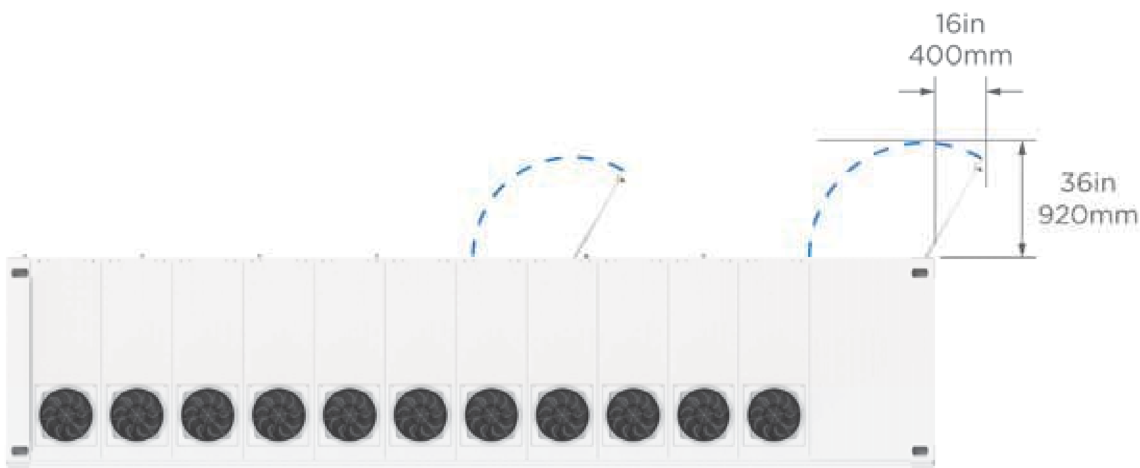
NOTE:

- Megapack is not intended to be installed within 10 ft (3 m) from accessible means of egress and exposures (such as buildings, public ways, and hazards not associated with electrical grid infrastructure as defined by the clearance requirements in the International Fire Code and NFPA 855).
- Any installation that requires clearances of less than 10 ft (3 m) to accessible means of egress or exposures may require a freestanding fire barrier per requirements in the International Fire Code and NFPA 855.

3.8.3 Door Swing

To allow full door clearance and access to all components, sites must be laid out to allow 16 in (400 mm) of clearance past the enclosure footprint for the last door on the left. The site layout must ensure that no wall or other structure interferes with any door opening fully:

Figure 28. Door Clearance and Maximum Door Swing Requirements



3.9 Site Conditions and Access

- For Tesla personnel to perform maintenance, Tesla must retain access to the site and all Tesla equipment, and must have the ability to remove any locks preventing such access. Refer to *Megapack Door Security* on page 36 for information on securing and locking doors while retaining Tesla access.
- The site shall provide and maintain a clear access route to the front of each Megapack for delivery, installation, replacement, and removal of Megapack components with weight as listed in *Mechanical Specifications* on page 25. The site must maintain access for both crane and forklift.
    - Refer to front and drive-asile clearance requirements as specified in *Observing Clearances* on page 32.
- For non-grade installations, please contact Tesla.
- Keep the doors of all enclosures free of obstruction (snow, sand, blown debris, etc.) during system operation. For any concerns, contact Tesla during the site design phase.
- Equipment cannot be tilted and shall be transported and lifted vertically at all times. For maximum temporary tilt during transportation, refer to the *Megapack Transportation and Storage Guidelines*.

3.9.1 Megapack Door Security

All Megapack doors have the ability to be locked. The Customer Interface Bay (*Customer Interface Bay Overview* on page 41), as the primary customer interface for Megapack, is not required to be locked. The other doors do not need regular access and should remain closed.

NOTE: Access to the Customer Interface Bay may be subject to local codes and regulations.

Installing Locks

Combination locks are shipped with Megapack, either pre-installed on Megapack doors or delivered in the Accessory Kit. Install these locks to ensure doors are not left open unnecessarily:

- **Set combination to 4585** for coordinated access with Tesla field service personnel. Tesla must have ability to unlock doors. If you choose a different combination, advise your Tesla contact in writing.
- If Tesla field service personnel arrives on site and observes locks are not installed, they will proactively install and coordinate with onsite personnel.
- For keyed locks, a double hasp is required to allow Tesla access by unlocking Tesla's lock.

3.10 Site-Level Lighting

Consider the following points when designing for site-level lighting:

- There are no provisions for power within the Megapack. Power and protection must be externally provided and routed to the Customer Interface Bay.
- A 250x100 mm (10x4 in) conduit passthrough provision from the Customer Interface Bay to the left and right sides of Megapack is provided (as illustrated in *Lighting Conduit Passthrough - 250x100 mm (10x4 in)* on page 37).
- No conduit is provided; this must be supplied.
- Support posts or Unistrut for lighting fixtures and conduit can be installed at either end of the Megapack using post feet for the bottom of the post, U-bolts, and associated hardware for the top of the post to secure it to the Megapack using the ISO corner fitting. See dimensions for the ISO corner fittings in *Appendix A – ISO Corner Dimensions* on page 65.
- No welding or penetration into the Megapack enclosure is allowed for mounting the support posts or conduit.
- Standard ISO corner anchors may be utilized; however, modification of the anchors is strongly advised to ensure a secure connection to the Megapack is maintained.
- If the lighting is to be installed between two Megapacks, this work must be done before the installation of the neighboring Megapack.

Figure 29. Lighting Conduit Passthrough - 250x100 mm (10x4 in)

3.11 Site-Level Power

To ensure that sites can be commissioned safely and serviced effectively, the site design shall include at least 1 (one) receptacle socket positioned such that the outlet is not more than 15 m (50 ft) from all Megapacks at the site. The receptacle should be designed to local requirements for human use & safety and should include a ground fault circuit interruptor (GFCI). Common access points can include the block-level transformer, lighting, or network enclosure. The receptacle socket shall be rated to at least 3 kVA at the local voltage.

4 Mechanical Design

4.1 Hazard Mitigation and Safety

Tesla conducts extensive analysis and testing to assess hazardous conditions related to Tesla products. Megapack includes multiple layers of protection to mitigate hazardous electrical and fire conditions. All built-in protection systems do not require user input or feedback. The following safety features are included in Megapack and have been tested and validated during UL9540A testing:

- **Over pressure vents in the internal roof (under the fans and radiators):** The vents are designed to allow for any build-up of smoke, gas, or flames to vent out of the roof rather than out of the front doors. The vents are passive and do not require actuation or external control.
- **A continuously operated "sparker" system designed to minimize the risk of deflagration in the event of hazardous gas build-up:** The system ensures that any gases cannot build up to hazardous concentrations. The system is powered internally and does not require external supply of power or controls.
- **A layer of external thermal insulation on the back and sides of the enclosure:** This material mitigates the risk of thermal runaway propagation from one Megapack to another even when installed 100 mm (4 in) apart.

Megapack does not contain built-in smoke, gas, or fire detection or suppression features. When required by the AHJ, third-party multi-spectrum IR heat or flame detectors can be installed externally at the site-level. These systems are a proven option to detect Tesla product thermal runaway events.

Water-based suppression is appropriate for mitigating the spread of fire involving a Megapack. Refer to the Tesla *Lithium-Ion Battery Emergency Response Guide* for detailed hazard and response information.

4.2 Thermal Management

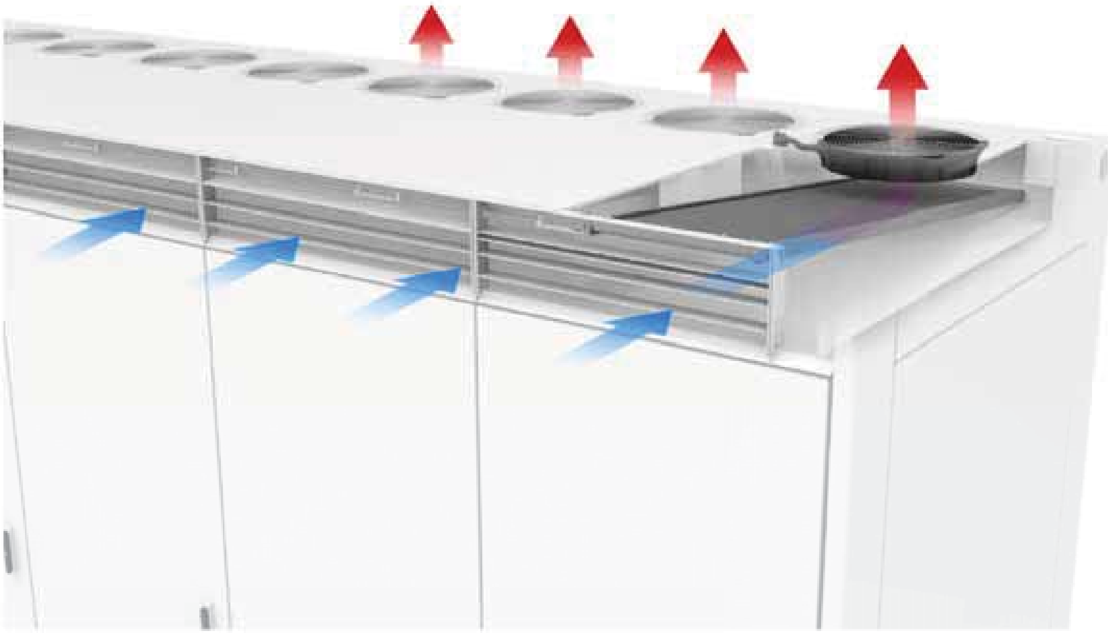
Megapack includes a thermal management system that provides active cooling and heating to the internal Megapack components. An external HVAC or thermal system is therefore not required for Megapack to operate.

Megapack is designed to be installed outdoors within the rated operating temperature specifications. Indoor installations are not allowed without consulting Tesla.

NOTE: The physical characteristics of the project site may cause localized heating effects (rise above ambient) adjacent to Megapack – for example, an installation in a location with a strong heat island effect, black pavement (parking lots), or in full direct sunlight. Although not required by Tesla, shade structures or canopies may help mitigate local environmental heating effects. Ultimately, the customer must understand the risk to performance of localized heating effects and take responsibility for any mitigation. Any shade structures must conform to the distances detailed in *Observing Clearances* on page 32.

Air flows through the enclosures as shown below:

Figure 30. Megapack Airflow



4.2.1 Megapack Thermal Subsystem

The thermal system includes radiators and pumps that circulate a 50/50 ethylene glycol / water coolant mix through the battery to maintain thermal control. The thermal subsystem also includes R134a (1,1,1,2-Tetrafluoroethane) refrigerant in a sealed system. All Megapacks ship with the necessary coolants and refrigerants included.

Since the thermal subsystem is a fully closed-loop system with a compressor, the refrigerant line includes a pressure relief valve that can activate if incorrect maintenance or operation creates excessive pressure. The system operates autonomously and does not require user feedback.

4.3 Service Roof and Snow Loading

Some service procedures may require an approved technician to access Megapack using the enclosure's roof. When necessary, Megapack is designed for a service load of ~150 kg (330 lbs).

Megapack's roof is designed to withstand up to 150 psf (730 kg/m^2) of snow loading. If the site may experience greater than 150 psf of snow loading, contact Tesla to discuss and approve mitigation solutions.

5 Electrical Design

5.1 Power Specifications

The Powerstage inverter modules in Megapack are a current-limited source rated at 86 A.

NOTE: Refer to the *Megapack Interconnection Datasheet* for additional information.

WARNING: In order to operate, Megapack requires a solidly grounded circuit such that the line-to-ground voltage does not exceed 300 V AC.

5.1.1 Grid-Connected (Utility-Interactive) Mode

Table 11. Grid-Connected Electrical Specification

Max Continuous Output Current (per Powerstage)	86 A
Overload Capability	120% of rated current (10 sec max)
Input Voltage Range	860-960 V DC
Output Voltage Range	360-555 V AC (380-505 V AC nominal)
Tesla Site Controller Input Voltage Range	120 V AC +/- 12 V AC 240 V AC +/- 24 V AC 480 V AC +/- 48 V AC
Nominal Frequency (configurable)	50 or 60 Hz
Frequency Range	40-70 Hz
Phases	3
System Configuration	3-wire, Wye **Note:** Grounded Wye required at transformer secondary
Peak Efficiency	> 98.9%
Full Load Efficiency	98.5%
CEC Weighted Efficiency	98.84%
Power Factor at Full Load	> 99%
Adjustable Power Factor (Controller Feature)	-1 to +1
Total Current Demand Distortion (TDD)	< 1.2%
Power Regulation Accuracy	< 2%
Overvoltage Category	Category III up to 3000 m
Maximum Short Circuit Current	85 kAIC

5.1.2 Supplemental Specifications for Grid-Forming (Islanding) Mode

Table 12. Grid-Forming Additional Electrical Specifications

Total Voltage Harmonic Distortion (THD)	< 8% (Individual Harmonic: Max 6%)

5.1.3 Short Circuit Current Values

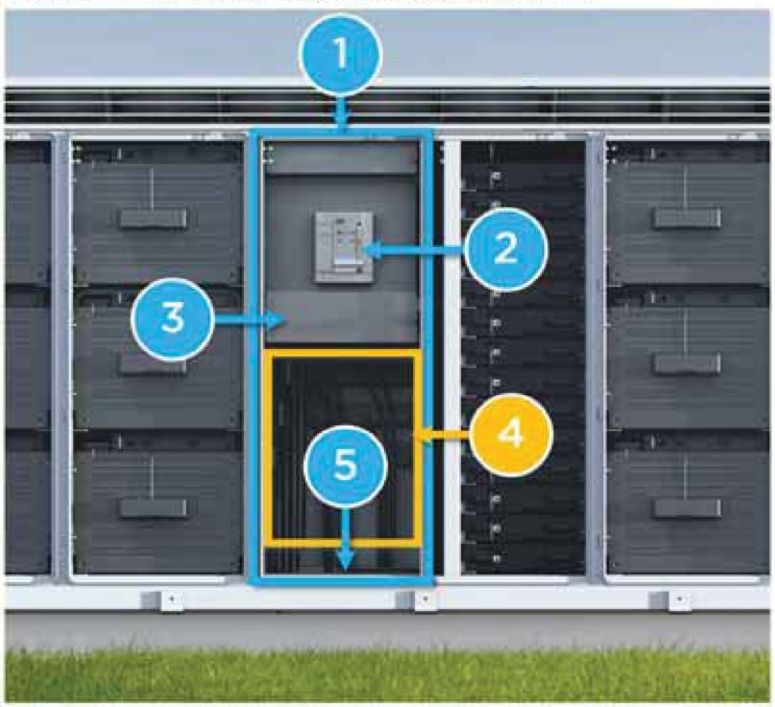
The per-unit short circuit current in the case of a three-phase-to-ground bolted fault is 1.2 per unit.

5.2 Customer Interface Bay Overview

After Megapack has been anchored, all of the interface required for installation, operation, and maintenance is located in the Customer Interface Bay. It contains:

- AC bus bars to allow for terminations to the site distribution transformer or AC distribution panel
- AC circuit breaker
- Customer I/O area, where all other terminations are made
- The interface port for rapid diagnostics and system health
- Access to the control boards for maintenance or repairs

Figure 31. Customer Interface Bay Overview



1. Customer Interface Bay
2. AC circuit breaker
3. Customer I/O area
4. AC bus bars
5. Conduit openings (3) covered by gasketed floor panels

5.3 Customer I/O Wiring Detail

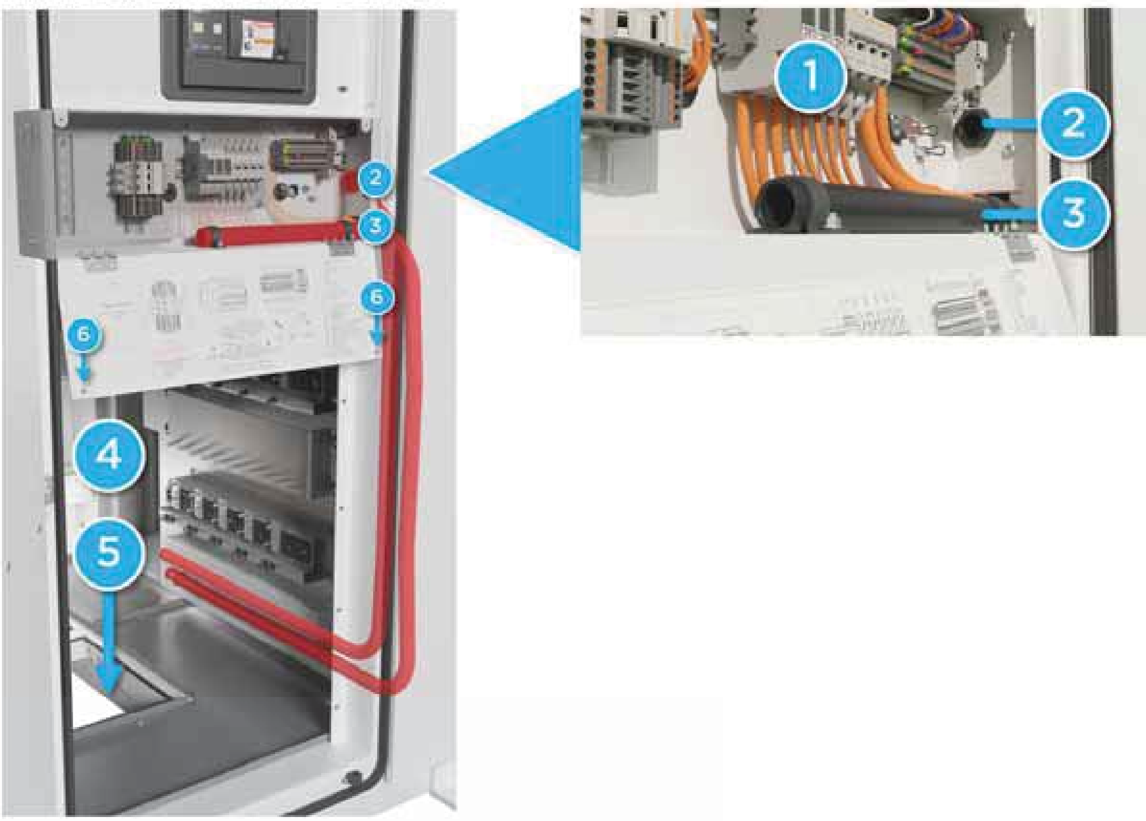
Each Megapack includes a single customer interface (I/O) area consisting of a wiring compartment inside the Customer Interface Bay. This compartment contains all the necessary non-power connections to be made to the Megapack. The compartment is behind a tool-accessible door (secured with Phillips head #3 screws) and shall only be accessed during operation while following site safety procedures.

Two conduits are provided to the right of the customer I/O area: one for LV (or communications) conductors and one for power conductors. Both conduits are 25 mm (1 in.) in diameter and run from the customer I/O area through the right side of the AC bus bar area to just above the gasketed floor panels.

NOTE: For detailed bus bar dimensions, refer to *Bus Bar Dimensions* in *Megapack Drawings* on the Partner Portal.

Pull wiring through the conduits as required (see below figure).

Figure 32. Customer I/O Conduit



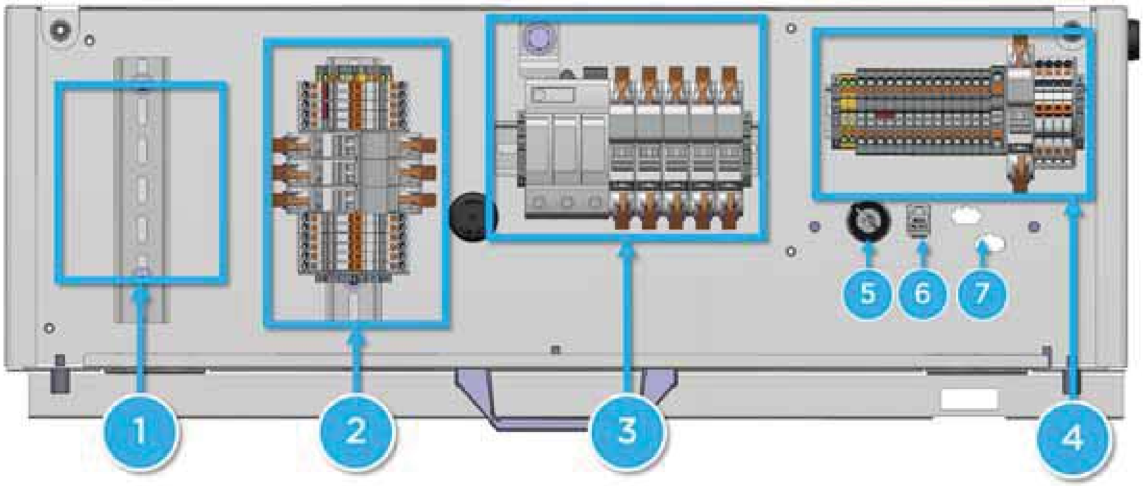
1. Customer I/O area
2. Communications conduit (25 mm / 1 in. diameter)
3. Power conduit (25 mm / 1 in. diameter)
4. AC bus bar area
5. Conduit openings
6. Phillips head #3 screws

DANGER: Always refer to *Important Safety Information* on page 4 at the beginning of this document before beginning any work on Megapack.

The customer I/O area is partially pre-wired. Only some on-site wiring is needed depending on the project needs. See wiring details below.

NOTE: Refer to detailed drawings of these terminals in *Customer I/O Terminal Blocks* in *Megapack Drawings* on the Partner Portal.

Figure 33. Customer I/O Wiring



1. **Customer-provided meter** – see detail below in *Customer-Provided Meter* on page 43.
2. **AC line side** – see detail below in *AC Line Side Area* on page 44.
3. **AC & DC load side** – see detail below in *AC & DC Load Side Area* on page 44.
4. **Low voltage** – see detail below in *Low Voltage Area* on page 45.
5. **DC lockout** - A safety feature (HVIL – High Voltage Interlock Loop) in the form of a captive-closed key contact for the enable line. When the key is opened and removed, the enable line is broken. This provides a keyed isolation point for working on the DC bus.
6. **Tesla Site Controller computer Ethernet** - An RJ45 female connection intended to be connected to the Tesla Site controller is provided.
7. **CMA low-voltage external interface**.

5.3.1 Customer-Provided Meter

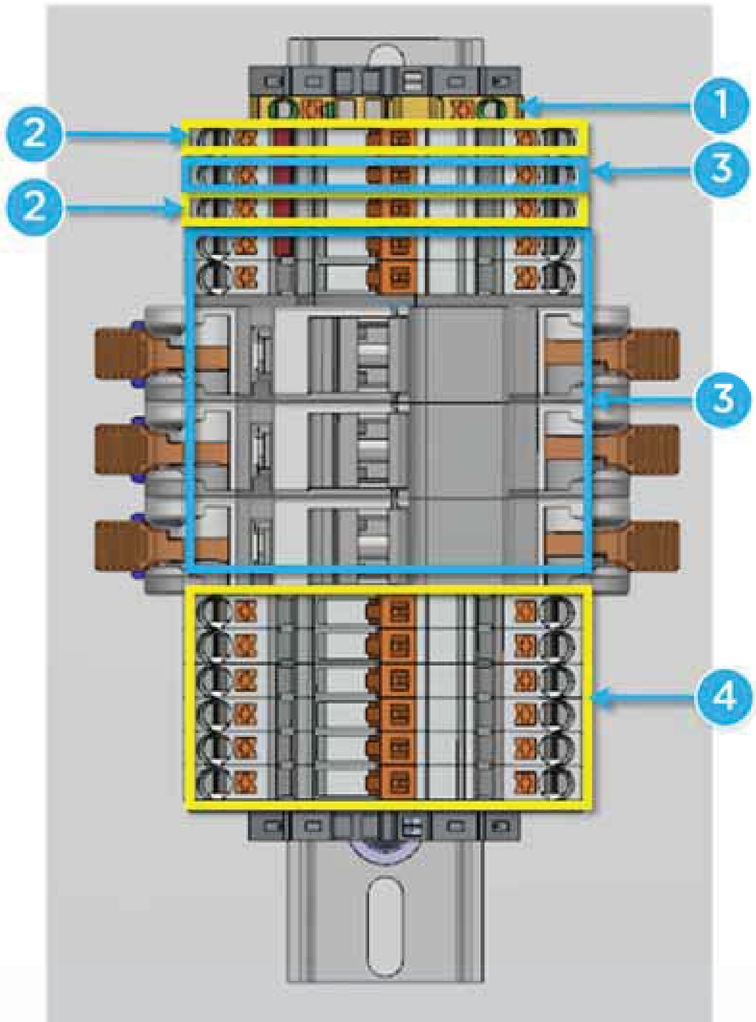
Dedicated space and a DIN rail for a customer-provided meter is located inside the customer I/O area in this space.

Bends in the AC bus bars (callout #4 *Customer Interface Bay Overview* on page 41) are provided for mounting a set of current transformers in order to wire the meter. Tesla recommends using Rogowski coils. See *Bus Bar Dimensions* in *Megapack Drawings* on the Partner Portal for detailed dimensions.

See the *Megapack Installation Manual* for more information about wiring meters.

5.3.2 AC Line Side Area

Figure 34. AC Line Side Area



1. **Ground** - A single ground terminal connected to chassis ground via the DIN rail is provided.
2. **AC power** - Two terminal blocks are provided to facilitate distribution of L-L AC power. Power is jumpered from the adjacent terminal blocks. This is intended to provide power for a Tesla POI SCADA enclosure or Tesla Field Network Enclosure. Contact Tesla for details.
3. **Line side bus bar taps** - The taps (L1, L2, L3) are each factory-connected to a fused (4A) terminal block. The fused terminal blocks are then field wired to the additional three disconnect terminal blocks for testing purposes.

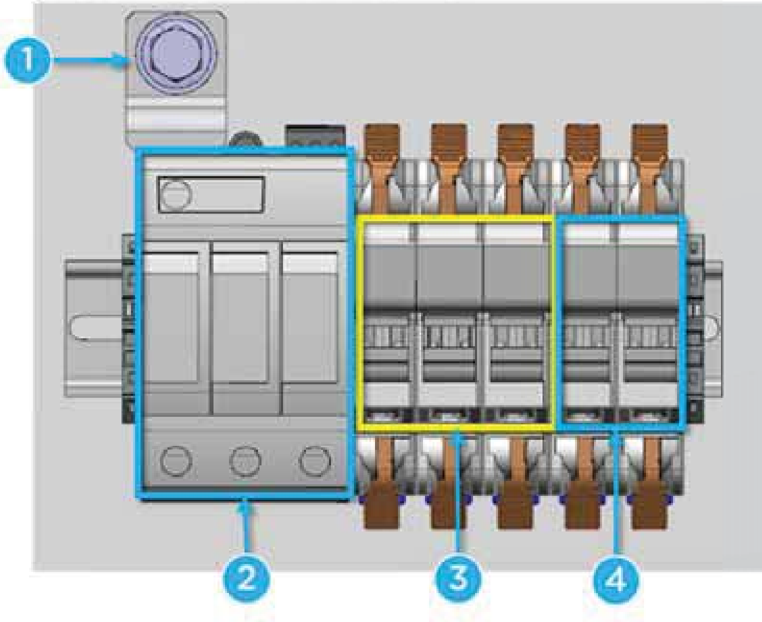
   ⚠ **DANGER:** These connections are directly connected to the line side bus bar and are not protected before entering the customer I/O area.

4. **Current transformer terminals** - Six test disconnect terminals are provided for current transformers to be connected to. The current transformers themselves are not provided.

5.3.3 AC & DC Load Side Area

The connections within this area are Tesla-only and do not require any site installation.

Figure 35. AC & DC Load Side Area



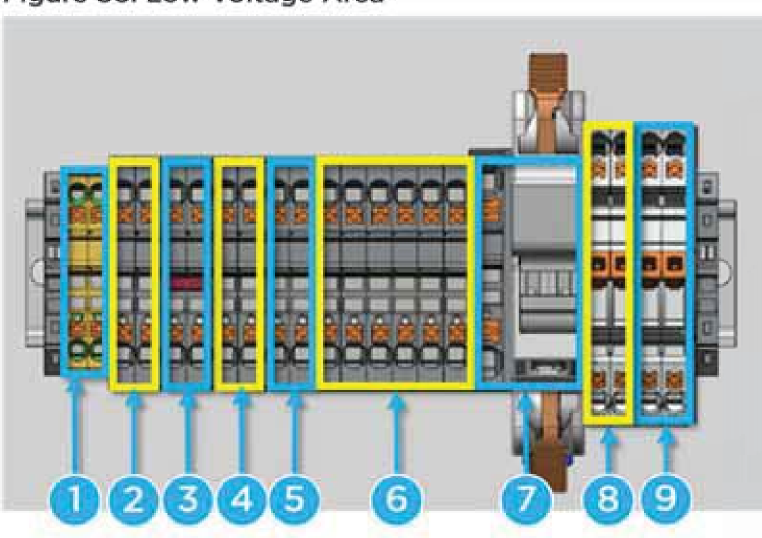
1. **Ground**
2. **SPD** - Factory-installed surge protection device.
3. **AC load side fuses** - Factory-installed load side AC fuses providing power to the Tesla control boards.
4. **DC fuses** - Factory-installed 30A fuses providing DC power to the thermal bay (+ and -)

DANGER: When working with SPD and AC load side fuses, ensure that the circuit breaker is in open position.

5.3.4 Low Voltage Area

CAUTION: All terminals in the low voltage (LV) area should be limited to 24 V. **Do not wire higher voltage in this area.** Wiring higher voltage into this area risks damage to terminals and internal components.

Figure 36. Low Voltage Area



1. **Ground** - A pair of terminals connected to chassis ground via the DIN rail.
2. **AC area dead front switch** - A pair of terminals connected to a dry-contact dead front switch.

- Intended to be connected to an upstream protection device to detect when the AC line side bus bar area is opened
- No power supply required

3. **Remote Shutdown Command** - A pair of terminals used to command the Megapack DC bus to 0 V DC and then, 100 ms later, shunt-trip the Megapack breaker.
   - The terminals ship with a jumper installed. Removing the jumper will command a remote shutdown by interrupting the integrated 20 mA DC signal circuit to the Megapack bus controller.
   - Closing the circuit must be done in a manner that mimics a jumper. Do not apply a wetting voltage, as the circuit cannot share a common/return with other circuits.
4. **12-24 V DC Jumpstart** - A pair of terminals intended for connecting to the 12-24 V DC jumpstart from the Tesla Site Controller. See *Jumpstart Power Requirements* on page 50 for details regarding the jumpstart functionality.
5. **24 V DC Backup** - A pair of terminals intended to provide 24 V DC backup power to the Tesla Site Controller. See *DC Backup Power Requirements* on page 49 for details regarding the 24 V DC backup functionality.
   - Megapack can provide up to 4 A at 24 V while in an active state (*Always Active* = true). In this state, the energy is provided from the battery modules and is available regardless of the incoming AC power to Megapack.
   - This feature cannot be used if Megapack is faulted, the DC interlock is open, or the system is off.

   NOTE: This feature was designed primarily for off-grid operation and may cause an on-grid system to consume additional energy (up to 35 kWh per Megapack per day).
6. **Breaker Open/Closed/Tripped Status** - 3 pairs of terminals directly connected to the breaker auxiliary dry-contact status terminals. See the *Siemens WL Breaker Manual* for more details.
   - "Breaker Open" is open when breaker is open
   - "Breaker Closed" is closed when breaker is open
   - "Tripped Status" closes when breaker trips
7. **External 24 V pre-charge input** - A pair of terminals (- and +) that accept pre-charge input of 24 V. Maximum 8 AWG (10 mm^2); minimum 480 W power supply.
   - XX36 (-)
   - XX37 (+) - fused at 30A
8. **Close Permissive command** - A pair of terminals used to permit or restrict closing of the Megapack breaker.
   - Closing the integrated 20 mA DC signal circuit to the Megapack bus controller will permit closing of the Megapack breaker. Opening the integrated 20 mA DC signal circuit will NOT cause a trip of the breaker.
   - Closing the circuit must be done in a manner that mimics a jumper. Do not apply a wetting voltage, as the circuit cannot share a common/return with other circuits.
   - Closing this circuit does not guarantee the Megapack breaker will close. If the enable line is open, the Megapack breaker will not close.
   - Megapack does not ship with a jumper installed but the breaker can always be manually closed. A motor can be field-retrofitted to allow automatic charging of the spring-loaded breaker.

   NOTE: Removing the Close Permissive will prevent remote close actuation; it will not trip the breaker.
9. **Trip Command** - A pair of terminals used to command a trip of the Megapack breaker.

- Closing the integrated 20 mA DC signal circuit to the Megapack bus controller will command the trip of the Megapack breaker
- Megapack ships without a jumper. Closing the circuit must be done in a manner that mimics a jumper. Do not apply a wetting voltage, as the circuit cannot share a common/return with other circuits.
- Trip Command logic takes precedence over the Close Permissive Command

5.4 Underground Conduit Positioning

Megapack requires conduit to run AC conductors and communications wiring between system components and to the site's main AC panel.

The table below summarizes the wiring interfaces needed. All wires and conduits are supplied by the contractor.

NOTE: For detailed conduit dimensions, refer to *Megapack Layout* in *Megapack Drawings* on the Partner Portal.

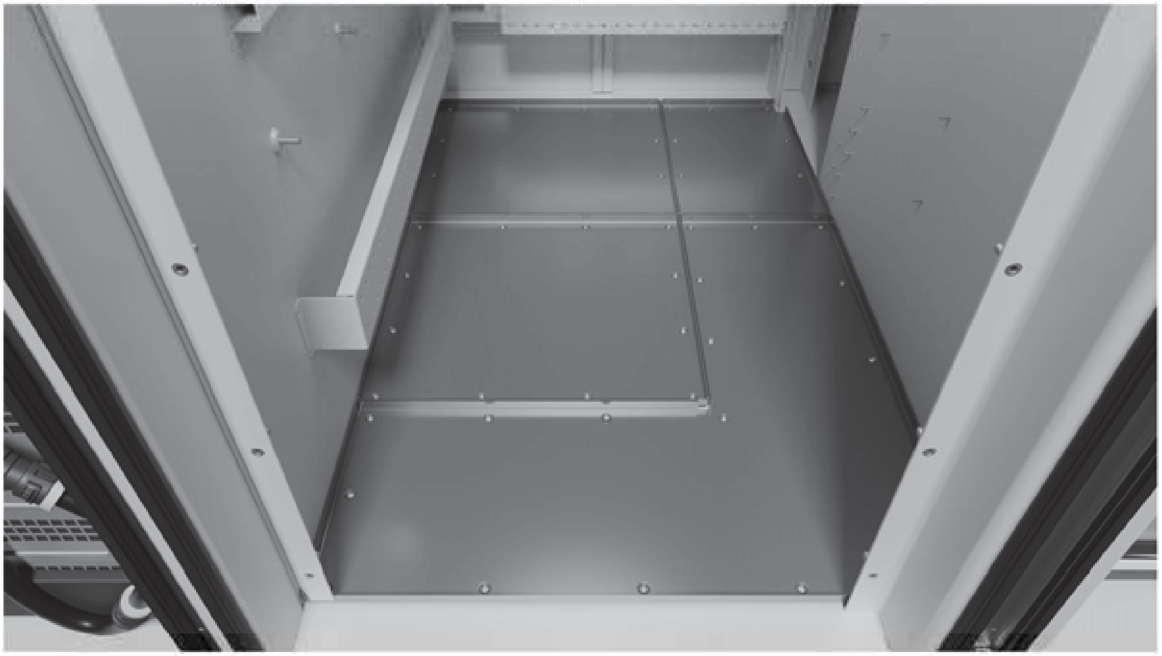
Table 13. System Wiring Interface Summary

From Equipment	To Equipment	Wiring Interface	Minimum Conduit Size
Megapack	Controller or field network enclosure	Shielded CAT5e or CAT6	25 mm (1")
Megapack	Controller or field network enclosure	DC conductors (for communication control power or microgrid applications)	25 mm (1")
Megapack	Grid interconnection	AC conductors (3-phase, and ground)	100 mm (4")
Controller	AC power supply	AC conductors (2-phase and ground), min. 2 mm^2 / 14 AWG	25 mm (1")
	Meters	TCP meters: Shielded CAT5e or CAT6	25 mm (1")

NOTE: All conduit stub-ups must land inside the AC window in the bottom of the Megapack enclosure.

Figure 37. Megapack AC Conduit Window Location (at bottom of Customer Interface Bay)

Figure 38. Megapack AC Conduit Window (as viewed looking from above into Customer Interface Bay)



CAUTION: Do not modify the outer enclosures of any Megapack component. Modification of any sort voids the warranty, as well as the certification and UL/NRTL listing provided with the product. If underground AC conduit cannot be run as shown, contact Tesla to discuss alternatives. Tesla must approve the non-standard installation before work begins.

Each Megapack requires a 3-wire circuit (3 phases, ground) connection. Conductors enter the Megapack via a bottom conduit window and terminate on the AC bus bars in the customer interface bay. Note that the transformer requires a grounded wye at the secondary (see *Transformer Design* on page 21 for details).

Megapack is provided with three AC bus bars to connect three phases with conductors with a maximum of 1000 MCM (500 mm^2) per connection:

- 2-hour Megapack: 9 sets of conductors
- 4-hour Megapack: 6 sets of conductors

NEMA 1.75 in, 2-hole grounding studs are also provided.

Auxiliary power is not required. Megapack pulls auxiliary power for the control power and thermal management from the DC bus, and therefore requires no field work.

5.5 Megapack Wiring

5.5.1 AC Power Requirements

Dedicate a separate 3-phase circuit for each Megapack. Use 90ºC copper or aluminum wire (the internal ambient temperature can reach 70ºC). The connections allow for 9 conductors per phase with a maximum of 1000 MCM (500 mm^2) conductors. Pre-installed threaded studs are provided on a tin-plated aluminum bus supporting NEMA 1.75 (44 mm) in 2-hole lugs. The earth connection allows for 9 connections of up to 500 MCM (250 mm^2), sized for NEMA 1.75 in (44 mm), 2-hole lug ground studs.

NOTE:

- Size the AC output wiring per local electrical codes.
- Megapack can have varying power ranges depending on the number of Powerstages installed. The contractor and engineer of record are responsible for sizing conductors accordingly.

Provide an equipment grounding conductor (EGC) for each power circuit. The grounding conductor size depends on local requirements and the Megapack breaker rating.

5.5.2 DC Backup Power Requirements

If designing for backup power, note the following wiring requirements:

- Wire length of 45 m or less, 2 mm^2 [14 AWG]
- Connect to Megapack terminals:
  - XX18 - 24V DC+ OUTPUT - SITE CONTROLLER CONN
  - XX19 - 24V DC- OUTPUT - SITE CONTROLLER CONN
- Max continuous current: 4 A

5.5.3 Jumpstart Wiring

If Megapack will be configured with hardwired jump-start ability, design the jumpstart wiring circuit per the instructions in *Backup Power Requirements* on page 49, and connect through conduit from Tesla Site Controller to these two Megapack terminals:

- XX16 - JUMPSTART INPUT +
- XX17 - JUMPSTART INPUT –

5.6 Tesla Site Controller Wiring

The Tesla Site Controller must be powered from a dedicated 120-480 V circuit. Its internal transformer adjusts voltage as required. The engineer of record must design the means and methods of pulling this circuit.

If you are implementing backup or jumpstart functionality, address electrical design of the Tesla Site Controller as indicated below.

5.6.1 Backup Power Requirements

To provide an uninterruptible power supply (UPS) to the Tesla Site Controller, three types of power supply are available:

1. **Megapack-provided power** - 24 V power is available as long as the DC bus is up and the power supply board is functional. The DC bus is always up when *Always Active* mode is true, unless the system is down for maintenance (the enable line is broken) or experiencing rare and severe types of faults. See *DC Backup Power Requirements* on page 49 for wiring requirements.
2. **Customer-provided DC power** - As an alternative to the 24 V DC from Megapack above, customers can provide a 24 V DC UPS that terminates into the 24 V DC redundancy module in the Tesla Site Controller.

3. **Customer-provided AC power** - Customers can supply power from a UPS or other backed-up power supply (strongly recommended for microgrids and high-reliability sites). This supply must terminate upstream of the AC transformer in the Standard Site Controller Enclosure. Do not add components to or modify the Standard Site Controller Enclosure

NOTE: When Megapack is faulted or in standby mode, the DC bus will go down.

5.6.2 Jumpstart Power Requirements

If the Tesla Site Controller will be configured with hardwired jump-start ability, design the jumpstart wiring circuit per the instructions below:

- Wire length of 15 m or less, 2 mm^2 [14 AWG]
- Power requirement: 20 W
- Input voltage range: 12-24 V

5.7 Megapack Settings

Megapack settings must be configured in advance by Tesla. Talk to your Tesla representative if any of the default settings should be modified. The defaults for the Megapack follow each region's grid code.

5.7.1 Overload

Megapack is capable of providing an additional 20% kVA overload for up to 10 seconds when followed by and preceded by a minimum of 10 minutes of operation at rated power or lower. In other words, Megapack can handle 1 equivalent full overload every 10 minutes if running at 100% current. This is purely a feature of the Megapack hardware. Actual realization of this overload power is also a function of the available DC power.

Overload capability can be configured by Tesla at the customer's request, with an allowed percentage of overload from 0-20% and allowed overload time from 0-10 seconds.

5.7.2 Voltage Ride-Through

Table 14. Setting Ranges

Parameter	Setting Range	Resolution
Voltages	0.00-Maximum HVRT Allowed	0.01 per unit
Times	0.00-60.00 sec*	0.01 sec

* *Time allowed a specific per-unit voltage depends on the nominal voltage rating. Typically, default settings and acceptable ranges are tested as part of a specific certification. For deviations from certified settings in a region, please contact a Tesla Sales Engineer.*

Megapack has five voltage and time setpoints for low voltage ride-through (LVRT), configurable to the following ranges:

Table 15. Megapack LVRT Settings

Parameter	Default Values for 480 V
LVRT Point 5	88% @ 2.00 sec
LVRT Point 4	60% @ 1.00 sec
LVRT Point 3	45% @ 0.13 sec

Parameter	Default Values for 480 V
LVRT Point 2	45% @ 0.13 sec
LVRT Point 1	45% @ 0.13 sec

Megapack has four high voltage ride-through (HVRT) setpoints, with one instantaneous trip voltage setting, configurable to the following ranges:

Table 16. Megapack HVRT Settings

Parameter	Default Values for 480 V
HVRT Point 3	120% @ 0.13 sec
HVRT Point 2	120% @ 0.13 sec
HVRT Point 1	110% @ 1.00 sec
HVRT max trip	121%

Table 17. Maximum HVRT Values

Nominal System Voltage	400 V AC	420 V AC	440 V AC	480 V AC	505 V AC
Maximum HVRT Allowed	168%	160%	153%	140%	133%

Table 18. Trip Accuracy

Trip Setting	Accuracy
Voltage	+/- 2% of nominal voltage
Time	Longer of +/- 100 mS or 1% of set point
Frequency	+/- 0.01 Hz

Megapack ships with the following pre-defined settings:

Table 19. Interconnection System Default Response to Abnormal Voltages

Default Settings	
Voltage range (% of base voltage)	Clearing time (s)
V < 45	0.16
45 ≤ V < 60	1
60 ≤ V < 88	2
110 < V < 120	1
V ≥ 120	0.16

In addition to ride-through capability, Megapack is capable of adding or removing VARs during VRT events to help support voltage regulation during the fault event.

LVRT behavior has two adjustable parameters: voltage and time pairs. K-factor (reactive current support coefficient) adjusts the amount of reactive current supplied to support grid voltage during a fault. This coefficient is multiplied by the per-unit voltage sag/swell to determine the amount of reactive current (up to rated current) supplied to support the voltage. There are separate coefficients for sag and swell.

Setting a K-factor to 0 disables reactive current support. This feature complies with the German Medium Voltage Grid Code requirements for renewable energy inverters (BDEW).

During VRT (grid fault) events, reactive current is automatically prioritized over real current. Megapack supplies negative sequence reactive current (up to rated current per phase) to support voltage imbalance due to grid faults under the same algorithm listed above.

During a grid fault, Megapack maintains its output power setpoint unless it is operating in current limit or the reactive current demand consumes the available output current capacity.

5.7.3 Frequency Ride-Through

Megapack has three under-frequency (UF) and three over-frequency (OF) trip points and times, as well as one under-frequency instantaneous trip point and one over-frequency instantaneous trip point. These parameters are configurable to the ranges listed in the table below:

Table 20. Megapack Frequency Trip Points

Trip Point	Frequency Range	Time (sec)	Notes
Instantaneous UF Trip	40 Hz-70 Hz	N/A	0.1 Hz resolution
UF Trip Time 3	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution
UF Trip Time 2	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution
UF Trip Time 1	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution
OF Trip Time 1	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution
OF Trip Time 2	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution
OF Trip Time 3	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution
Instantaneous OF Trip	40 Hz-70 Hz	N/A	0.1 Hz resolution

The Frequency Ride-Through (FQRT) settings are pre-programmed in the Megapack to comply with IEEE 1547 requirements per the table below:

Table 21. Megapack FQRT Default Settings

Function	Frequency (Hz)	Clearing Time (s)
UF1	< 57	0.16
UF2	< 59.5	2
OF1	> 60.5	2
OF2	> 62	0.16

5.7.4 Harmonics

When in grid-connected mode, Megapack complies with the IEEE 1547 harmonic current distortion requirements.

5.7.5 Grid-Connected Features

5.7.5.1 Active Anti-Islanding

All systems are equipped with active anti-islanding using the Sandia Frequency Shift methodology. Megapack autonomously and automatically detects an island condition, in which case it isolates from the grid and reports a trip to the user. Megapack can detect the island condition and trip within 2 seconds of island creation. An island condition is detected even if multiple Megapacks are connected on the same island area.

5.7.5.2 Passive Anti-Islanding

Megapack also optionally includes a rate of change of frequency (ROCOF) trip, which is configurable to site and user requirements. ROCOF is disabled by default, but Megapack detects an island condition and trips regardless of whether or not this feature is enabled. The ROCOF parameters available include:

Table 22. ROCOF Settings

Feature Name	Effect	Setting Range	Default
ROCOF Enable	Turns ROCOF on or off	n/a	Off
ROCOF Fault Limit	Sets the rate of change required for a trip	0.1-100.0 Hz/sec	1 Hz/sec
ROCOF Time Delay	Sets how long the rate of change has to be present for the Megapack to trip	0-1 seconds	1 second

NOTE: Anti-islanding can be disabled by a qualified Tesla technician or personnel only.

5.7.5.3 Automatic Grid Reconnection

Megapack automatically reconnects to the grid after a serious grid fault event. Megapack's configurable settings determine when and under what conditions it automatically reconnects to the grid.

Table 23. Reconnection Delay Timer Default Settings

Feature Name	Effect	Setting Range	Default
Reconnect Time Delay	The amount of time Megapack waits before reconnection, after the grid returns within the frequency and voltage windows defined above	0-1,000 sec	300 sec
Reconnect Min. Voltage	The minimum voltage at which Megapack interprets the grid is within tolerable conditions	0-150%	88.33%
Reconnect Max. Voltage	The maximum voltage at which Megapack interprets the grid is within tolerable conditions	0-150%	105.83%
Reconnect Min. Frequency	The minimum frequency at which Megapack interprets the grid is within tolerable conditions	40-70 Hz	59.3 Hz
Reconnect Max. Frequency	The maximum frequency at which Megapack interprets the grid is within tolerable conditions	40-70 Hz	60.5 Hz

The Reconnect voltage and frequency parameters are also used to determine whether it is safe for Megapack to synchronize to the grid upon initial start-up. Megapack has no time delay to connect to the grid after initial start-up.

5.7.6 Island Grid Controls

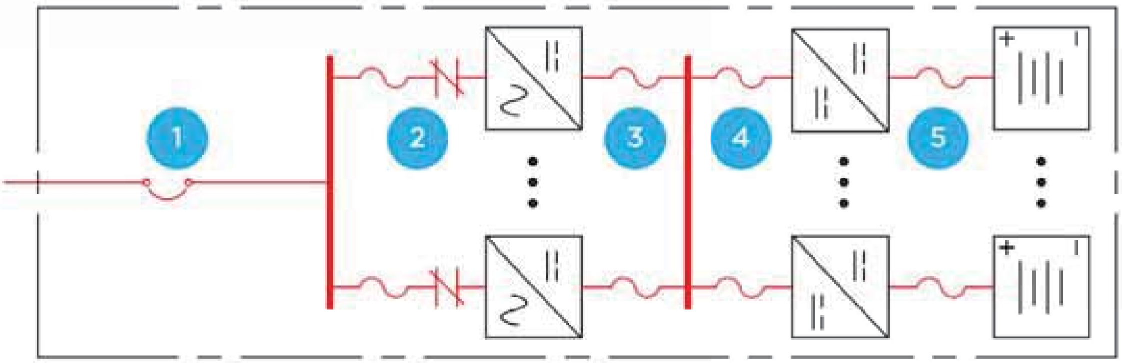
Megapack is capable of generating an island grid voltage. Its algorithm has been designed to be compatible with generators, renewable energy sources, and other microgrid assets. There are practical and sizing restrictions with microgrids that must be considered during site design.

Islanding typically requires additional hardware. For further design questions on this feature, talk to your Tesla representative.

5.8 System Protection Features

Megapack has both software and hardware system protection features as detailed below.

Figure 39. Megapack Protection Features



1. AC circuit breaker
2. Powerstage AC fuse and contactor
3. Powerstage DC fuse
4. DC/DC fuse
5. Battery module fuse

5.8.1 Battery Module Overcurrent Protection

The battery modules contain DC high speed, single use disconnects located in touch-safe holders mounted on the battery modules. Battery modules are also fused at both the input and output of the DC/DC (see callouts #4 and #5 in *Megapack Protection Features* on page 54). Fuses must only be serviced by Tesla-approved personnel.

5.8.2 Powerstage DC Fuses

Each Powerstage is equipped with its own set of DC fuses.

5.8.3 Powerstage AC Protection

Each Powerstage is equipped with its own AC contactor and AC fuses.

DANGER: Capacitors might have residual stored energy after the DC disconnect handle is actuated. Wait at least 5 minutes before entering the cabinet.

5.8.4 AC Circuit Breaker

The Customer Interface Bay contains a pre-installed AC circuit breaker to provide distribution system protection. Upon fault detection, the bi-directional circuit breaker will open to isolate the Megapack system. The breaker is not part of the internal Megapack protection scheme and must be programmed on-site according to site-specific plans or engineering guidance.

WARNING: Opening the circuit breaker will not ensure that the Megapack DC bus is de-energized. Refer to *Remote Shutdown* in *Low Voltage Area* on page 45 or the *Tesla Energy Controls and Communications Manual* for complete BESS shutdown command information.

NOTE: Additional protection or switching means at the output of the Megapack may be required depending on the jurisdiction. Protection and switching philosophy must be verified by the customer's engineer of record and should comply with regional and local codes.

Consult the manufacturer's documentation for the full AC circuit breaker specification:

Siemens Reference Documents

- *Siemens Low Voltage WL Circuit Breakers Selection and Application Guide: https://www.downloads.siemens.com/download-center/download?BTLV_43311*
- Product URL: *https://new.siemens.com/us/en/products/energy/low-voltage/low-voltage-circuit-breakers/wl-power-circuit-breakers.html*

Figure 40. AC Circuit Breaker

The circuit breaker is shipped with pre-configured general trip settings that must be changed upon arrival through the Electronic Trip Unit (ETU). The ETU has configurable settings for Long-time overcurrent protection (L), Short-time delayed overcurrent protection (S), Instantaneous Overcurrent Protection (I), Ground Fault Protection (G), and other features provided below. The Engineer of Record is responsible for the configuration of the ETU settings for system protection and proper operation.

External monitoring and control of the Megapack-specified circuit breaker is not a default offering. Through the Customer Interface Bay one can access terminals for external closing (Close Permissive Command), opening (Trip Command), and breaker status. The Customer Interface Bay allows for the use of external relays to command the breaker however, Megapack will only close the breaker if the system has been deemed safe from the Megapack logic. The Trip Command takes precedence over the Close Permissive Command.

NOTE: See *Low Voltage Area* on page 45 for more information on these commands and design of breaker monitoring and control.

Tesla AC circuit breaker part numbers:

- Megapack 4 Hour – L2F316UGJAXXAVN
- Megapack 2 Hour – L2F320UGJAXXAVN

NOTE: The breaker trip power supply is fed from multiple sources in the customer I/O area. While operating normally (above 0% state-of-charge and not faulted) power is provided by the battery modules. Jumpstart power (if provided) can also be used.

NOTE: The breaker open/close buttons are located 1730 mm (68.1 in) from the base of the Megapack. If the chosen foundation will place these buttons outside of local regulatory height requirements, ensure another method of compliance is provided (raised workstation, remote open/close terminals, etc.).

Table 24. Default Circuit Breaker Settings

ETU Pre-Configured Trip Settings	Megapack 4 Hour	Megapack 2 Hour
I_n (Plug Rating)	1600A	2000A
I_r (Long-time Current)	0.7 (1120A)	1.0 (2000A)
t_r* (Long-time Delay)	2 sec (6720A)	2 sec (12000A)
I_{sd} (Short-time Current)	1.25 (2000A)	1.25 (2500A)
t_{sd} (Short-time Delay)	0.1 sec (I^2t)	0.1 sec (I^2t)
I_i (Instantaneous Current)	1.5 (2400A)	1.5 (3000A)
I_g (Ground-fault Current)	B (300A)	C (600A)
t_g (Ground-fault Delay)	0.2 sec (I^2t)	0.2 sec (I^2t)
Toggle Switches	I^2t, I_n=Off	I^2t, I_n=Off

*I_n uses the same delay as t_r, long time delay.

Table 25. AC Circuit Breaker Control Summary

Breaker State	Trip Command	Close Permissive Command	Resulting Megapack Behavior
Open	Not Asserted	Asserted	Depending on desired behavior, the Megapack will perform internal checks and may close the breaker autonomously.
Open	Not Asserted	Not Asserted	The breaker will remain open until the Close Permissive is asserted.
Open	Asserted	Asserted	The breaker will remain open; the Trip Command takes precedence over the Close Permissive Command and the internal Megapack breaker operations.
Open	Asserted	Not Asserted	The breaker will remain open; the Trip Command takes precedence over the internal Megapack breaker operations.
Closed	Not Asserted	Asserted	The Megapack will operate per its internal logic; which may open the breaker
Closed	Not Asserted	Not Asserted	The Megapack will operate per its internal logic; which may open the breaker
Closed	Asserted	Asserted	The breaker will be tripped
Closed	Asserted	Not Asserted	The breaker will be tripped

5.8.5 Ground Fault Protection

Megapack is provided with a DC ground fault detection system. Megapack measures insulation resistance prior to operation and looks for excessive leakage current during operation.

The 900 V DC system is ungrounded (neither side of the DC link is grounded). The DC system is controlled, monitored, and protected by Tesla's DC Bus Controller (DCBC), which is located in the customer interface area and interfaces with all battery modules on a given DC bus. The DCBC contains ground fault protection in the form of isolation detection that continually monitors resistance to ground on both legs.

The 450 V battery side of the DCDC is also ungrounded, and protection is similar to the 900 V DC system. The battery module BMS runs isolation detection to ensure both legs are isolated from ground. A ground fault within the battery module turns the faulted Module off and allows the Megapack to continue operating.

Megapack also contains an AC circuit breaker with ground-fault trip settings. See *AC Circuit Breaker* on page 54 for more information.

5.8.6 Enclosure Safety and Enable Circuit

Megapack includes an enable circuit as a safety feature. Opening the door of any battery module or Powerstage bay shuts down all components that have sourcing abilities (DC/DC, DC/AC, or thermal controls).

The customer interface bay contains an AC circuit breaker that can be locked in the open position, as well as a DC Bus Keyed Lockout that can interrupt the enable circuit. The customer interface bay door is not part of the enable circuit, as it does not provide direct access to high voltage equipment. The enable circuit does not trip the AC breaker.

A remote shutoff connection is provided to which customers can connect via terminals in the customer I/O area. Operating the remote shutoff will trip the enable circuit and the AC circuit breaker.

Within the customer interface bay, the AC bus bars are covered by a touch-safe dead front panel that must be removed for access. This touch-safe panel has a dead front switch that will open the enable line when the panel is removed. The switch has an additional dry contact that can be wired to an upstream protection device to trip the upstream breaker and de-energize the line side bus bars.

Customer I/O also includes a captive-key DC Bus Keyed Lockout that is tied to the enable line for service and maintenance procedures. When the switch is opened the enable line is broken and the key can be used to manage LOTO procedures or similar.

The Megapack internal monitoring system uses the enable circuit to monitor for critical system faults and de-energize the system if needed. It is not recommended to use the enable feature as a means to de-energize the system; for example, do not open a Megapack door during operation as a means of shutting the system down. When deliberately de-energizing the system, always use the Tesla Site Controller to command a soft shutdown.

5.8.7 Required Protective Studies

While Megapack provides system protection features as outlined above, the system design engineer is responsible for providing Tesla the following information based on site conditions and protection studies for Tesla's review and approval:

- Arc flash calculations showing the available energy at the Megapack AC bus
- Isolating methods plan or switching scheme identifying the order of opening and who is responsible for each step
- See the *Megapack Construction Checklist* for more information on submitting switching scheme information

5.8.8 Lightning Protection Design

Protection from direct lightning strike: Megapack enclosures have internal frames that act like a Faraday cage, diverting currents to flow around the internal components but not through them. There is no expected impact on Megapack functionality due to a direct lightning strike. Hence, air terminations or lightning masts are not required to protect Megapack enclosures.

Protection from indirect lightning strike: Megapacks are designed with adequate power electronic component sizing and creepage clearance, in addition to monitored surge protection on the line side of Powerstages. Tests in accordance with IEEE C62.41.2 and IEEE C62.45 demonstrate that internal circuits and components of Megapack are protected from induced overvoltage from indirect lightning strikes.

5.9 Shutting the System Down

5.9.1 Shutting Down in an Emergency

WARNING: If smoke or fire is visible, do not approach the Megapack and do not open any of its doors.

CAUTION: External safety features such as E-stops and upstream breakers differ by region and design. Always be aware of your site's safety design and external safety features.

To shut down the system in an emergency or for unknown behavior:

1. If an external E-stop button or remote shutdown contact to Megapack is present, engage it.
2. If Megapack is serviced upstream by an external AC breaker or disconnect, open the breaker or disconnect.
3. Only if safe to do so, open the Customer Interface Bay door to access the AC breaker, remove the DC lockout key, and apply Lock Out, Tag Out (LOTO) if needed (see *Performing a Lock Out, Tag Out on page 59*).
4. Contact Tesla at *IndustrialStorageSupport@tesla.com* to advise that the system has been shut down.

Refer to the *Lithium-Ion Battery Emergency Response Guide* for details on response to a hazardous event.

5.9.2 Performing a Planned Shutdown

Perform this procedure for a single Megapack configuration:

1. If possible, command a soft shutdown of the system using the software via the Tesla Site Controller by commanding a power set point of zero. If the site manager does not have the means to command power, contact *IndustrialStorageSupport@tesla.com* to request the power shutdown command.
2. Open the site or feeder AC breaker or disconnect (if one is present).
3. Open the Megapack AC breaker to isolate the Megapack from the grid or other energy sources.

5.9.3 Performing a Planned Shutdown, Multiple Megapacks

If Tesla requests a qualified technician to prepare a site for a service action, or all power to a site must be suspended, follow these steps to safely de-energize Megapack and isolate upstream equipment:

1. Determine whether the entire site should be shut down, or only one Megapack.
    - **If shutting down power to the entire site,** command a soft shutdown of the system using the software via the Tesla Site Controller. If the site manager does not have the means to command power, contact *IndustrialStorageSupport@tesla.com* to request the power shutdown command.
        - On-grid system: command a power setting of zero
        - Microgrid system: change *Island Control Mode* to 2

- **If shutting down power to only one Megapack**, the power commands on the Tesla Site Controller do not require a change (but a change is permitted if desired).

2. Isolate AC power at the appropriate AC breaker.
   - **If shutting down power to the entire site,** open the site-wide AC breaker or disconnect to remove grid power.
   - **If shutting down power to one Megapack**, open the nearest upstream AC branch breaker (if a true breaker is present) that isolates that block.
3. Lock and tag out the AC breaker with an approved lock and tag that shows your personal information.
4. Open the Megapack AC disconnect to isolate the Megapack(s) from the grid or other energy sources.
5. **Wait** for Tesla Service or a Tesla-approved entity to arrive or provide further direction.

5.9.4 Performing a Lock Out, Tag Out

Lock Out, Tag Out (LOTO) is a procedure by which potentially dangerous machinery is ensured to be de-energized and locked in a de-energized state. Obtain and use an approved lock and a tag with your personal information on it. Notify all personnel that may be operating on, or within the vicinity of, the system being locked out. LOTO should be used any time the system is turned off and power is removed.

NOTE: Only Tesla or a Tesla-approved entity shall perform any corrective maintenance within the Megapack. All Tesla or Tesla-approved entities must complete Tesla's LOTO training.

WARNING: Only the person indicated on the lock and tag may move or remove the lockout device. Never move or remove locks and tags of other personnel on-site.

To perform a Lock Out, Tag Out:

1. Open the Customer Interface Bay to access the AC circuit breaker (see *Customer Interface Bay Overview* on page 41).

Figure 41. AC Circuit Breaker

1. Lock ring

2. Spring-loaded lever

2. Push up on the spring-loaded lever (callout #2, above) to unlock the lock ring (callout #1, above), and use a flat-head screwdriver to pull out the lock ring:

Figure 42. AC Circuit Breaker – Unlocking the Lock Ring

3. Insert the lock, lock it, and secure the AC circuit breaker:

Figure 43. AC Circuit Breaker – Locked

NOTE: This is the preferred LOTO procedure inside Megapack since it physically depresses the *Open* circuit button and forces the circuit breaker to stay open.

4. Optionally, customers can also lock out the spring charging handle (below), but this should only be in addition to the procedure outlined above, not alone:

Figure 44. AC Circuit Breaker - With Additional Spring Charging Lock Out

6 Installation

6.1 Logistics

The Megapack enclosure can be treated like an ISO standard shipping container, despite its custom dimensions. ISO 1161-type corner fittings are provided in all top corners to aid transportation and logistics. Megapack arrives onsite on a flatbed trailer and can be offloaded by lifting from the four top corners. Depending on site constraints and lifting equipment, additional rigging (spreader bars, shackles, etc.) may be required. Non-North American Megapacks may be delivered within a 40 foot High Cube (HC) shipping container.

See the *Megapack Transportation and Storage Guidelines* document for additional details.

6.2 Site Activities

The following site activities must take place for every Megapack being installed:

- Unloading
- Anchoring
- Wire and cable connections
  - 380-505 V (3 wire + ground circuit)
  - Communications (Ethernet/Fiber)
  - Control (Breaker status, etc...)
- Megapack commissioning, system commissioning and miscellaneous fine tuning
- Electrical inspection and testing

6.3 Signage Requirements

Signage must be posted in approved locations in accordance with local codes and standards.

7 Regulatory Compliance

7.1 General Compliance Information

Megapack will be compliant with all major global safety and grid code standards for battery energy storage systems. *Megapack Compliance Packet*, a full compliance packet of completed certifications in all regions, is available on the Tesla Partner Portal.

7.2 Environmental Compliance

Each Megapack contains approximately 540 L (140 gal) of 50-50 ethylene glycol-water mix, and approximately 7.6 kg (16.8 lb) of R-134a refrigerant in the coolant system. These substances are built into the Megapack and do not need to be added at the time of installation at site. Depending on the number of Megapacks installed on a site, storage, use and handling of these substances during maintenance events may require reporting, hazard management plans, or containment procedures as required by local codes.

7.2.1 Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)

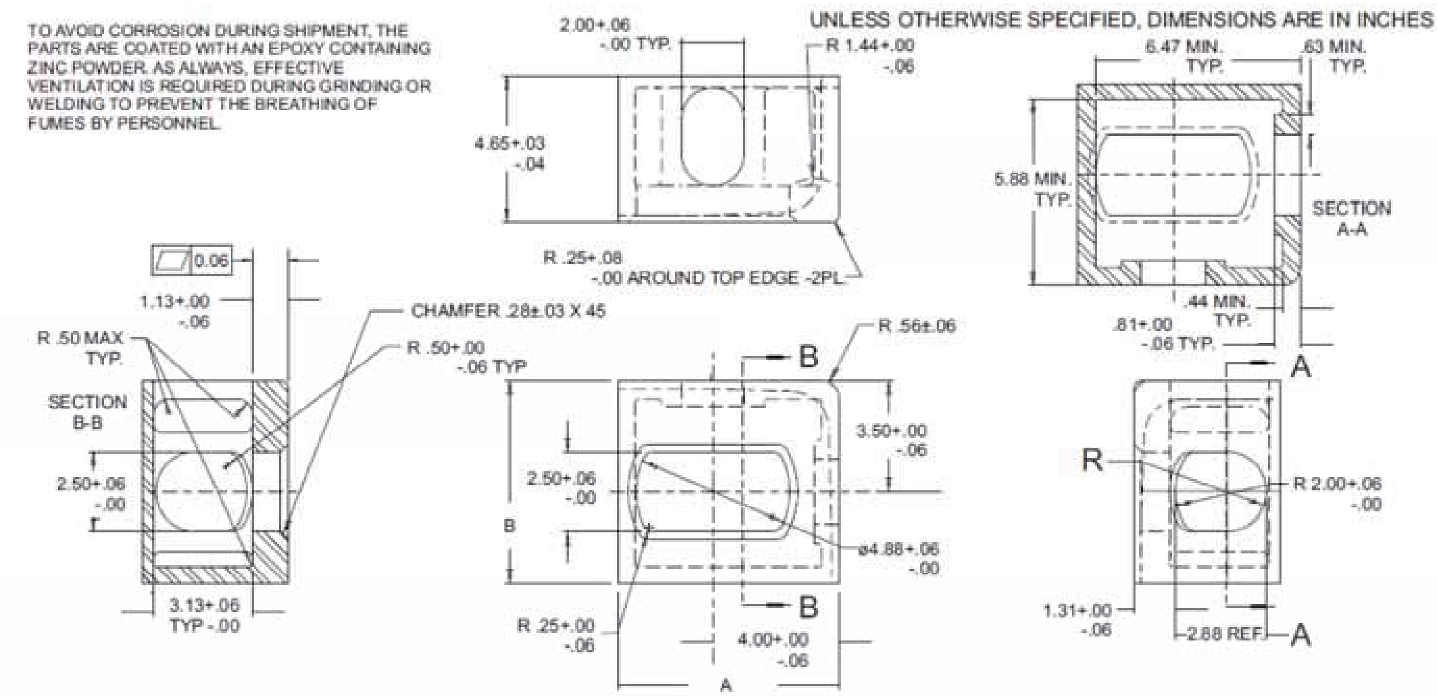
The Regulation (EC) No 1907/2006 of the European Parliament and of the Council of December 18, 2006 concerning the Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) entered into force on June 1, 2007. Tesla agrees with the purpose of REACH, which is to ensure a high level of protection of human health and the environment. Tesla is compliant with all applicable requirements of REACH.

The registration requirements do not apply to Tesla, since it is neither a manufacturer nor an importer of preparations into Europe.

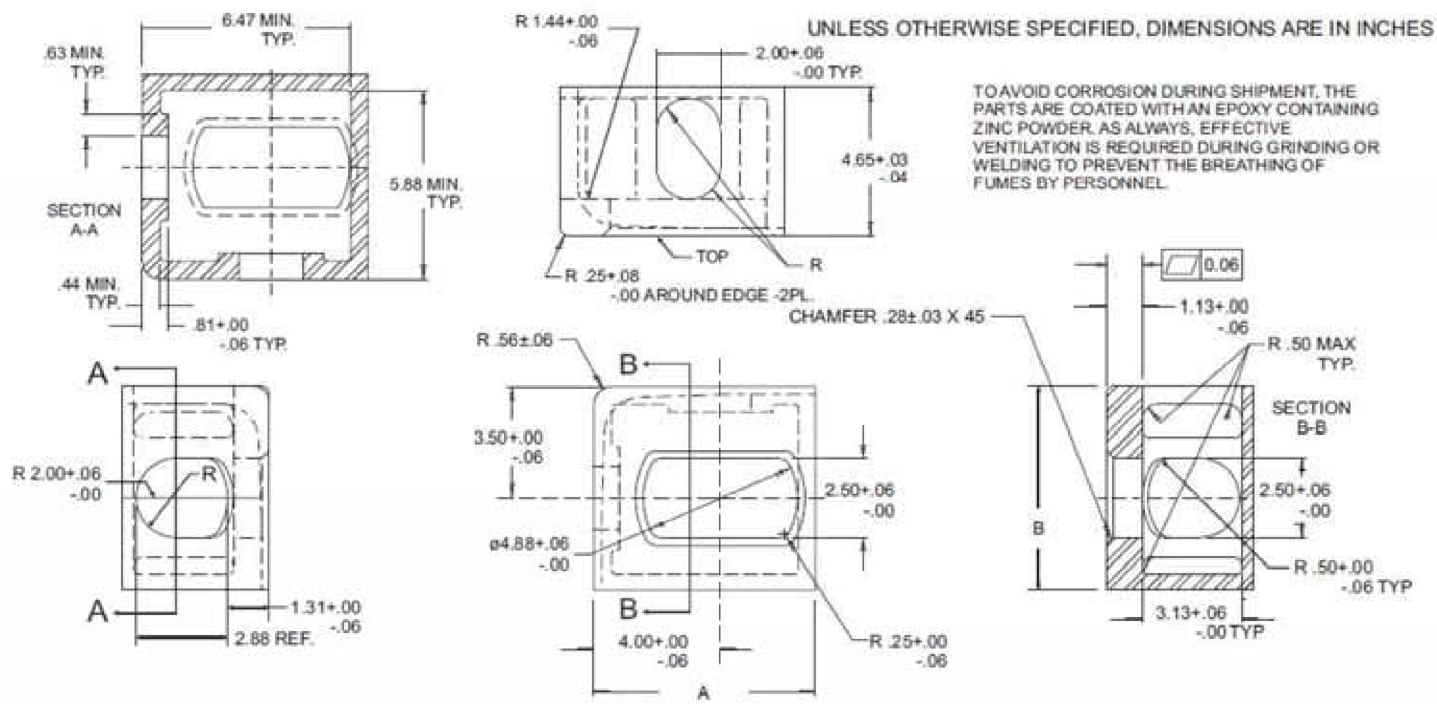
However, product (article) manufacturers or importers into Europe are obligated under Article 33 of REACH to inform recipients of any articles that contain chemicals on the Substances of Very High Concern (SVHC) candidate list above a 0.1% concentration (by weight per article). As of October 2016, products manufactured and marketed by Tesla do not contain substances on the REACH SVHC candidate list in concentrations greater than 0.1% by weight per article. Tesla continues to monitor the developments of the REACH legislation and will communicate with our customers according to the requirement above.

Appendix A – ISO Corner Dimensions

CORNER FITTING ISO 1161 TYPE - TOP RIGHT (243000C-TR)



CORNER FITTING ISO 1161 TYPE - TOP LEFT (243000C-TL)



Revision History

Revision #	Date	Description	Initials
1.0.0	07-01-2019	• Initial Release	JG/JK
1.1.0	09-20-2019	• Updated language for 3-wire configuration • Removed erroneous Powerpack references • Updated Circuit Breaker PNs and information • Updated Voltage-Ride Through tables	JK
1.1.1	01-29-2020	• Abbreviated short-circuit information	MW
1.2	February 26, 2020	• Removed pre-production watermark • All new Tesla Site Controller information • New Customer I/O wiring figures • New Customer I/O wiring drawing • New Customer Interface Bay Conduit Entry diagram • Updated anchoring requirements • Added site-level lighting language • Added signage requirement language • More detailed description of component locations, added detail on AC conduit window, added component numbering key • Clarified breaker trip power supply options • Added grounded circuit voltage requirements • Clarified clearance spec and language • Added total short-circuit withstand rating 85 kAIC • Updated electrical specifications • Updated product specs • Fixed and clarified pad slope deviation requirements • Changed wire specifications for backup and jump start	MW
1.3	March 2, 2020	• Edited Maximum HVRT table • Edited Customer I/O LV wiring spec • Added conduit diameter and figure to Customer I/O area	MW
1.4	June 26, 2020	• Format changes for transfer to DITA system • Updated drawings in Appendix • Updated anchoring information • Clarified electrical powering of Tesla Site Controller from a dedicated 120-480 V circuit	MW

Revision #	Date	Description	Initials
		• Removed details of 518 V operation; updated output voltage range • Removed the Over-Temperature topic • Enhanced backup power wiring section • Enhanced LV area wiring details • Updated XX36 and XX37 terminal wire spec • Updated DC fuses spec in AC & DC Load Side Area • Updated noise rating and provided additional information • Added DC/DC detail in System Protection Features • Added Megapack Schematic functional line diagram • Updated enclosure dimensions and weight • Removed imbalanced phase load note • Added new Site Safety section • Enhanced Hazard Mitigation and Safety as well as fire protection information • Enhanced transformer information • Updated label • Updated clearance information • Modified quantities of 2-hour and 4-hour conductor sets • Added arc flash safety information • Updated circuit breaker image • Added information about shutting the system down	
1.5	June 30, 2020	• Updated language about clearances to include egresses • Updated fencing language • Clarified 100 ms delay for Remote Shutdown • Removed Switchgear section and added note about potential switching to AC Circuit Breaker section	MW
1.6	July 14, 2020	• Added ISO corner fitting drawings • Modified jumpstart wiring voltage range • Added site-level power guidance • Replaced references to HV cables with power conductors • Added note about clearances to non-Megapack equipment • Clarified site access requirement	MW
1.8	August 7, 2020	• Clarified (increased) sustained wind speed specification (Cat 5)	MW
1.9	October 16, 2020	• Added *Voltage Classification* topic. • Generalized foundation language to replace pad- or grade-beam-specific language	MW

Revision #	Date	Description	Initials
		• Added diagram of location of site-level lighting conduit • Moved drawings from appendix to a ZIP file on Partner Portal • Added minimum drive aisle clearance requirement between Megapack foundations • Clarified minimum foundation overhang and other clearance figures and provided new diagrams • Enhanced content about wiring for backup power • Clarified maximum anchor protrusion in *Anchoring Design* • Added UL 1741 PCS requirements • Updated with improved fully populated energy ratings	
2.0	November 5, 2020	• Amended UL 1741 PCS requirements • Updated clearance diagrams for clarity • Added new *Lightning Protection Design* topic	MW
2.1	December 23, 2020	• Provided more specific foundation slope requirements in *Foundation Installation Requirements* on page 31. • Added section about protecting the IP66 enclosure: *The Megapack IP66 Enclosure* on page 10. • Added *Megapack Door Security* on page 36 section. • Added wye/delta configuration to *Transformer Design* on page 21. • Added illustration to *Center of Gravity* on page 28. • Introduced terminology for variants of Tesla Site Controller: Standard Site Controller, and Large Site Controller. Umbrella name still Tesla Site Controller. • Aligned terminology on Customer Interface Bay flooring: openings in floor are *conduit openings* (was: AC conduit window, AC window); covers for the openings are *gasketed floor panels* (was: AC gland plates, gland plates). • Added non-combustible clearance requirement for Megapacks with option code C008 in *Exposures and Fire Clearances* on page 34.	MW

TESLA

Megapack Site Design Manual – Revision 2.1 – Published December 23, 2020

Exhibit E

2020 Emergency Response Guide

Lithium-Ion Battery Emergency Response Guide

For Tesla Energy Products including Powerwall, Powerpack, and Megapack – TS-00004027 – REV 2.1

PRODUCT SPECIFICATIONS

All specifications and descriptions contained in this document are verified to be accurate at the time of printing. However, because continuous improvement is a goal at Tesla, we reserve the right to make product or documentation modifications at any time, with or without notice.

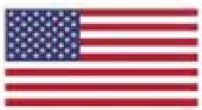
The images provided in this document are for demonstration purposes only. Depending on product version and market region, details may appear slightly different.

This document does not create contractual obligations for Tesla or its affiliates, except to the extent expressly agreed in a contract.

ERRORS OR OMISSIONS

To communicate any inaccuracies or omissions in this manual, please send an email to: *energy-pubs@tesla.com*.

MADE IN THE USA



CONTENTS

1.1 Scope

This guide serves as a resource for emergency responders and Authorities Having Jurisdiction (AHJs) with regards to safety surrounding Tesla Energy Products. Tesla Energy Products are defined as rechargeable lithium-ion battery energy storage products designed, manufactured, and sold by Tesla, and include products such as Megapack, Powerpack, and Powerwall. The information and recommendations set forth are made in good faith and believed to be accurate as of the date of preparation. TESLA, INC. makes no warranty, expressed or implied, with respect to this information.

2.1 Identification of Company and Contact Information

Table 1. Company and Contact Information

Products	Tesla Energy Products, designed for residential, commercial, and industrial/utility energy applications, and modules and sub-assemblies that can be installed in such products. Specific part numbers are listed below.	
Locations	Headquarters (USA)	3500 Deer Creek Road Palo Alto, CA 94304 USA Tel. No. +1 650-681-5000 (do not use for emergencies, see below)
	Europe and Africa	Burgemeester Stramanweg 122 1101EN Amsterdam, The Netherlands Tel. No. +31 20 258 3916 (do not use for emergencies, see below)
	Australia and Asia	Eastern Aoyama Building 4F 8-5-41 Akasaka, Minato-ku, Tokyo, Japan 107-0052 Tel: +81 3 6890 7700 (do not use for emergencies, see below)
	Manufacturer (USA)	3500 Deer Creek Road Palo Alto, CA 94304 USA Tel. No. +1 650-681-5000 (do not use for emergencies, see below)
Emergency Contacts	CHEMTREC	For Hazardous Materials (or Dangerous Goods) Incidents: Spill, Leak, Fire, Exposure, or Accident Call CHEMTREC Day or Night Within USA and Canada: 1-800-424-9300 Contract Number: CCN204273 Outside USA and Canada: +1 703-741-5970 (collect calls accepted)
	Tesla Service Support Contacts	Powerpack & Megapack: • Hotline numbers (24h / 7 coverage): ◦ North America: +1 (650) 681-6060 ◦ Australia: +1800 294 431 ◦ New Zealand: +0800 995 020 ◦ Japan: +0120 975 214

		◦ Asia/Pacific: +61 2 432 802 81 • Email support: *IndustrialStorageSupport@tesla.com* Powerwall: • Hotline numbers (24h / 7 coverage): ◦ North America: +(877) 798-3752 ◦ United Kingdom: +44 8000988064 ◦ Germany: +49 800 724 4529 ◦ Italy: +39 800596849 ◦ South Africa: +27 87 550 3480 • Email support: ◦ North America: *PowerwallSupportNA@tesla.com* ◦ Australia/New Zealand: *PowerwallSupportNA@tesla.com* ◦ Japan: *EnergyCustomerSupportJP@tesla.com* ◦ Europe/Middle East/Africa: *EnergySupportEmea@tesla.com*

2.2 SDS and Product Information

Safety Data Sheets (SDS) are a sub-requirement of the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard, 29 CFR Subpart 1910.1200. This Hazard Communication Standard does not apply to various subcategories including anything defined by OSHA as an "article." OSHA has defined "article" as a manufactured item other than a fluid or particle; (i) which is formed to a specific shape or design during manufacture; (ii) which has end use function(s) dependent in whole or in part upon its shape or design during end use; and (iii) which under normal conditions of use does not release more than very small quantities (e.g., minute or trace amounts) of a hazardous chemical, and does not pose a physical hazard or health risk to employees.

Tesla Energy Products referenced herein meet the OSHA definition of "article." Thus, they are exempt from the requirements of the Hazard Communication Standard and do not require an SDS. However, SDS are available for non-cell materials found inside these products.

Tesla Energy Products contain sealed lithium-ion battery cells (cells) that are similar to rechargeable batteries in many consumer electronic products. Cells are individually hermetically sealed cylinders approximately 21 mm in diameter and 70 mm in length.

Cells each contain lithium ion electrodes, which can be composed of either:

- Lithium Nickel Cobalt Aluminum Oxide (NCA material), $LiNi_xCo_yAl_zO_2$;
- Lithium Nickel, Manganese, Cobalt Oxide (NMC material) $LiNi_xMn_yCo_zO_2$;
- Lithium Nickel, Manganese Oxide (NMO material), $LiNi_xMn_yO_2$
- Lithium Cobalt Oxide, $LiCoO_2$;
- or a mixture of these compounds

THE CELLS AND BATTERIES DO NOT CONTAIN METALLIC LITHIUM. Individual cells have nominal voltages of approximately 3.6 V.

Tesla Energy Products also include sealed thermal management systems containing coolants and/or refrigerants. Safety Data Sheets (SDS) are available for these liquid materials.

Table 2. Thermal Contents

Non-Cell Materials with SDS found in Tesla Energy Products	Approximate Quantity
Ethylene glycol 50/50 mixture with water	Powerwall 1: 1.6 L of 50/50 mixture Powerwall 2: 2.3 L of 50/50 mixture Powerpack 1: 22 L of 50/50 mixture Powerpack 2: 26 L of 50/50 mixture Powerpack Inverter: 11 L of 50/50 mixture Megapack: 540 L of 50/50 mixture Powerpack Pod Module: none Megapack Battery Module: none
R134a: 1,1,1,2-Tetrafluoroethane refrigerant	Powerwall 1, 2: none Powerpack 1, 2: 400 g Megapack: 7.6 kg Powerpack Pod Module: none Megapack Battery Module: none

Individual lithium-ion cells are connected to form modules. Modules are battery sub-assemblies. These modules are installed in Tesla Energy Products. Approximate specifications of Tesla Energy Products are listed below.

Table 3. Approximate Tesla Energy Product Specifications

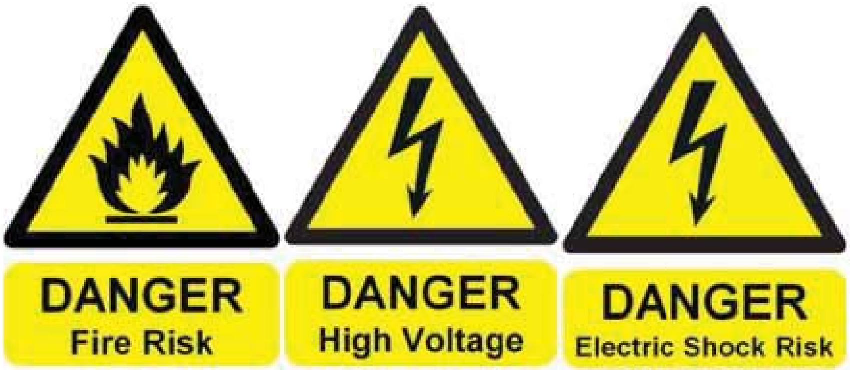
Part Number (Reman Number if available)	Description	Module Voltage – as shipped (V)	Max System DC Voltage	Max System AC Voltage	Weight (kg)	Height (cm)	Width (cm)	Depth (cm)
Powerwall 1 Versions								
1050100-x*y*-z*	POWERWALL, 2KW, 7KWH	<30 (DC)	450 (DC)	-	95 (210 lb)	130 (51 in)	86 (34 in)	18 (7 in)
1067000-x*y*-z*	POWERWALL, 3.3KW, 7KWH	<30 (DC)	450 (DC)	-	95 (210 lb)	130 (51 in)	86 (34 in)	18 (7 in)

Part Number (Reman Number if available)	Description	Module Voltage – as shipped (V)	Max System DC Voltage	Max System AC Voltage	Weight (kg)	Height (cm)	Width (cm)	Depth (cm)
1068000-x*y*-z*	POWERWALL, 6.6KW, 10KWH	<30 (DC)	450 (DC)	-	101 (223 lb)	130 (51 in)	86 (34 in)	18 (7 in)
Powerwall 2 Versions								
1092170-x*y*-z*	AC POWERWALL	<30 (DC)	450 (DC)	300 (AC)	114 (251.3 lb)	115 (45.3 in)	75 (29.6 in)	14 (5.75 in)
1112170-x*y*-z*	DC POWERWALL	<30 (DC)	450 (DC)	-	115 (254 lb)	112 (44 in)	74 (29 in)	14 (5.5 in)
Powerpack 1 Versions								
1047404-x*y*-z*	POWERPACK (2hr continuous net discharge)	<30 (DC)	450 (DC)	480 (AC)	1680 (3700 lb)	219 (86 in)	97 (38 in)	132 (52 in)
1060119-x*y*-z*	POWERPACK (4hr continuous net discharge)	<30 (DC)	450 (DC)	480 (AC)	1665 (3670 lb)	219 (86 in)	97 (38 in)	132 (52 in)
1121229-x*y*-z*	POWERPACK (4hr continuous net discharge)	<30 (DC)	450 (DC)	480 (AC)	2160 (4765 lb)	219 (86 in)	97 (38 in)	132 (52 in)
Powerpack 1.5 Version								
1089288-x*y*-z*	POWERPACK 1.5 C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	1622 (3575 lb)	219 (86 in)	131 (51.5 in)	82 (32.5 in)
Powerpack 2 / 2.5 Versions								
1083931-x*y*-z* (1130518-x*y*-z*)	POWERPACK 2,C/4 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160	219 (86 in)	131 (51.5 in)	82 (32.5 in)

Part Number (Reman Number if available)	Description	Module Voltage – as shipped (V)	Max System DC Voltage	Max System AC Voltage	Weight (kg)	Height (cm)	Width (cm)	Depth (cm)
					(4765 lb)			
1083932-x*y*-z*	POWERPACK 2,C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 (4765 lb)	219 (86 in)	131 (51.5 in)	82 (32.5 in)
1490025-x*y*-z*	POWERPACK 2.5,C/4 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 (4765 lb)	219 (86 in)	131 (51.5 in)	82 (32.5 in)
1490026-x*y*-z*	POWERPACK 2.5,C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 (4765 lb)	219 (86 in)	131 (51.5 in)	82 (32.5 in)
1490027-x*y*-z*	POWERPACK 2.5,C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 (4765 lb)	219 (86 in)	131 (51.5 in)	82 (32.5 in)
Megapack (all versions - dimensions as measured for enclosure envelope for 1462965-x*y*-z*)								
1462965-x*y*-z*	MEGAPACK	<450 (DC)	960 (DC)	505 (AC)	25,400 (56,000 lb) (max)	252.2 (99 ¼ in)	716.8 (282 ¼ in) (length)	165.9 (65 ¼ in)
Spare Parts								
N/A	POWERPACK POD MODULE	<30 (DC)	960 (DC)	N/A	98 (215 lb)	12 (5 in)	100 (39 ½ in)	75 (29 ½ in)
N/A	MEGAPACK BATTERY MODULE	<450 (DC)	960 (DC)	N/A	1,085 (2,400 lb)	66 (26 in)	81 (32 in)	149 (59 ½ in)

* *Note that the 8th or 9th digit could be any number or letter and the 10th digit could be any letter.*

3.1 General Precautions



The products described by this document are dangerous if mishandled. Injury to property or person, including loss of life is possible if mishandled.

Tesla Energy Products contain lithium-ion batteries. A battery is a source of energy. Do not short circuit, puncture, incinerate, crush, immerse, force discharge or expose to temperatures above the declared operating temperature range of the product. An internal or external short circuit can cause significant overheating and provide an ignition source resulting in fire, including surrounding materials or materials within the cell or battery. Under normal conditions of use, the electrode materials and electrolyte they contain are not exposed, provided the battery integrity is maintained and seals remain intact. Risk of exposure may occur only in cases of abuse (mechanical, thermal, electrical).

3.2 High-Voltage Hazards

Under normal conditions of use, provided that a Tesla Energy Product enclosure remains closed, handling the product does not pose an electrical hazard. Numerous safeguards have been designed into Tesla Energy Products to help ensure that the high voltage battery is kept safe and secure as a result of a number of expected abuse conditions. All of the constituent component battery cells are sealed within the product as sub-groups within enclosures (Pods for Powerpack or battery modules for Megapack).

In Powerpack and Megapack, the exterior of each Pod/battery module is isolated from internal components and connectors are touch-safe. Pods are then installed in a rigid metal enclosure, which is isolated from high voltage. Megapack battery modules are similarly sealed and cannot be accessed from the exterior. In the Powerwall, the module is contained within the unit and not accessible to non-Tesla personnel. Access to these components is limited to Tesla-authorized personnel only.

A Tesla Energy Product may pose a significant high voltage and electrocution risk if the outer enclosure, Pod / battery module enclosures and/or safety circuits have been compromised or have been significantly damaged. A battery pack, even in a normally discharged condition, is likely to contain substantial electrical charge and can cause injury or death if mishandled. If a Tesla Energy Product has been significantly visibly damaged or its enclosure compromised, practice appropriate high-voltage preventative measures until the danger has been assessed (and dissipated if necessary).

WARNING: NEVER CUT INTO A SEALED TESLA ENERGY PRODUCT ENCLOSURE due to the high voltage and electrocution risks.

For proper installation / removal instructions please contact the Tesla Service Support team.

3.3 Hazards Associated with Mechanical Damage

Mechanical damage to Tesla Energy Products can result in a number of hazardous conditions (discussed below) including:

- Leaked battery pack coolant (see *Hazards Associated with Leaked Coolant* on page 9)
- Leaked refrigerant (Powerpack System and Megapack only, see *Hazards Associated with Leaked Refrigerant (Powerpack and Megapack Only)* on page 9)
- Leaked cell electrolyte (see *Hazards Associated with Leaked Electrolyte* on page 10)
- Rapid heating of individual cells due to exothermic reaction of constituent materials (cell thermal runaway), venting of cells, and propagation of self-heating and thermal runaway reactions to neighboring cells.
- Fire

To prevent mechanical damage to Tesla Energy Products, these items should be stored in their original packaging when not in use or prior to being installed (see *Storage Precautions* on page 16).

3.4 Hazards Associated with Elevated Temperature Exposure

Tesla Energy Products are designed to withstand operating ambient temperatures up to 50°C (122°F), with up to 100% operating humidity (condensing), and storage temperatures up to 60°C (140°F) and <95% relative humidity (non-condensing) for up to 24 hours without affecting the health of the unit.

Prolonged exposure of Tesla Energy Products to temperatures beyond that can drive battery cells into thermal runaway and result in a fire. Exposure of battery packs to localized heat sources such as flames could result in cell thermal runaway reactions and should be avoided.

3.5 Hazards Associated with Leaked Coolant

Thermal management of Tesla Energy Products is achieved via liquid cooling using a 50/50 mixture of ethylene glycol and water. A typical Powerpack battery unit includes about 26 L of coolant (Powerpack 2/2.5) or about 22 L of coolant (Powerpack 1). A typical Powerwall unit includes about 1.6 L of coolant (Powerwall 1) or about 2.3 L of coolant (Powerwall 2). The Powerpack Inverter (fully populated) includes about 11 L of coolant. A typical Megapack includes about 540 L of coolant. Mechanical damage of a Tesla Energy Product that has been installed could result in leakage of the coolant. The fluid is blue in color and does not emit a strong odor.

For information regarding the toxicological hazards associated with ethylene glycol, as well as ecological effects and disposal considerations, refer to the specific Safety Data Sheet (SDS) for battery coolant.

Extended exposure of a Tesla Energy Product to leaked coolant could cause additional damage to the product such as corrosion and compromise of protection electronics.

3.6 Hazards Associated with Leaked Refrigerant (Powerpack and Megapack Only)

The Powerpack and Megapack thermal management system includes 400 g and 7.6 kg respectively of R134a: 1,1,1,2-Tetrafluoroethane refrigerant in a sealed system. Mechanical damage of a Powerpack or Megapack could result in a release of the refrigerant. Such a release would appear similar to the emission of smoke.

For information regarding the toxicological hazards associated with R134a, as well as ecological effects and disposal considerations, refer to the specific Safety Data Sheet (SDS) for R134a.

3.7 Hazards Associated with Leaked Electrolyte

The electrolyte within constituent cells includes a volatile hydrocarbon-based liquid and a dissolved lithium salt (which is a source of lithium ions) such as lithium hexafluorophosphate. The electrolyte in Tesla Energy Products' cells is largely absorbed in electrodes within individual sealed cells. The electrolyte reacts with those materials and is consumed during normal operation of the batteries. As such, the absence of free liquid electrolyte makes it impractical to report the volume of electrolyte within Tesla Energy Products.

The possibility of a spill of electrolyte from Tesla Energy Products is very remote. Electrolyte can be extracted from a single cell using a centrifuge, or under some extreme abuse conditions such as a severe crush. However, it is very difficult to mechanically damage cells in such a way as to cause leakage of electrolyte. Even if a single cell were damaged in a manner that could cause electrolyte leakage, it is extremely difficult to cause a leak from more than a few cells due to any incident. Furthermore, cells are connected into modules which are placed within a sealed steel compartmentalized enclosure. Each compartment has the capacity to contain liquid from a large number of individual cells. For the electrolyte liquid to come into contact with a user of a Tesla Energy Product, the external enclosure, the Pod/battery module enclosure, and the cell would have to be severely mechanically damaged. As such, Tesla Energy Products are deemed not to pose a liquid electrolyte release hazard.

Any released electrolyte liquid is likely to evaporate rapidly, leaving a white salt residue. Evaporated electrolyte is flammable and will contain alkyl-carbonate compounds. Leaked electrolyte is colorless and characterized by a sweet odor. If an odor is obvious, evacuate or clear the surrounding area and ventilate the area.

WARNING: AVOID CONTACT WITH ELECTROLYTE.

Leaked electrolyte solution is flammable and corrosive / irritating to the eyes and skin. If a liquid is observed that is suspected electrolyte, ventilate the area and avoid contact with the liquid until a positive identification can be made and sufficient protective equipment can be obtained (eye, skin, and respiratory protection). Chemical classifier strips can be used to identify the spilled liquid (electrolyte will contain petroleum/organic solvent and fluoride compounds).

In case of an electrolyte leak, the following protective equipment is recommended: an air purifying respirator with organic vapor/acid gas cartridges, safety goggles or a full-face respirator, and safety gloves (Butyl rubber or laminated film (e.g., Silver Shield)). Protective clothing should be worn. Use a dry absorbent material to clean up a spill.

NOTE: An acceptable exposure concentration of electrolyte has not been identified by the American Council of Governmental Industrial Hygienists (ACGIH). In case of electrolyte leakage from the battery, the oral (rat) LD50 is greater than 2 g/kg (estimated).

3.8 Hazards Associated with Vented Electrolyte

Lithium-ion cells are sealed units, and thus under normal usage conditions, venting of electrolyte should not occur. If subjected to abnormal heating or other abuse conditions, electrolyte and electrolyte decomposition products can vaporize and be vented from cells. Accumulation of liquid electrolyte is unlikely in the case of abnormal heating. Vented gases are a common early indicator of a thermal runaway reaction - an abnormal and hazardous condition.

If gases or smoke are observed escaping from a Tesla Energy Product, evacuate the area and notify a first responder team and/or the local fire department. Gases or smoke exiting a lithium-ion battery pack are likely flammable and could ignite unexpectedly as the condition that led to cell venting may also cause ignition of the vent gases. A venting Tesla Energy Product should only be approached with extreme caution by trained first responders equipped with appropriate personal protective equipment (PPE), as discussed in *Firefighter PPE* on page 13.

Cell vent gas composition will depend upon a number of factors, including cell composition, cell state of charge, and the cause of cell venting. Vent gases may include volatile organic compounds (VOCs) such as alkyl-carbonates, methane, ethylene, and ethane; hydrogen gas; carbon dioxide; carbon monoxide; soot; and particulates containing oxides of nickel, aluminum, lithium, copper, and cobalt. Additionally, phosphorus pentafluoride, POF3, and HF vapors may form.

WARNING: AVOID CONTACT WITH VENTED GASES.

Vented gases may irritate the eyes, skin, and throat. Cell vent gases are typically hot; upon exit from a cell, vent gas temperatures can exceed 600°C (1,110°F). Contact with hot gases can cause thermal burns. Vented electrolyte is flammable and may ignite on contact with a competent ignition source such as an open flame, spark, or a sufficiently heated surface. Vented electrolyte may also ignite on contact with cells undergoing a thermal runaway reaction.

4.1 Firefighting Measures

CAUTION: In the event of a response to a Tesla product fire or hazardous event, contact Tesla immediately for technical guidance. Response should only be performed by trained professionals.

To create a significant fire in Tesla Energy Products, the enclosure of the battery unit needs to be subject to an extreme external event, such as direct exposure to a large prolonged fire or severe physical impact. A single cell thermal runaway does not propagate to neighboring cells as demonstrated in testing per UL and IEC standards. In the event of a fire, rigorous full-scale fire testing has shown that Tesla Energy Products perform in a safe and controlled manner, consuming themselves slowly without explosive bursts, deflagrations, or unexpected hazards, and without propagating to neighboring enclosure units. These claims have been validated through large-scale fire testing, with available third-party reports.

4.1.1 Responding to a Venting Tesla Energy Product

Smoke emanating from a Tesla Energy Product can be an indication of an abnormal and hazardous condition. Battery thermal runaway fires are preceded by a period of smoke. The smoke is likely flammable and may ignite at any time. If fire or smoke is observed emanating from a Tesla Energy Product at any time, the following should be performed:

1. If possible, shut off the unit/system (see *Shutting Down in an Emergency* on page 14)
2. Evacuate the area
3. Notify appropriately trained first responders, the local fire department, and any appointed subject matter expert (SME) if available

WARNING: When responding to a fire event with the **Powerpack System**, do not approach the Powerpack units from the front (door-side). Perform all incident response from the sides or rear of the unit. Do not attempt to open the enclosure door or come in contact with the unit. Per testing results, a Powerpack fire will not propagate to neighboring Powerpacks.

WARNING: When responding to a fire event with **Megapack**, do not approach the unit and attempt to open any doors. The doors are designed to remain shut, and built-in deflagration vents in the roof of the unit will vent any smoke and flame out of the top of the unit and front thermal system intake louvers. Per testing results, a Megapack fire will not propagate to neighboring Megapacks.

The Tesla Energy Product should then be monitored for evidence of continued smoke venting. If a fire develops and visible flames appear, it is recommended to apply water spray to neighboring battery enclosures and exposures (see *Defensive Firefighting* on page 13), rather than directly onto the burning unit. Applying water directly to the affected enclosure will not stop the thermal runaway event, as the fire will be located behind several layers of steel material, and direct application of water has shown to only delay the eventual combustion of the entire unit. The door(s) should not be opened in such an event. Testing has shown that a thermal runaway event in a single Powerpack or Megapack does not propagate to a neighboring enclosure, even without the application of water or other suppression sources, but water can be used to further mitigate the hazard spread to exposures and surroundings.

Water spray has been deemed safe as an agent for use on exposed Tesla Energy Products. Water is considered the preferred agent for suppressing lithium-ion battery fires. Water has superior cooling capacity, is plentiful (in many areas), and is easy to transport to the seat of the fire. Gaseous agents such as CO2, Halon, or dry chemical suppressants may temporarily suppress flaming of lithium-ion battery packs, but they will not cool lithium-ion batteries and will not limit the propagation of cell thermal runaway reactions. Metal fire suppressants such as LITH-X, graphite powder, or copper powder are not appropriate agents for suppressing fires involving lithium-ion battery packs as they are unlikely to be effective.

If water is used directly on the enclosure that is burning, electrolysis of water (splitting of water into hydrogen and oxygen) may contribute to the flammable gas mixture formed by venting cells, burning plastic, and burning of other combustibles.

A battery fire may continue for several hours and it may take 24 hours or longer for the battery pack to cool after it has been fully consumed by a thermal runaway event. A lithium-ion battery fire that has been seemingly extinguished can flare up again if all cells have not been consumed due to the exothermic reaction of constituent materials from broken or damaged cells, or unburnt cells. Allow the battery pack to fully consume itself and then cool the burned mass by flooding with water. After all fire and smoke has visibly subsided, a thermal imaging camera can be used to actively measure the temperature of the unit.

4.1.2 Defensive Firefighting

Tesla's recommendation is to fight a Tesla Energy Product fire defensively. The fire crew should maintain a safe distance and allow the battery to burn itself out. Fire crews should utilize a fog pattern to protect neighboring units or exposures or control the path of smoke. A single one-and-three-quarter inch (~5cm) hand line has shown to be sufficient. Applying water directly on the burning unit will only delay the burn and not suppress it. A battery fire may continue for several hours and may result in multiple flare-up events due to the way thermal runaway propagates throughout the enclosure. It may take 24 hours or longer for the battery pack to cool once completely consumed.

4.1.3 Firefighter PPE

Firefighters should wear self-contained breathing apparatus (SCBA) and fire protective turnout gear. Cells or batteries may flame or leak potentially hazardous organic vapors if exposed to excessive heat, fire or over voltage conditions. These vapors may include volatile organic compounds (VOCs), hydrogen gas, carbon dioxide, carbon monoxide, soot, and particulates containing oxides of nickel, aluminum, lithium, copper, and cobalt. Additionally, phosphorus pentafluoride, POF3 and HF vapors may form.

WARNING: Shutting off power to a Tesla Energy Product does not de-energize the battery, and a shock hazard may still be present.

WARNING: If smoke or fire is visible, do not approach the product or open any of its doors.

To shut off the Powerpack System, Megapack, or Powerwall in an emergency:

5.1 Powerpack System

1. If an external E-stop button or remote shutdown contact to Powerpack is present, engage it.
2. If Powerpack is serviced upstream by an external AC breaker or disconnect, open the breaker or disconnect.
3. Only if safe to do so, open the DC disconnect switch on the inverter door.

5.2 Megapack

1. If an external E-stop button or remote shutdown contact to Megapack is present, engage it.
2. If Megapack is serviced upstream by an external AC breaker or disconnect, open the breaker or disconnect.
3. Only if safe to do so, open the customer interface bay door to access the AC breaker, remove the DC lockout key, and apply Lock Out, Tag Out (LOTO) if needed.

5.3 Powerwall

1. If an E-Stop button is present, engage the E-Stop.
2. Open the AC disconnect installed upstream of the system.

6.1 First Aid Measures

6.1.1 Electric Shock / Electrocution

Seek immediate medical assistance if an electrical shock or electrocution has occurred (or is suspected).

6.1.2 Contact with Leaked Electrolyte

The constituent battery cells are sealed. Contents of an open (broken) constituent battery cell can cause skin irritation and/or chemical burns. If materials from a ruptured or otherwise damaged cell or battery contact skin, flush immediately with water and wash affected area with soap and water. If a chemical burn occurs or if irritation persists, seek medical assistance.

For eye contact, flush with significant amounts of water for 15 minutes without rubbing and see a physician at once.

6.1.3 Inhalation of Electrolyte Vapors

If inhalation of electrolyte vapors occurs, move person into fresh air. If not breathing give artificial respiration and seek immediate medical assistance.

6.1.4 Vent Gas Inhalation

The constituent battery cells are sealed and venting of cells should not occur during normal use. If inhalation of vent gases occurs, move person into fresh air. If not breathing give artificial respiration. Seek immediate medical assistance.

7.1 Storage Precautions

Powerpack systems, Powerwalls, and sub-assemblies should be stored in approved packaging prior to installation. Megapack does not include packaging and can be stored as-shipped with a tarp.

Do not store Tesla Energy Products in a manner that allows terminals to short circuit (do not allow the formation of an electrically-conductive path).

Elevated temperatures can result in reduced battery service life. Tesla Energy Products can withstand ambient temperatures of -40°C to 60°C for up to 24 hours. However, Tesla Energy Products stored for longer than one month should be stored at ambient temperatures between -20°C and 30°C (-4°F and 86°F), at humidity <95%, and protected from condensation. Storing at temperatures outside the recommended range can result in degradation of product lifetime. Do not store Tesla Energy Products near heating equipment.

Ideally, a Tesla Energy Product should be stored at 50% state of charge (SOC) or less. Tesla Energy Products should not be stored for extended periods either at a full SOC or completely discharged since both conditions adversely impact battery life. Tesla Energy Products should not be stored untended for longer than twelve months since battery service life likely will be adversely impacted.

The storage area should be protected from flooding.

Long-term storage areas should be compliant with the appropriate local fire code requirements.

Acceptable storage density of battery packs and storage height of battery packs will be defined by the local authority having jurisdiction (AHJ). Requirements and limits will be based upon a number of factors including the structural and fire protection characteristics of the storage area and recommendations for fire protection promulgated by the National Fire Protection Association (NFPA) and similar organizations. At the time of this writing, no standard Commodity Classification has been defined for lithium-ion cells or battery packs (see 2016 NFPA 13: Standard for the Installation of Sprinkler Systems). Tesla products only have a 30-40 % state of charge (SOC) while in storage which reduces the energy impact on fire occurrences. As an example of the reduced energy, the 30% level has been determined to be acceptable for air flight shipping based upon extensive testing and analysis in conjunction with the FAA. Tesla recommends treating lithium-ion cells and batteries in packaging as equivalent to a Group A Plastic Commodity.

8.1 Handling, Storage, and Transportation of Damaged Tesla Energy Products

If the event of damage to a Tesla Energy Product, contact Tesla immediately.

If a Tesla Energy Product has been damaged (battery enclosure has been dented or compromised), it is possible that heating is occurring that may eventually lead to a fire. Damaged or opened cells/batteries can result in rapid heating (due to exothermic reaction of constituent materials), the release of flammable vapors, and propagation of self-heating and thermal runaway reactions to neighboring cells.

Before handling or transporting a damaged Tesla Energy Product, wait at least 24 hours. Smoke may be an indication that a thermal reaction is in progress. If no smoke, flame, sign of coolant leakage, or signs of heat has been observed for 24 hours, the Tesla Energy Product may be disconnected and moved to a safe location. To obtain specific instructions for evaluating, disconnecting, and preparing a damaged Tesla Energy Product for transport, please contact the Tesla Service team.

A damaged Tesla Energy Product should be monitored during storage for evidence of smoke, flame, sign of coolant leakage, or signs of heat. If full-time monitoring of the Product is not possible (for example during extended storage), the Product should be moved to a safe storage location.

A safe storage location for a damaged battery will be free of flammable materials, accessible only by trained professionals, and 50 feet (15m) downwind of occupied structures. For example, a fenced, open yard may be an appropriate safe location. DO NOT STORE DAMAGED TESLA ENERGY PRODUCTS ADJACENT TO UNDAMAGED TESLA ENERGY PRODUCTS. It is possible that a damaged battery may sustain further damage during transportation and may lead to a fire. To further reduce this risk, handle the damaged battery with extreme caution.

9.1 Disposal Procedures

Tesla Energy lithium-ion batteries do not contain heavy metals such as lead, cadmium, or mercury.

The procedures below apply to Tesla Energy Products at the end of their life (EOL). For disposal after a fire or thermal event, please contact Tesla for guidance.

Tesla Energy Products should be disposed of or recycled in accordance with local, state, and federal regulations. Note that regulations regarding disposal of batteries vary by jurisdiction. In the United States, batteries are classified as Universal Waste, and in addition, many individual states have specific regulations regarding disposal of battery packs. For example, in California, all batteries must be taken to a Universal Waste handler or authorized recycling facility.

Tesla Energy Products contain recyclable materials. Tesla strongly encourages recycling. At this time, when a Tesla product must be decommissioned, we request that it be returned to a Tesla facility for disassembly and further processing.

If disposing without return to Tesla, please consult with local, state and/or federal authorities on the appropriate methods for disposal and recycling. Tesla has confirmed that at least two recycling processors are capable of recycling Tesla battery products in North America and three in the Europe, the Middle East and Africa (EMEA) region.

10.1 Maintenance or Repair

Tesla requests all maintenance, service, and repairs of Tesla Energy Products be performed by Tesla-approved service personnel or Tesla authorized repair facilities. This includes all proactive and corrective maintenance over the lifetime of a Tesla Energy Product. Improper service or repair by personnel not approved nor authorized by Tesla could void the product's Limited Warranty, lead to failure of the Tesla Energy product, and potentially result in development of an unsafe condition and unexpected electrical events.

11.1 Transport Information

Lithium-ion batteries are regulated as Class 9 Miscellaneous dangerous goods (also known as "hazardous materials") pursuant to the International Civil Aviation Organization (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air, International Air Transport Association (IATA) Dangerous Goods Regulations, the International Maritime Dangerous Goods (IMDG) Code, European Agreements concerning the International Carriage of Dangerous Goods by Rail (RID) and Road (ADR), and applicable national regulations such as the USA's hazardous materials regulations (see 49 CFR 173.185). These regulations contain very specific packaging, labeling, marking, and documentation requirements. The regulations also require that individuals involved in the preparation of dangerous goods for transport be trained on how to properly package, label, mark and prepare shipping documents.

UN Number	3480
Proper Shipping Name	Lithium Ion Batteries
Hazard Classification	Class 9 Miscellaneous
Packing Group	N/A

NOTE: The information and recommendations set forth are made in good faith and believed to be accurate as of the date of preparation. TESLA, INC. makes no warranty, expressed or implied, with respect to this information.

Revision #	Date	Description
01	14-July-2015	ERG for Tesla Powerpack systems, Powerwalls, and Sub-assemblies
02	3-Sept-2015	Added part numbers, updated weights, voltages, and temperatures, clarified hazards associated with spilled electrolyte, updated storage requirements, updated warning label icons, updated packing group.
03	3-Oct-2016	Added part numbers, minor edits
04	30-June-2017	Added fire ground operations response for Powerpack 2, including approach; exhaust gases; and safety. Updated general product information and contacts, as well as part numbers and reman numbers
05	22-Oct 2018	Reformatted for ease of use and translation; removed Confidential status; corrected phone number for CHEMTREC
06	27-Feb-2019	Updated storage conditions and firefighting measures section to provide further context on response tactics to Tesla Energy Product fires. Adjusted formatting, included graphics for warnings and notices.
07	17-Dec-2019	Updates to contact information (Tesla contact), product specs section, leaked electrolyte section, and inclusion of Megapack throughout the document.
1.8	March 11, 2020	Fixed footer; fixed styles.
2.0	July 8, 2020	• Updated formatting • Updated product specs • Updated contact info • Corrected elevated temperature topic to include Megapack • Corrected name of Tesla Inverter to Powerpack Inverter • Separated information on shutting down into its own topic for visibility • Reorganized the Firefighting section for clarity • Updated language on re-ignition risks
2.1	August 28, 2020	• Added spare parts specifications: ◦ Megapack battery module ◦ Powerpack Pod module

Exhibit F

Calculations