Overview of Power Efficient Design Strategies

An Initiative of the Consortium for Power Efficiency

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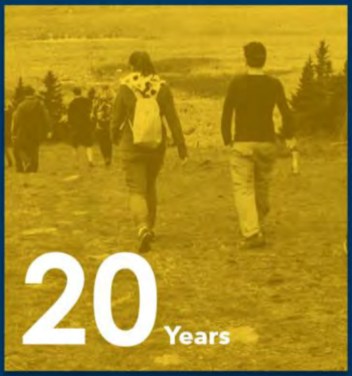
About Dunsky



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With deep expertise across the Buildings, Mobility, Industry and Energy sectors, we support our clients in two ways: through rigorous **Analysis** (of technical, economic and market opportunities) and by designing or assessing **Strategies** (plans, programs and policies) to achieve success.

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List of Acronyms

AC	Alternating Current
AHJ	Authority Having Jurisdiction
ASHP	Air Source Heat Pump
BIA	Battery Integrated Appliance
ccASHP	Cold-Climate Air Source Heat Pump
CE Code	Canadian Electrical Code
CSA	Canadian Standards Association
CT	Current Transformer
DHW	Domestic Hot Water
DSM	Demand Side Management
EMS	Energy Management System
EV	Electric Vehicle
EVEMS	Electric Vehicle Energy Management System
EVSE	Electric Vehicle Supply Equipment
GSHP	Ground Source Heat Pump
HPWH	Hybrid Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
kW	Kilowatt
NEC	National Electrical Code (United States)
PED	Power Efficient Design
SDO	Standards Development Organization
UL	Underwriters Laboratories
VRF	Variable Refrigerant Flow
W	Watt

Executive Summary

What is Power Efficient Design?

Power efficient design (PED) refers to strategies to limit buildings' electricity use, ensuring that power demands stay within the constraints of buildings' electrical services (i.e., their connections to the electrical grid) and other infrastructure. PED is important to enable a lower-cost transition to electric heating, cooling and electric vehicle (EV) charging. Likewise, PED can enable denser new development in existing neighbourhoods by avoiding higher-capacity, more expensive electrical services. This helps keep costs down for new construction while allowing more electrification.

Power Efficiency vs. Energy Efficiency: Power efficiency focuses on reducing the *instantaneous* use of electrical power to stay within specific limits, while energy efficiency focuses on reducing the *overall* amount of electricity used over time. With good design, both power efficiency and energy efficiency can be achieved.

Table 1: Categories of PED

Optimize Load Calculations	Efficiency and Right-Sizing	Energy Management	Energy Storage
Calculate loads to better reflect true demand	Save power through energy efficiency.	Monitor and control power to stay within capacity limits.	Store power for when it is most needed.

PED strategies fall into four broad categories:

- **Optimizing Load Calculations:** Electrical codes require load calculations to demonstrate that the electrical capacity of electrical services, feeders and other infrastructure are not exceeded. Prescribed load calculation methodologies can be better optimized, and historical load calculation pathways better enabled, to more accurately calculate design loads while ensuring electrical safety.
- **Building Efficiency and Right-Sizing Loads:** More efficient building systems (for example, building envelope, heating, cooling, lighting, etc.) can reduce the peak power consumption in buildings and enable use of lower amperage equipment. In turn, selecting lower-amperage equipment ensures that the electrical capacity is used more effectively, minimizing peak loads.
- **Energy Management Systems:** Energy management systems monitor and control electrical loads so as not to exceed capacity limits. They can temporarily reduce demands

from flexible electrical loads (for example, EV chargers, hot water tanks, etc.) to stay within the limits of a building.

- **Energy Storage:** On-site energy storage solutions such as battery or thermal storage can be used to meet buildings' or facilities' peak power needs beyond the capacity of a service. Energy storage could charge when capacity is available, then serve certain loads when capacity becomes constrained. Use of onsite energy storage for this purpose is very rare today. However, it could become more viable in the future, as battery costs decline and more onsite energy storage technologies become available. Use of energy storage as a PED strategy could comprise a further value stream for storage, complementing other applications such as resiliency, utility bill optimization, and/or power export. Thus, we include this opportunity for completeness, though as of the time of this writing, it is largely speculative.

The Consortium for Power Efficiency (the Consortium), convened by Dunsky Energy + Climate Advisors, is a partnership of utility, government, and non-profit partners that share the common goal of accelerating building decarbonization while minimizing costs for Canadians. Consortium funding partners have engaged Dunsky to lead several initiatives to support adoption of PED strategies that can help avoid unnecessary electrical upgrades in both existing buildings and new construction.

Why Power Efficient Design?

Canadians are increasingly switching from fossil fuel systems to electric alternatives in homes, buildings, and vehicles. This **electrification** is driven by new technology, superior economics, consumer demand, and supportive policies. As a result, buildings are facing new electric demands from EV charging, heat pumps, and other electric appliances.

At the same time, many Canadian neighbourhoods are **densifying**. Notably, communities that were once mostly single-family homes are seeing more "missing middle" housing like multiplexes, townhomes, row houses, and small apartment buildings.

These energy transition and densification trends will reduce emissions and air pollution, make housing and transportation more affordable, drive economic development, and improve Canadians' quality of life.

However, electrification and densification are **increasingly leading to electrical service upgrades** to handle the increased demand, in both existing buildings and new construction. Often, larger electrical services bring significant costs for both customers and utilities. For example, upgrading existing services can mean significant architectural, electrical, civil and/or arboreal costs for existing buildings. Likewise, higher capacity electrical services often entail greater costs for developers and utilities. For example, an undergrounded 400A electrical service for a 3-unit multiplex can often cost homebuilders $30,000-$100,000+ more than the overhead 200A service typical for new single-family homes.

How Power Efficient Design Can Help

PED can often avoid these expensive electrical upgrades. PED can allow full electrification – including EV chargers, heat pumps, and more – without upsizing electrical utility services, panels and other infrastructure. For example, a home with a 100A electrical panel can often fully electrify without a service upgrade. Likewise, a denser all-electric multiplex building can often feature an equivalent service to a new single-family home, when using PED.

Many PED strategies also lower buildings' contribution to utilities' system-wide peak electricity demand. This lower costs for utilities and puts downward pressure on electricity rates. And energy management systems can enable grid-interactivity, further reducing strain on the broader system.

PED can be used in all building types and is a key tool for affordable, efficient electrification across Canada.

Barriers to Power Efficient Design

Some of the barriers to unlocking the benefits of PED include:

- **Codes:** Several PED strategies are not fully supported by current electrical codes. For example, in some case, electrical codes can have overly conservative load calculation assumptions and do not enable energy management for all applicable electrical loads. Additionally, inconsistent adoption and interpretation of codes across Canadian jurisdictions create further barriers.
- **Product certification & availability:** A complicated landscape of Canadian standards and certifications for PED technologies leads to uncertainty for electrical safety regulators, manufacturers, and contractors, and slows its adoption.
- **Industry and customer awareness**: Contractors, designers, and building owners are often unfamiliar with PED strategies.
- **Access to utility data:** It is often difficult to access accurate utility data, making it harder to use historical energy data for load calculations.

About the CE Code

The Canadian Electrical Code (CE Code), issued by CSA Group, governs electrical work and equipment. Part I applies to installations on the consumer's side of the utility service. Part II sets safety standards for the construction, testing, and marking of electrical equipment. Adoption and versions vary across jurisdictions.

How to Enable Power Efficient Design

There are several opportunities to better enable PED, including:

- **CE Code Amendments.** Amendments to the Canadian Electrical Code (CE Code) represent one of the most impactful ways to enable PED. Dunsky is currently drafting these and other CE Code amendment proposals on behalf of the Consortium.
- **Energy Management Standards.** Standards for energy management systems (EMS) are key to enabling PED. While EMS can monitor and control electrical loads effectively, Canada lacks a unified EMS standard for the purposes of PED and electrical codes' compliance, leading to regulatory confusion, delays, and higher costs. The Consortium is preparing a report to identify opportunities to simplify and align EMS standards, with recommendations expected by March 2025.
- **Education and Capacity Building.** Building industry knowledge and skills is critical to enabling PED strategies. Many contractors, designers, and building owners are not yet familiar with these PED strategies. Accordingly, there is a need to share best practices and provide practical tools and resources to help them understand and adopt these approaches. The Consortium is currently developing industry resources, including a PED Guide for Electrification Retrofits and a Power Efficient Electrification Calculator (PEEC), each designed to help homeowners and contractors plan for electrification. Going forward, additional guides and calculators could address new buildings, multifamily units, and non-residential properties to broaden PED adoption, to equip industry stakeholders with the knowledge and tools to implement PED strategies effectively across a wider range of projects.
- **Optimizing Utility and Electrical Safety Authority Processes.** There several opportunities for provincial and municipal governments, safety authorities, regulators and utilities to better enable determination of historical loads in existing facilities. Utilities can improve access to buildings' historical load data, as well as data on capacity of distribution grid assets. And electrical safety authorities can better align processes to support PED strategies.

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Introduction

Introduction

About the Consortium for Power Efficiency

The **Consortium for Power Efficiency (the Consortium)** is a partnership of utility, government, and non-profit partners, that share the common goal of accelerating decarbonization by providing cost-effective alternatives to increasing the capacity of electric utility services. Dunsky Energy + Climate Advisors ("Dunsky") convened the Consortium. Consortium funding partners have engaged Dunsky to lead several initiatives to support use of **power efficient design (PED)** strategies that can avoid increasing electric utility service sizes in both existing buildings and new construction. This report provides an overview of PED strategies, and is part of the first phase of the Consortium's work (see Box 1 below).

Box 1. **SUMMARY OF THE FIRST PHASES OF THE CONSORTIUM'S WORK**

This report comprises part of the Consortium's first phases of work to better enable PED. Other activities that the Consortium has engaged Dunsky to lead include:

- **PED Summary for Decision-Makers:** Accompanying this report is a concise summary of PED strategies, tailored for elected officials and senior decision-makers, to highlight key insights, market relevance, and barriers to adoption.
- **Canadian Electrical Code Amendment Proposals:** Dunsky is drafting proposed amendments to the Canadian Electrical Code, Part I (CE Code, Part I) to better enable PED. We will represent the Consortium at relevant CE Code, Part I, sub-committees and technical committees considering proposed changes. Likewise, we will engage with provincial electrical safety authorities and provincial staff to support PED-friendly policies and electrical codes.
- **Energy Management Standards Review:** We will summarize standards relating to energy management systems (EMS) to control loads to avoid exceeding the capacity of buildings' electrical services and feeders. We will then recommend any options to rationalize this standards landscape that can be advanced by the Consortium and Canadian standards development organizations (SDOs). This work includes stakeholder engagement, particularly with technology vendors and SDOs.
- **Power Efficient Electrification Calculator:** We are developing an excel-based tool to help contractors and households plan proactively for how to avoid service upgrades as households electrify various equipment over time. Modeled on the "Watt Diet Calculator" developed in California, the tool developed in Phase 1 of the Consortium will focus on single family homes and other buildings subject to Rule 8-200 (Single dwellings) of the CE Code.
- **PED Guide for Home Electrification Retrofits:** This design guide will help industry stakeholders apply PED strategies in home electrification retrofits to avoid service upgrades. The guide is intended for contractors and households.

As buildings increasingly electrify their loads – through the addition of electric vehicle (EV) charging, electric heating, hot water systems, cooking appliances and other electric equipment – and as neighborhoods densify, there is often pressure to increase buildings' utility services' capacities. Providing alternatives to unnecessarily upsizing services can reduce costs, speed decarbonization, provide downward pressure on utility rates, and reduce electrical workforce capacity constraints.

PED strategies are central to optimizing buildings' electric utility service capacities. These strategies include:

- Optimizing electrical **load calculation methodologies**.
- Building **efficiency** and **right-sizing** the power/amperage of equipment loads.
- **Energy management systems** to monitor and control electrical loads so as not to exceed appropriate power thresholds.
- **Energy storage** to meet buildings'/facilities' peak power needs beyond the capacity of a service.

In addition to optimizing buildings' electrical service capacities, many of these PED strategies can also provide **other value streams**. For example, reducing customers' demand charges, energy arbitrage (where customers are exposed to time varying pricing), utility demand response, improved building comfort, etc.

However, a variety of **market and regulatory barriers** impede widespread use of different PED strategies, including: Barriers related to electrical codes, lack of awareness of such strategies amongst the electrical and mechanical design and contracting industry, utility data-sharing processes, and demand side management (DSM) programs' designs. The Consortium's work is intended to help overcome such barriers to PED in jurisdictions across Canada.

Overview of this Report

This report summarizes a wide range of different PED strategies, organized into the following categories:

- Optimizing load calculations.
- Building efficiency and right-sizing loads.
- Energy management systems.
- Energy storage.

It describes how different PED strategies can contribute to avoiding electrical service size increases in various applications (e.g. retrofit versus new buildings; single family, multifamily, commercial, etc.). It notes where CE Code rules can pose barriers to using certain PED strategies. Likewise, it notes other opportunities for governments and utilities to better enable PED. The target audience for this report are government, utility and industry stakeholders interested in how PED can broadly be enabled.

This report is not intended as an exhaustive guide to the application of all possible PED strategies for all building types. Rather, it offers a substantive overview of some of the most important strategies identified through our research.

The strategies profiled in this report are applicable to a broad range of building types. However, for ease of illustration, many examples in this report focus on residential single-dwelling units (covered under Section 8-200 of the CE Code, Part I), as they represent an important portion of Canada's building stock for which PED will be particularly important.

Research Methodology

The project team – comprising Dunsky, FRESCo, Good Gridizen, RBQ Engineering, and AES Engineering – leveraged our collective expertise to identify and catalog PED strategies currently in use, as well as emerging strategies. We reviewed recent literature on PED strategies. We also conducted 29 interviews with experts and stakeholders from Canada and the United States. Interview participants included electrical and mechanical engineers, contractors, equipment vendors, industry associations, electrical safety authorities, and utility personnel. A semi-structured interview guide was used to ensure consistency while allowing flexibility for participants to focus on their areas of expertise. Insights gathered from these interviews informed the characterization of additional PED opportunities and barriers.

Structure of Report

This report is structured into the following sections:

- **About Power Efficient Design**. This section provides an overview of power efficient design, explaining its importance and the associated benefits. Key barriers to enabling PED are also identified.
- **About Electrical Codes.** This section provides a brief overview of the electrical codes that govern load calculations in new and existing buildings, highlighting their role in determining electrical service requirements.

1. **Optimizing Load Calculations.** This section explores opportunities to improve load calculation methodologies in future versions of the CE Code. It also identifies ways for safety authorities and utilities to better assess historical loads in existing buildings. This section focuses on general ways to better optimize load calculations, with specific technology-related opportunities discussed in later sections.
2. **Building Efficiency and Right-Sizing Loads**. "Right-sizing" refers to managing and optimizing electrical demand within a building to minimize panel size, service capacity, and costs. This section emphasizes the importance of understanding the impact of each end-use on demand and how right-sizing and efficiency can reduce peak electrical demand.
3. **Energy Management Systems** (EMS). This section provides an overview of various EMS technologies, explaining how each can be used to limit electrical capacities.
4. **Energy Storage.** This section briefly summarizes how energy storage, such as batteries, could be used in concert with EMS to limit electrical service capacities.

- **Discussion and Conclusion.** This section summarizes key opportunities to update the CE Code, Part I, as well as other opportunities for governments and utilities to enable PED.

Throughout this report, the icons presented below are used to highlight key information and improve navigation:

🗎	This icon identifies pertinent statements from the CE Code, Part I.
💡	This icon summarizes key recommendations, particularly those related to potential code amendments.
❗	This icon draws attention to important points, considerations, or caveats that readers should keep in mind while reviewing the content.

About Power Efficient Design

About Power Efficient Design

This section provides a high-level overview of PED, including a description of the four categories strategies covered in this report: Optimizing load calculations, building efficiency and right-sizing loads, energy management systems, and energy storage. It also highlights several benefits of PED. Finally, it notes the categories of barriers to PEDs that are discussed in detail in their respective sections.

What is Power Efficient Design?

Power efficient design (PED) refers to strategies that limit buildings' and facilities' instantaneous use of electrical power, so as to avoid exceeding the electrical capacity limits of utility services and/or other electrical equipment (e.g. buildings' electrical feeders, panels, branch circuits, etc. – See Section 0 for an overview of the components of buildings' electrical systems). Likewise, PED strategies can also address the challenge of limited physical space on electrical panels by minimizing the number and size of breakers required.

Power Efficiency vs. Energy Efficiency: Power efficiency focuses on reducing the *instantaneous* use of electrical power to stay within specific limits, while energy efficiency focuses on reducing the *overall* amount of energy used over time. With good design, both power efficiency and energy efficiency can be achieved.

PED strategies fall into four broad categories:

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we include this opportunity for completeness, though at this point in time it is largely speculative.

The subsequent sections of this report explore each of these PED strategies in greater detail. These sections highlight key barriers related to codes and standards associated with some PED strategies. Likewise, we note other types of market barriers identified in our research. Where relevant, we note which sectors and applications—such as residential versus non-residential settings, or new construction versus retrofits—are most suited to different PED strategies.

Why is it important to enable Power Efficient Design?

Enabling the use of PED supports cost-effective building electrification and deployment of EV charging in both new and existing buildings. As part of the solution for simple and affordable electrification, PED is important for Canada's economic prosperity and climate action.

Example: Research from USA and Canadian organizations have found that most single family homes could add EV charging and electrify the vast majority of their energy use (including space heating, hot water, cooking, etc.) without a panel or service upgrade. In many cases, electrical panels are significantly underused. Most homes, including single-family houses with 100-amp panels and multifamily buildings with even lower capacities, utilize less than 50% of their available panel capacity (SPUR, 2024).

PED also supports denser new developments. As our communities grow, cities and provinces are increasingly allowing denser developments (for example, "missing middle" housing) in pre-existing neighbourhoods. PED can enable multifamily housing and non-residential buildings to use smaller electrical services, in some cases significantly reducing costs for such developments, making them more viable.

PED reduces the cost of electrification and density

Larger peak electrical demand increases the costs of electrical systems in buildings. Electrical equipment such as transformers, switchgear and feeders must all be sized to accommodate the peak possible load (see Box 4 for a brief layperson review of electrical equipment in buildings). Likewise, greater electrical demand can trigger the need for a larger **electrical service** (i.e. the electrical conductors connect the building to the utility distribution system) – either a larger service than might otherwise occur in new construction, or an electrical service upgrade in an existing building.

Larger electrical services entail costs for both customers and utilities.

- **Customers** are typically responsible for electrical works on their side of the service connection point. Likewise, they often must prepare the site with civil engineering works and/or architectural features. Finally, they often must pay the utility an extension fee (i.e. service charge) that covers a portion of the utility costs for such upgrades.
- **Utilities** must pay the cost of connecting a larger service to the customer. This can entail works that are proximate to the building, such as a larger gauge wire to the building, a larger capacity transformer, utility poles, or concrete pad-mounted equipment. Likewise,

the added demand can necessitate upgrades to utility infrastructure that is upstream of the project, such as utility distribution feeders, substations, etc.[1]

Costs for these works are paid by the utility. Some portion is often charged to the customer in the form of an extension fee (see Box 2). The remainder will be rate-based and paid off by all electricity customers collectively through utility rates.

As an illustration of these costs, Figure 2 summarizes the extent of costs that can be associated with electrical upgrades of a single-family home.

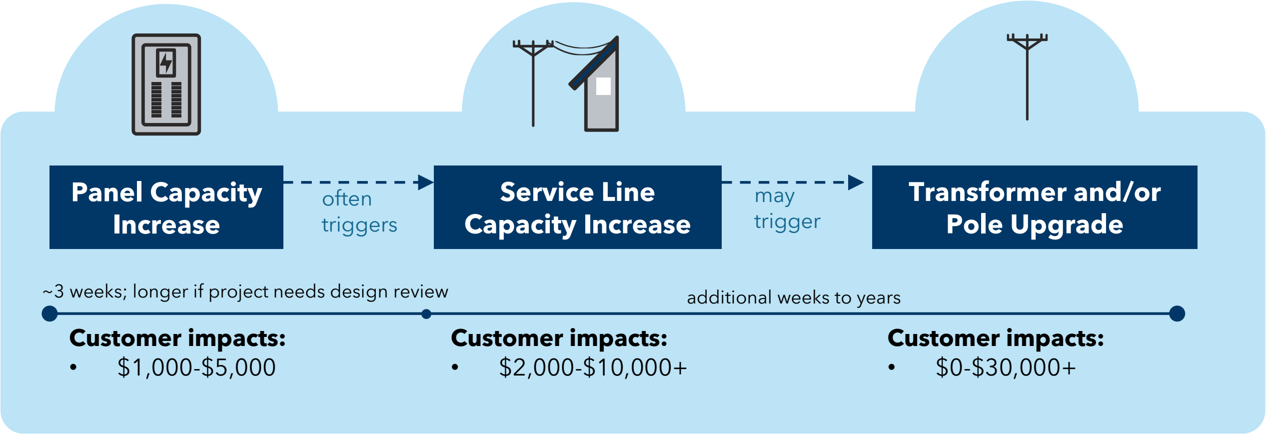

Figure 1: Cost ranges for electrical service upgrades for a single-family home.

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[1] It is important to note that even when PED strategies eliminate the need for a service size increase at the customer level, the added load from increased electrification or density can trigger upstream infrastructure upgrades. For this reason, utility tariffs often include requirements that customers notify utilities when adding loads. Nevertheless, by reducing peak demand, PED can help mitigate the likelihood and magnitude of additional peak load on utility systems, particularly for distribution assets close to the customer (e.g. the end-line transformer).

Box 2. COST ALLOCATION MODELS FOR UTILITY SERVICE UPGRADE FEES

There are **different models for how utility service extension fees are structured**, and therefore what costs customers will pay for the electrical service.

The types of cost incurred by an electrical service upgrade impacts how these costs are allocated between the utility (ratepayers) and the customer. As shown in **Figure 1** below, equipment upgrades can range from localized, customer-specific upgrades to large-scale infrastructure investments, depending on whether upstream distribution assets (e.g., feeders or substations) have sufficient capacity for new loads.

Local/customer-specific upgrades required

Under these circumstances, the following may be required:

- An **extension** of the distribution-voltage wiring to site
- A new **transformer**
- Upgrade of a **service line** to the customer meter

Larger scale of infrastructure upgrades required

Depending on how far down the distribution system capacity limits extend, the following may be required:

- A new **feeder**
- Upgrade of **equipment** in the **nearest substation**
- An entirely **new substation** (in extreme cases only)

Note that these upgrades are likely to benefit a larger group of customers.

Figure 2. Types of equipment upgrades that may be required under different scenarios

Different fee structures in use or under consideration by Canadian utilities include:

1. **Actual Costs.** Charging the actual costs of the service upgrade associated with a project, less the value of future revenues received by the utility for customers' subsequent use of electricity. For example, a customer might pay the cost of the upgrade quoted by the utility, less a credit for the value of their future demand (e.g., $200/kW). Future demand values (kW) may be estimated; alternatively, customers may need to make a deposit for distribution system upgrades, that they can earn back if and when their own demand or neighbouring properties' demand materializes in a specified period of time (e.g., 5 to 10 years). For example, a customer would pay a

deposit covering the full upgrade costs, but then receive repayment (e.g., $200/kW) for their demand and/or their neighbours' demand on that distribution feeder. This way of structuring utility service upgrade fees results in customers assuming the risk of whether loads at neighbouring properties will materialize.

This way of structuring these fees can result in **highly unpredictable** costs for customers. Often, costs will be modest because no significant upgrades to the utility distribution system are necessary. However, certain customers can face significant costs if their project happens to trigger upstream investments.

2. **Average system improvement fees.** Alternately, the distribution system upgrade component of the fee can be structured as an average for all distribution system upgrade costs across a utility. This structure recognizes that all customers contribute towards the eventual need for distribution system improvements. Thus, all customers are allocated a portion of these costs proportional to their added load, with new services charged a standard $/kW proportional to the distribution peak load they represent. However, customers are still charged the real cost of the extension to the distribution grid.
3. **Demand-based fees.** Building on #2 above, upgrade fees can be structured to normalize service connections into a simple average $/kW of new distribution peak demand. This not only normalizes the average cost of distribution system upgrades but also normalizes between customers depending on the cost of the service extension to their site (which can be influenced by where distribution lines run, civil works, vagaries of construction, etc.).
4. **Connection-size based fees.** For all customers, not just the ones increasing their service sizes, a volumetric energy electric rate reduction (e.g. $/kWh) can lower the rate if part of the T&D revenue requirement is moved to be collected on the basis of a of a rate structure that better reflects their contribution to demand on local distribution assets (e.g. a $/Amp-month connection fee on the main disconnect breaker size; a $/kW transformer demand charge that reflects the approximate demands that customer puts on the last transformer and secondary services; etc.). Under such rate designs, customer rates are better aligned with their cost-causation for the local distribution systems, and they have an incentive to avoid upsizing their electric service lines. Such rate designs can also provide bill relief for equity deserving populations (e.g. customers in older homes and apartment dwellers with smaller main disconnect breakers).

The different ways of calculating service upgrade fees noted above are provided as illustrative examples, and may not encompass all the ways such fees are calculated. We are not aware of any comprehensive publicly accessible database of such fee structures. The key takeaway is that **service upgrade fees are often significant, vary by jurisdiction and can be unpredictable and non-linear, depending on the unique state of local distribution systems** (e.g., the capacity of the upstream feeders and substations).[2]

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[2] Moreover, the design of utility service upgrade fees is in flux. We are aware of several utilities and regulatory commissions that are considering changes to the design of these fees (e.g., see the Ontario Energy Board's "Proposed Amendments to the Distribution System Code to Facilitate Connection of EV Charging Infrastructure", BC Hydro's Distribution Extension Policy engagements, etc.).

PED accelerates the pace of electrification

Utility service upgrades can significantly delay electrification projects. Modifying electrical panels requires navigating utility approval processes, which can be lengthy and complex. Additionally, utilities often face long backlogs for service upgrades, including for distribution grid work and new energy-source interconnections, creating further delays. PED helps minimize these bottlenecks by reducing the need for such upgrades, enabling projects to proceed more quickly.

Box 3. **UTILITY UPGRADE PROCESS AND TIMELINE**

The timeline for utility upgrades varies depending on the scope of the project. Below is an overview of the key stages and the typical durations for each:

- **Preliminary Steps (1–6 months):** The preliminary steps of online requests and preliminary design are standard across utilities. These steps are generally expected to take between one to six months, depending on the number of customers in the utility's queue.
- **Detailed Design, Permitting, and Agreements (up to 2 years):** This phase involves finalizing designs, obtaining permits, establishing connection agreements, and resolving other dependencies (such as easements). For minor upgrades, this process typically takes less than six months. However, for major projects that require upgrades to the distribution system, it can extend up to two years. Many of these tasks—such as permitting and easements—can proceed in parallel with the development of detailed designs to reduce timelines.
- **Construction and Installation (2 months to 18 months):** Construction timelines depend on the scale of the upgrades. Minor upgrades, such as transformer replacements or service extensions, can be completed in a few months. Larger distribution system improvements can take up to 18 months to complete.
- **Energization (2 weeks):** The final step involves activating the new or upgraded service, which is typically straightforward and completed within two weeks.

Under the right conditions, **a minor utility service upgrade** (e.g., one that solely requires a transformer upgrade or system extension to the customer) **can be completed in approximately six months**. However, major projects that require upgrades to the distribution system may require **upwards of two years**.

By minimizing the need for service upgrades, PED significantly reduces project timelines and streamlines the overall electrification process. This not only benefits individual projects but also accelerates progress toward the broader goal of building decarbonization while producing more electric energy sales across the existing infrastructure that reduces electric rates and encourages the beneficial spiral of PED electrification and rate relief.

PED can reduce demand for electrician labour and utility service crews

Panel or service modifications not only increase the cost and complexity of electrification projects, but also require licensed electricians. Additionally, panel upgrades may trigger service line upgrades, which itself may trigger transformer and/or pole upgrades, requiring specialized utility service crews. By avoiding panel or service upgrades, home electrification projects – such as installing heat pump water heaters EV chargers or space heat pumps – can often be completed by specialty contractors like plumbers or HVAC technicians, without the need for licensed electricians and/or utility service crews. This reduces costs, makes efficient use of limited skilled labor, and expedites project timelines. By simplifying installations, PED makes it faster, easier, and more affordable for homeowners to electrify their homes.

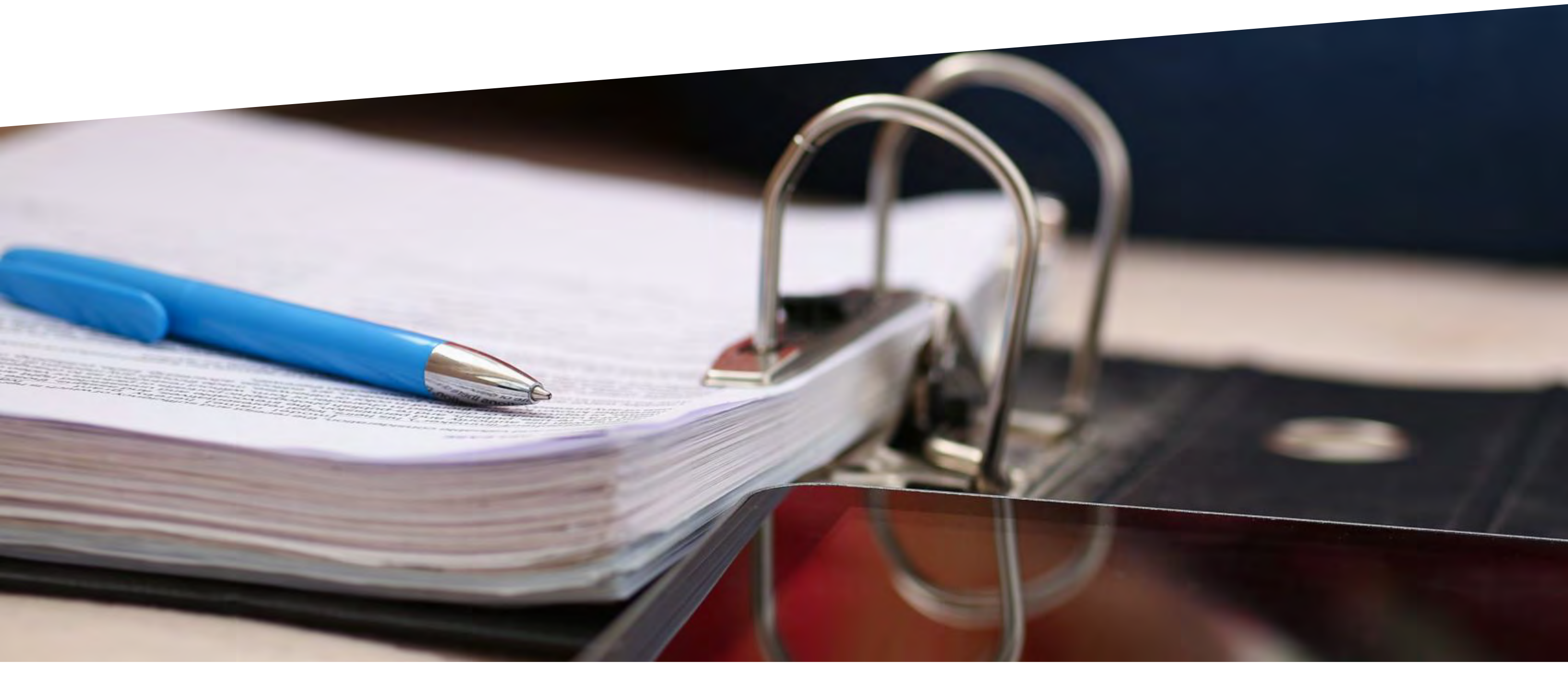
Key Barriers

The adoption and implementation of PED strategies outlined in this report – including optimizing load calculations, building efficiency and right-sizing loads, energy management systems (EMS), and battery storage — face several market and regulatory barriers.

- **Codes**: Some PED strategies are not yet fully enabled in electrical codes or recognized by relevant electrical safety authorities. In some cases, codes do not acknowledge PED strategies that could reduce electrical loads, limiting their potential to avoid unnecessary panel and service upgrades. Furthermore, approval processes can differ based on local authorities or inspectors.
- **Product certification & availability:** A lack of product standards and certification in Canada limits access to relevant technologies through traditional distribution channels. Several new PED technologies and solutions are not yet certified, and in many cases, relevant certification standards do not yet exist, creating uncertainty for manufacturers, distributors, designers, contractors and electrical safety authorities. This can delay projects, as well as discourage technology providers from entering the Canadian market. Additionally, a lack of standardization and certification results in approval processes that vary across regions, posing further challenges for vendors, contractors, and prospective customers.
- **Industry and customer awareness:** The widespread implementation of PED strategies is deterred by a lack of industry and customer awareness of such strategies. Broadly, as noted by several stakeholders interviewed for this report, the electrical and mechanical design and contracting industry is not yet well versed in PED strategies. Some stakeholders also noted that electrical contractors often face a financial incentive to suggest panel upsizing as opposed to power-efficient alternatives, as panel upsizing can generate more revenue for them compared to lower-cost PED strategies. Finally, building owners and tenants may be averse to PED strategies due to concerns about costs, performance, or unfamiliarity, further limiting their uptake.
- **Access to utility data:** Utility data sharing processes and demand side management (DSM) programs do not always best enable PEDs. Utility processes and/or regulatory restrictions often limit access to the utility data necessary for accurate historical load calculations. This lack of data makes it difficult to optimize system design, accurately size electrical systems, or identify opportunities for right-sizing loads, reducing the effectiveness of PED strategies. While issues pertaining to lack of access to utility is not within the scope of Dunsky's engagement on Phases 1 and 2 of the Consortium, further work in this area could be considered for a future phase.

In subsequent sections of this report, we provide additional detail on the above barriers, as well as note specific barriers applicable to individual PED strategies as applicable.

About Electrical Codes



About Electrical Codes

This section provides a brief overview of the electrical codes that regulate the calculation of electrical loads in new and existing buildings. This background information is intended for people without electrical expertise. Electrical engineers and contractors are expected to understand the relevant regulations, beyond the overview presented below.

Chapter 1 below notes some ways electrical load calculation methodologies in electrical codes might be better optimized. Likewise, where relevant, Chapters 5, 6 and 7 note instances where power efficient design strategies can be better enabled by electrical codes as means to reduce calculated loads.

About the CE Code, Part I, and Provincial Electrical Codes

The Canadian Electrical Code is a publication issued by CSA Group in several parts.[3] The Canadian Electrical Code, Part I, Safety Standard for Electrical Installations (CSA Group Standard 22.1, referred in this report as the "CE Code, Part I") is a model code published by CSA Group (formerly the Canadian Standards Association). The most recent version of the CE Code is the Canadian Electrical Code, Part I, 26th Edition (CSA C22.1-24), referred in this report as the "CE Code, Part I, (CSA 22.1-24)".

The CE Code, Part I, applies to all electrical work and electrical equipment in buildings, structures and premises on the consumer's side of a utility's electric service entrance. The CE Code's objective is to reduce risks of electric shock, fires, and other electrical hazards.

Provinces and territories have responsibility for electrical safety. Every Canadian province and territory, as well as some cities with delegated authority from provinces (e.g. Vancouver, Winnipeg), adopt electrical codes based on the CE Code, Part I, sometimes with amendments. It is these provincial, territorial or municipal codes that have legal effect. Different jurisdictions may adopt different versions of the CE Code, Part I, at different times.

Provincial/territorial safety authorities, municipalities and/or utilities are authorized to administer the electrical safety regulations in their jurisdiction. These authorities having jurisdiction (AHJs) may:

- Issue communications (e.g. bulletins) clarifying interpretation of electrical codes, and acceptable practices.
- Establish licensing requirements for contractors performing electrical work.
- Provide oversight of electrical work, including issuing permits and conducting inspections. This can include providing variances to the electrical code.

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[3] The Canadian Electrical Code is published in several parts: Part I is the safety standard for electrical installations. Part II is a collection of individual standards for the evaluation of electrical equipment or installations (as noted in Section 3.2 below, Part I requires that electrical products be approved to a Part II standard). Part III is the safety standard for utility power distribution and transmission circuits. Part IV is set of objective-based standards that may be used in certain industrial or institutional installations. Part VI establishes standards for the inspection of electrical installation in residential buildings.

About the CE Code, Part II, and Electrical Safety Standards

In addition to the CE Code, Part I, CSA Group publishes CSA C22.2, *General requirements – Canadian Electrical Code, Part II* (referred to in this report as the "CE Code, Part II"). The latest version of the CE Code, Part II, is CSA C22.2 No 0:20, published in 2020.

The CE Code, Part II consists of safety standards governing the construction, testing, and marking of electrical equipment. The CE Code, Part II includes general requirements that apply to all equipment. Likewise, it establishes the scope of individual standards including definitions, specifications and testing requirements for classes or groups of related types of electrical equipment.

Rule 2-024 of CE Code, Part I, requires that electrical equipment be approved for the specific purpose for which it is to be employed. Appendix A of the CE Code, Part I, includes safety standards for electrical equipment that can be used to certify that equipment is approved for the purposes of Section 2-024. Appendix A references a variety of CE Code, Part II standards, as well as standards published by other accredited standards development organizations.

If there is not an appropriate standard for a type of electrical equipment's purpose noted in Appendix A, then electrical AHJs may need to develop criteria to enable its implementation (for example, a letter of assurance from a professional engineer). Notably, CSA Group has been in the process of developing the CSA C22.2 No. 343 *Electric Vehicle Energy Management Systems* standard since 2019; at the time of this writing, CSA C22.2 No. 343, was not yet published though listed as proceeding to development by the Standards Council of Canada.[4] Accordingly, without an EV energy management system (EVEMS) standard for EVEMS providers to certify equipment and software to, electrical AHJs have established other interim approvals processes.

As a separate deliverable to the Consortium for Power Efficiency, Dunsky will be developing an *Overview of the Standards Landscape for Power Efficient Design*, targeting March 2025 for publication.

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[4] The Standards Council of Canada (SCC) is a Crown corporation established under the auspices of the Standards Council of Canada Act. The SCC represents Canada in international standardization efforts, and accredits various standards development organizations including CSA Group.

Determining Electrical Circuit Loads

Section 8 of the CE Code, Part I, establishes requirements for load calculations for buildings' **electrical services**, **feeders** and **branch circuits**. These and other elements of buildings' electrical installations are reviewed in the text box below. These electrical systems must have sufficient capacity to accommodate the calculated load. Likewise, the capacity calculated dictates the electrical service capacity that must be requested from utilities.

Regulated electrical utilities typically have processes and standards regarding what type of equipment can be deployed for new electrical services of different sizes, and standard increments for the capacity of electrical services. Typically, regulators (e.g. utility commissions) approve these standards, as well as the extension fee calculations determining how much money a utility customer must pay to receive a utility connection. Likewise, the utility and regulator may specify what works the utility will be responsible for paying and what works a customer must undertake. Thus, avoiding an electrical service upgrade during a building retrofit (e.g. electrifying equipment or adding EV charging), or minimizing the size of an electrical service for a new building, can help minimize costs for the customer.

Box 4. **BASIC ELEMENTS OF BUILDINGS' ELECTRICAL SYSTEMS**

Figure 3 and Figure 4 below summarize basic elements of electrical systems in smaller and larger, more complex buildings, respectively. All these systems must be sized adequately to deliver their peak electrical use. The key components of these systems include:

- The **Main transformer**, which reduces voltages from utility distribution system voltages (e.g., 25kV, 12.5kV, other voltages) to those used in building systems (e.g., 120/240V in small buildings; 277/480V or 347/600V in larger buildings). Utilities typically own the transformers serving small buildings and many larger buildings. However, some larger buildings obtain utility service connection at distribution system voltages and install customer-owned transformers.
- A consumer's **electrical service**, which are the electrical conductors connecting the utility service point to the building's **service box.** The service box contains an overcurrent device, such as a breaker or switch, that can shut off power to the building or facility. In many cases, the service box is part of the building or facility's **main panel** or **switchgear**.
- A main **electrical meter** may be installed to measure overall consumption at the building or facility level. Additional utility meters, as well as non-utility sub-metering, may be used for specific areas (e.g., meters for common building loads, individual residential units, or commercial spaces).
- Switchgear distributes power to various **feeders,** which are the portion an electrical circuit between the service box and branch **panels** that serve different areas of a building (e.g., residential panels in a multifamily building, a commercial premises' panel, common area panels).
- **Branch circuits** are distributed off from branch panels. A branch circuit is the portion of a wiring installation between the final overcurrent device (e.g., a circuit breaker)

protecting the circuit and an **outlet(s)**. An outlet is the point in a wiring installation at which current is drawn to power electrical equipment.

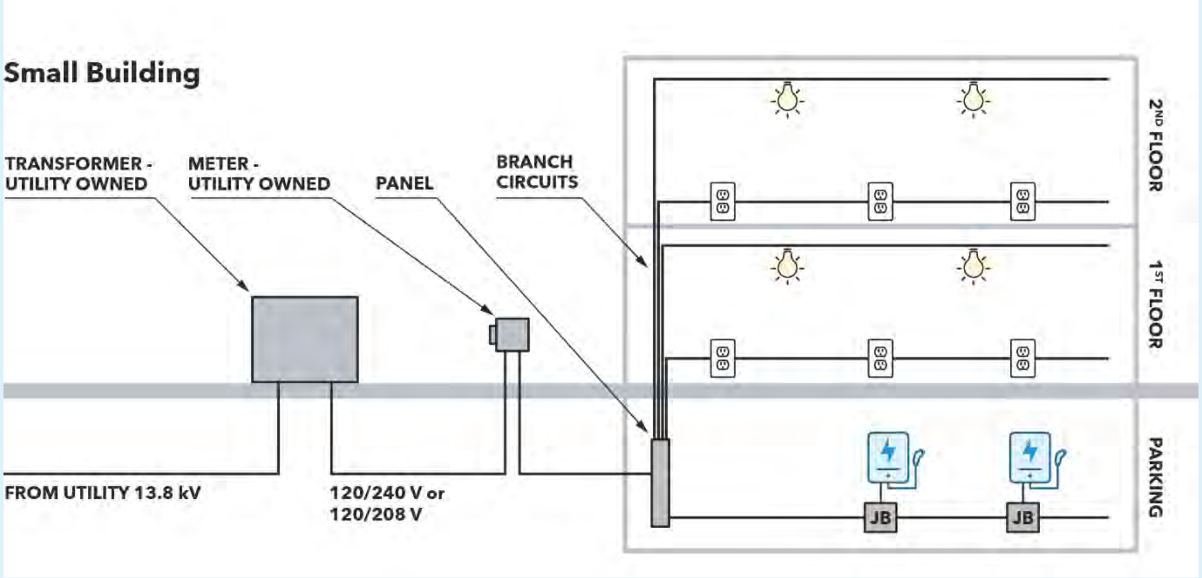


Figure 3: Basic elements of a small building's electrical system

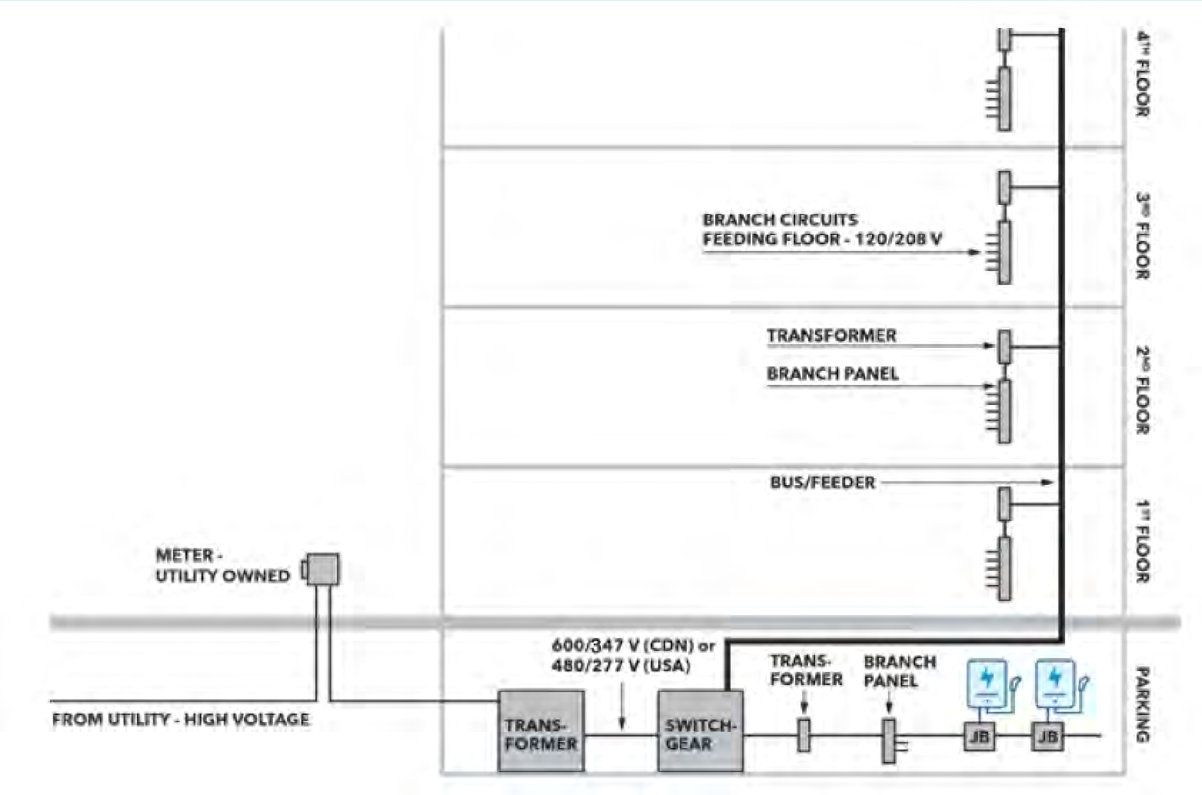


Figure 4: Basic elements of a large building's electrical system

Service load calculations

Rules 8-200, 8-202, 8-204, 8-206, 8-208 and 8-210 respectively specify load calculation methodologies for services and feeders for single dwellings (i.e. a detached, semi-detached, duplex, triplex, quadraplex, or row-housing unit); apartments; schools; hospitals; hotels, motels, dormitories, and buildings of similar occupancy; and other types of occupancies.

In brief, the CE Code, Part I, load calculations for services involve summing a variety of different types of loads.

- A **"basic load"** for lighting and receptacle circuits loads, determined through a Watts per square (W/m^2) meter factor multiplied by building area.
- For some facility types (e.g. schools, hospitals, other types of occupancies), **cord-connected equipment** for higher power that are intended to connect to receptacles rated more than 125 V or 20 A.
- Electrical loads associated with **space heating** and **air conditioning** equipment. Section 8-106 specifies that where interlocks prevent simultaneous operation of electric space-heating and air-conditioning loads, the greater load is used in load calculations.
- **Electric vehicle supply equipment** (EVSE) loads.
- In residences, **electric range** loads for cooking, and other loads (e.g. hot tub, other loads not encompassed in other parts of the load calculation).

The CE Code, Part I, prescribes various derating factors that may be applied to some of these loads, reducing the proportion of the load that must be considered in the service load calculation. This accounts for the fact that not all loads are likely to operate simultaneously, especially in a larger facility with greater "electrical diversity". The total calculated load determines the size of the customers' electrical service.

Use of demand factors

Rule 8-106 contains several sub-rules regarding the use of demand factors that can be applied during load calculations. Applying these sub-rules can help ensure that calculated loads do not exceed key thresholds that would necessitate a new electrical service, or other electrical works (e.g., a feeder upgrade). These rules can be summarized as follows (see the CE Code for precise language):

- Rule 8-106 (2) specifies that where two or more loads are installed so that only one can be used at any one time, the one providing the greatest demand shall be used in determining the calculated demand. This enables switching devices that can be an important PED strategy.
- Rule 8-106 (8) permits use of metered data in lieu of a load calculation where the most recent 12-month period is available.
- Rule 8-106 (9) permits use of data for similar building types and conditions, termed as demonstrated load. The rule was introduced in the 2015 edition, is rarely used, and is subject to approval from the AHJ.
- Rule 8-106 (10) permits limitation of the calculated demand load for EV charging to the maximum load established by an EV energy management system (EVEMS).
- Rule 8-106 (11) permits the demand load for EV charging to be disregarded, where an EMS with service monitoring capability is used.

Additionally, Sections 8-200 through 8-210 include demand factors that reduce certain types of calculated loads (typically not space heating, air conditioning or EV charging) by a prescribed percentage for floor area beyond a threshold area, and for additional units in a residential building. These demand factors recognize the inherent “electrical diversity” of larger buildings, recognizing that not all loads in a larger building are likely to be on at the same time.

These and other provisions in the CE Code enable a substantial array of PED strategies. However, there are some PED strategies that are not fully enabled in the CE Code, Part I. The remainder of this report summarizes various PED strategies, and includes notes where there may be opportunities to better enable these strategies in the CE Code, Part I.

STRATEGY 1

Optimizing Load Calculations

1. Optimizing Load Calculations

This section notes some potential opportunities to optimize electrical load calculation methodologies in future versions of the CE Code. Likewise, it notes opportunities for safety authorities and utilities to better enable determination of historical loads in existing facilities. This section relates to opportunities that are of a more general nature and not related to specific technologies (e.g., battery integrated appliances); such opportunities are noted in subsequent sections of this report.

1.1 "Basic Load" Factors in Load Calculations

Multiple stakeholders we interviewed noted that load calculation methodologies for services and feeders in sections 8-200 through 8-210 are inherently very conservative. Several noted that the actual real-world peak loading on services is consistently 30% to 50% of the nominal value calculated in accordance with the CE Code, Part I. While it is critical that these load calculation methodologies be conservative to ensure adequate capacity to meet the peak demand at facilities, several stakeholders noted that the "basic loads" prescribed in CE Code, Part I, could warrant revisions to reflect the lower power demand in new buildings.

As noted in Chapter 0 above, load calculations for services and feeders include a basic load to account for loads from lighting and receptacles. This load is determined through a prescribed Watts per square (W/m^2) meter factor multiplied by building area for that occupancy. The basic load, along with some other components of calculated loads, may be further reduced by applying demand factors that reduce the calculated loads by a prescribed percentage in cases where that occupancy type exceeds certain floor area thresholds. Similarly, progressively greater demand factors are applied for each residential unit as the number of units in a multifamily building increases. These demand factors reflect the "electrical diversity" of these loads, i.e. that it is very unlikely that all such loads will be in use at the same time on a service or feeder serving multiple units or large area.

The "basic load" is defined in Rule 8-002 as "the load of lighting and receptacle circuits, based on the outside dimensions of a specific area of building occupancy, as listed in Table 14."

To calculate the service size in an **office building**, per CE Code, Part I, Table 14, a baseload of 50 W/m^2 must be considered in the load calculation, with a demand factor between 70% and 90%.

In comparison, the **National Energy Code of Canada for Buildings 2020** (NECB 2020) establishes a baseline office's lighting power density at 6.9 W/m^2 and plug load at 7.5 W/m^2, for a **total of 14.4 W/m^2**, less than half the CE Code considering the lowest demand factor.

Projects are **generally able to achieve lower power density**.

Lighting loads used in the CE Code, Part I, could be updated to reflect the actual capacity.

There are several opportunities to improve basic load factors in the CE Code, Part I that should be considered, including:

- An **optional path** could be introduced to the CE Code, Part I, that allows lighting and receptacle loads to be calculated based on either a lighting audit in the case of pre-existing facilities, or proposed lighting design.
- A study that **disaggregates building loads to determine appropriate peak values to use in revised basic loads** could be undertaken. Such a study could leverage granular utility metering data for a large population of common relevant building types (e.g., individual dwellings subject to 8-200; apartments subject to 8-202; office buildings subject to 8-210; etc.). Leading an original study is not within the scope of Dunsky's engagement on Phases 1 and 2 of the Consortium, though could be considered for a future phase.

To optimize "basic load" factors in load calculations, the CE Code, Part I could allow for an **optional path** to calculate lighting and receptacle loads based on audits or proposed designs.

Additionally, **a load disaggregation study** could be undertaken to update peak values for basic loads in the CE Code, Part I.

1.2 Historical Load Calculations

The CE Code, Part I, allows for the use of historical utility data to be used in lieu of conventional load calculations where new loads are added to an existing service or feeder. Using historical loads almost always reveals that more capacity is available than what is indicated by conventional load calculation methodologies. Thus, historical utility data can be useful in avoiding electrical service upgrades when electrifying building systems or adding EV charging in retrofit contexts.

> CE Code, Part I, sub-rule **8-106 8)** stipulates that "where additional loads are to be added to an existing service or feeder, the augmented load shall be permitted to be calculated by adding the sum of the additional loads, with demand factors as permitted by this Code, to the maximum demand load of the existing installation as measured over the most recent 12-month period…"

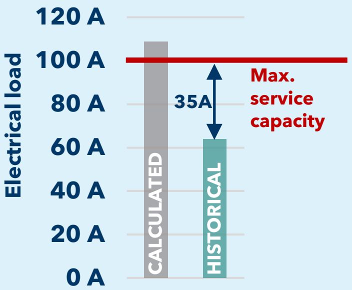
How much of an impact can using historical have?

Stakeholders reported using this approach can reveals significant spare capacity in many buildings. Anecdotal evidence suggests historical load calculations typically indicate **40-50% spare capacity** compared to the conventional load calculation.

For example, consider the 1940s electrically heated single-family dwelling in Montréal shown to the right. This home has a 100A panel that, according to conventional load calculations, is undersized.

However, when evaluated using historical load data, the analysis **reveals 35A of available capacity** – enough to support additional demand without an upgrade.

While the conclusion is always case-specific, integrating historical load data into design can help optimize service capacity and reduce costs.



However, in many markets and building types, using historical loads for such electrification initiatives is uncommon; typical practice is to rely only on calculated loads. Furthermore, for some buildings and facilities, there is no master meter, requiring that loads from multiple meters on the service are aggregated together to determine the historical load. Accessing such data is often challenging.

Stakeholders suggested ways in which the CE Code, Part I, could be amended to better enable determination of historical loads, including:

- Specifying in the CE Code, Part I, the electric metering interval over which the maximum demand load in is determined. Several stakeholders noted that a 15-minute meter interval is considered appropriate by electrical engineers and safety authorities. However, 8-106 sub-rule (8) does not specify the appropriate duration of time. For clarity, this time duration could be specified in the CE Code, or potentially established in some other standard and referenced in the CE Code, Part I. Likewise, factors that can be applied to lower granularity data (e.g. 60 minute interval metering) could be included in the CE Code.

- Allowing historical loads to be calculated over shorter periods of time (e.g. 30 days) during which onsite supply is disabled and certain loads (e.g. the larger of space heating or cooling) are added manually. This could enable shorter measurement periods in the shoulder season to determine relevant loads.
- Some stakeholders suggested the CE Code, Part I, could require master metering for a service. This could simplify historical load calculations.

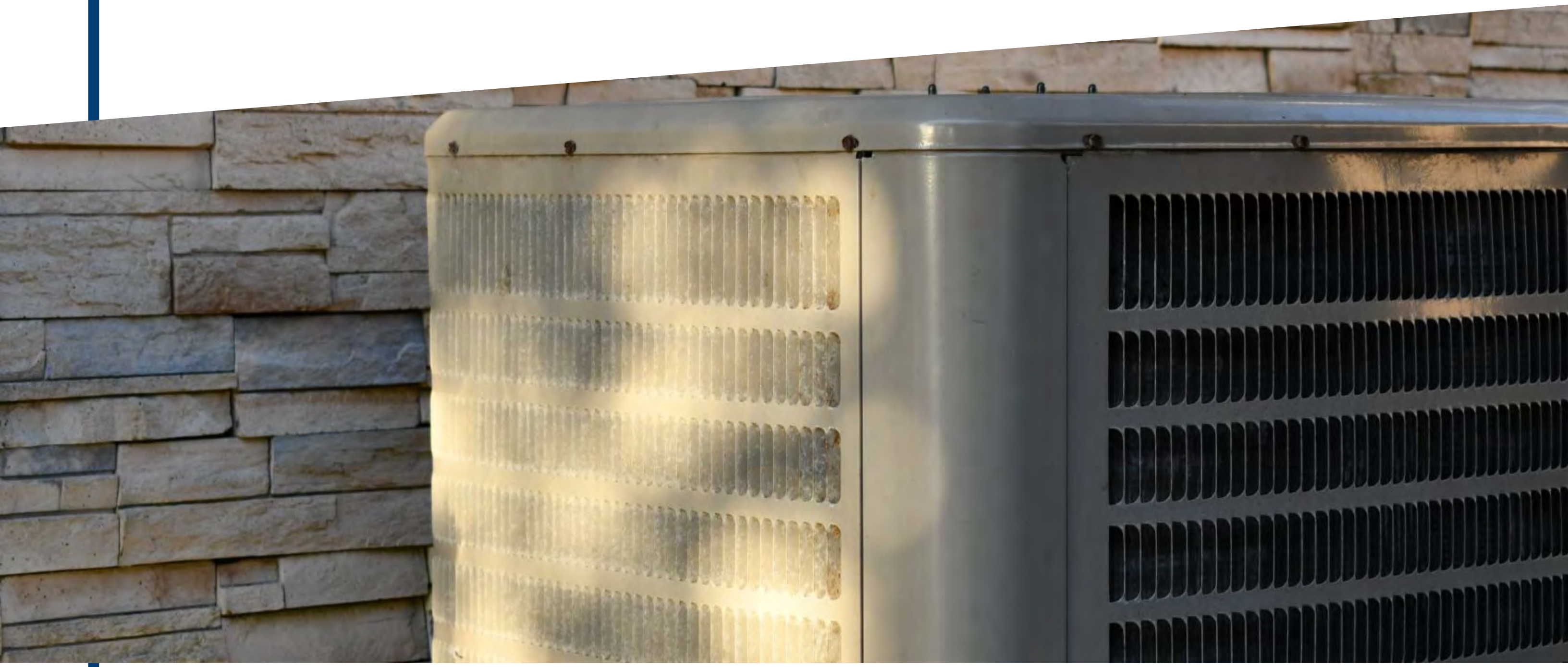
> To better enable the use of historical utility data, the CE Code, Part I could specify electric metering interval, factors to determine peak from less granular data (e.g. hourly) and provisions for shorter 30 day metering.
>
> Additionally, the CE Code, Part I could require master metering for a service.

Likewise, several opportunities for provincial and municipal governments, safety authorities, regulators and utilities to better enable determination of historical loads in existing facilities were identified:

- Utilities could deploy master metering in anticipation of future electrification and the need to support historic load determination.
- Several stakeholders noted that processes for obtaining historical load data from utilities are often inefficient and result in considerable delays and/or incorrect information. Utilities can provide better access to data for historical load calculations.
    - For single family homes or buildings with one meter, this could include providing easy access to peak historical load as part of customer account info (e.g. on billing statements and web interfaces).
    - For buildings and facilities with multiple meters, it entails establishing better automated systems for timely provision of aggregated load data. Relatedly, utilities can indicate the extent to which upstream electrical infrastructure has sufficient capacity to accommodate electrification. Though not in scope of phases 1 and 2 of the Consortium, detailed recommendations of appropriate processes can be explored for future phases. We recommend utilities establish dedicated teams tasked with better enabling access to historical load data for their customers.
- Electrical safety authorities can establish correction factors to convert less granular interval data into a values appropriate to assume as the historical maximum demand load in 8-106 subrule 8). Notably, utilities often only provide smart meter data on an hourly basis, and not the 15-minute interval basis considered appropriate for determination of maximum demand loads. For single dwellings subject to 8-200, Technical Safety BC and the Ontario Electrical Safety Authority have issued bulletins establishing a correction factor, whereby 125% of the 1-hour demand can be used to determine the maximum demand load. Other electrical safety authorities can establish the same or similar factors. Likewise, appropriate factors to aggregate loads for multiple dwellings (e.g. those subject to 8-202) should be considered to enable electrification in multifamily buildings.

STRATEGY 2

Building Efficiency And Right-Sizing Loads



2. Building Efficiency and Right-Sizing Loads

This section reviews opportunities to reduce calculated loads through efficiency and equipment right-sizing.

2.1 What loads are most important to minimize?

To optimize the potential of PED, we must first understand the relative impact of each end use. This will help us understand the role each PED strategy can play.

Figure 5 below shows the **typical load breakdown for a 100 m² single dwelling** part of a larger multi-unit residential building in a mild climate, such as Vancouver.

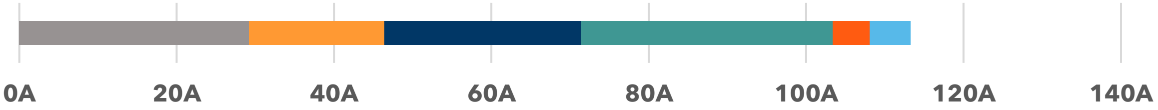


Figure 5: Load breakdown of a fully electrified dwelling in Vancouver

- ◼ An initial **baseload** proportional to the size of the living area is first allocated to account for lighting and the various equipment that will use the electrical outlets. While this load is significant at the dwelling level, its impact on the service size in a multifamily building is diminished by a load diversity that increases with the number of units (per CE Code 8-202 1) a) i) to iii) and 8-202 3) a)).
- 🟧 **Space heating and air-conditioning** loads based on 100% of the installed equipment capacity – with some exceptions at 75%. This is a significant load at the dwelling level and the service level as very little diversity can be accounted for (per 8-202 1) a) iv) and Section 62).
- ⬛ **Electric range** load based on the range capacity– 6000W at a minimum – with some diversity for anything above (per 8-202 1) a) v)).
- 🟩 **EVSE** load installed on the dwelling's electrical panel, considering a 40 A Level 2 charger (per 8-202 1) a) vii)).
- 🟥 **Hot water heating** load, 25% of the equipment rating (per 8-202 1) a) viii)).
- 🟦 **Electric dryer** load, 25% of the equipment rating (per 8-202 1) a) viii)).

Higher heating demand in colder climates increases the relative importance of space heating loads. The figure below shows this effect using a calculation in a colder climate, such as Montréal's, where the higher heating demand increases the unit's required feeder by 25 A (+20%).

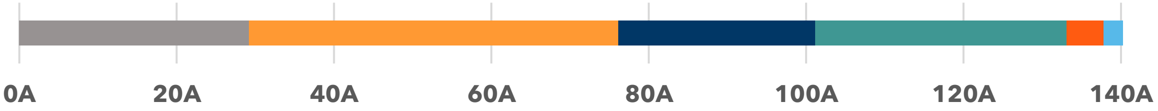


Figure 6: Load breakdown of a fully electrified dwelling in Montréal

Across climate zones, **three takeaways must be highlighted**:

- An important portion of the load cannot be reduced through PED strategies under the current CE Code, Part I. The **baseload** is determined by the building's floor area, and the **electric range** has a minimum demand. These loads have a greater impact in smaller buildings – accounting for up to 45% of the load in the Vancouver example above – but this impact diminishes as the number of units in a building increases, as the CE Code, Part I, accounts for greater diversity with larger buildings.
- **EVSE** and **space heating and cooling** are significant loads, with space heating being more significant in colder regions. Both can be effectively managed using PED strategies.
- While the remaining **hot water heating** and **electric dryer loads** can be reduced with PED strategies, the overall potential is limited. The CE Code, Part I, applies diversity factors to these loads, even when unmitigated, which lowers their weight in the load calculation. Nevertheless, some PED strategies can be useful in shaving enough power to attain a lower service capacity increment, when the calculated load is close to the threshold for a smaller service size.

! This report covers a **broad range of building types.** However, for ease of illustration, many case studies presented will focus on **residential buildings**, as they represent a significant portion of Canada's building stock.

Nevertheless, the **high-level takeaways are generally applicable to other building types**.

The following sub-sections will focus on PED strategies **in order of their impact on load calculations and their potential to reduce service capacity**. Since this report covers all types of residential buildings and other building types, we highlight, where relevant, **the differences between ground-oriented homes and apartment buildings**, explaining how PED strategies vary between them.

! **Right-sizing does not always result in reduced service capacity**.

Equipment capacities and **service sizes tend to proceed in rather large increments** (e.g. 200A vs. 400A services, without intermediate options). While optimizing loads through right-sizing can lower the building's electrical load enough to maintain the existing service (or a lower capacity in new constructions), in other cases, it may not be sufficient to avoid upgrading the breaker box or service size.

Lastly, while these calculations are based on actual load data, they are presented outside of a specific project context. Stakeholders across the country have expressed that **service size decisions are often made very early in the project** timeline, during the preliminary design stage. At this point, **conservative assumptions are typically used**, as few are willing to risk adopting a minimalist approach from the outset. To maximize its potential benefits, it is important that PED be more normalized and integrated into preliminary design processes for all sorts of buildings, but particularly residential construction. This could be accomplished through design guides, education, demand side management programs, and other market transformation efforts.

2.2 Lower Power Level 1 & Level 2 EV Charging

EV charging loads represent the greatest opportunity for PED, particularly in buildings where a large percentage of parking space feature EV charging. PED can be achieved through right sizing EV charging loads (using lower power charging), as well as load-sharing using EV energy management systems (EVEMS). Section 3 reviews EVEMS control strategies.

In residential and many longer-term non-residential settings, two types of EVSE are commonly installed:

- **Level 1 EVSE** using standard 120V outlets, offer slower charging speeds. Level 1 can be viable for users with low daily or weekly driving needs (under 60 km per day or 450 km per week for charging sessions of 8+ hours per day). Level 1 EVSEs are a more power-efficient option for charging EVs compared to unmitigated Level 2 EVSEs. However, this is no longer the case when an EMS is implemented (see strategy 3) – which can provide a better charging experience with a lower load impact.

Larger batteries do not require larger chargers.

Contrary to customer intuition, larger EV batteries do not require larger EVSE. They allow charging to meet fluctuating usage by letting cars carry unused battery energy storage from one day to another, so the weekly charging capability becomes the operative limit for home charging.)

- **Level 2 EVSE** provide faster charging, sufficient to meet daily driving requirements of the vast majority of drivers. However, unless EVEMS is used (see strategy 3), these more powerful chargers have a greater impact on the electrical load calculation. However, lower-power Level 2 has a more modest impact on load calculations while providing a good quality of EV charging - **research shows that most urban households can often achieve satisfactory home charging performance from a 20 A Level 2 EVSE.**[5]

Many cities require Level 2 futureproofing for parking spaces:

As of this writing, 20 local governments in British Columbia, as well as the cities of Toronto, Laval, and parts of Montreal require **all residential parking** in new developments to be futureproofed for Level 2 EV charging. Likewise, several have requirements that a portion of non-residential parking be futureproofed. These communities typically specify that parking must feature an adjacent outlet at which Level 2 EV charging can be installed in the future, and allow developments to use EVEMS to comply in power efficient ways.

In multifamily buildings, given the significant impact EVSEs can have on an electrical service, it is crucial to answer the fundamental question of **how much power is required?** Without answering this, there is no ability to right-size the infrastructure design and subsequent installation. A **charging performance analysis** can be used to establishing reasonable guidelines that balance charging performance and electrical infrastructure costs, based on driving habits, vehicle specs, climate and geography, among others. Guidelines published in BC ensure vehicles are fully charged 90% of the time from overnight charging, and sufficiently charged for the subsequent day greater than 99% of the time.[6]

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[5] EV Charging Performance Requirements, Clean Air Partnership (2021)

[6] As part of the Go Electric EV Charger Rebate Program, cleanBC, October 2023

	Level 1	**Level 2**
Voltage	120V 1-Phase AC	208-240V 1-Phase AC
Amps (min. breaker size)	12 to 16 A (15 to 20 A)	6 to 80 A (10 to 100 A)
Charging Loads	1.4 to 1.9 kW	1.42 to 19 kW
Range Speed	5 to 8 km of range per hour	16 to 32 km of range per hour
Examples of Manufacturers and Models	Generally provided by EV manufacturer	flo X3 and X6 (up to 50A) X8 (up to 80A) eVduty EVC 30 to 48 (up to 48A) EVC 80 (up to 80A)

When calculating a building's required service capacity under the latest version of the CE Code, Part I, **EV loads must be accounted for using a 100% demand factor** regardless of the building type, number and location of EVSEs, **unless an EVEMS** is used.

This results in a significant impact on electrical load calculations, often resulting in the necessity for electrical system upgrades, making it essential to explore PED strategies and achieve benefits in terms of feasibility and cost.

> In a single dwelling, CE Code, Part I, Rule **8-200 1) a) vi)** stipulates that "any electric vehicle supply equipment loads [must be considered] with a demand factor of 100%".
>
> In apartments, the same demand factor must be used under Rule **8-202 1) a) vii)** and **8-202 3) d)** depending on whether the EVSE is supplied from a panel board inside or outside the dwelling units.

2.3 Lower Power Space Conditioning Equipment

Under the CE Code, Part I, electrical space heating and cooling loads must be accounted for with little to no diversity, both at the panel and service level, with the following exceptions:

- Heating loads exceeding 10 kW can be accounted for at 75% of the rating, if the heating equipment is used in a residential occupancy and each room or heated area has its own thermostatic control.

> Per CE Code, Part I, Rule **62-118 3)**,"where a heating installation in a building for residential occupancy is provided with automatic thermostatic control devices in each room or heated area, the ampacity of service or feeder […] supplying heating devices shall be permitted to be based on the following for that portion of the demand: a) the first 10kW of connected heating load at 100% demand factor; plus b) the balance of the connected heating load at 75% demand factor.

- The lowest of the heating or cooling loads can be disregarded provided that an interlock mechanism is installed between the two systems.

> Per CE Code, Part I, Rule **8-106 3)**, "where interlock are installed to prevent simultaneous operation of electric space-heating and air-conditioning loads, whichever is the greater load shall be used in calculating the demand".

As shown at the beginning of the section, the heating load significantly affects the electrical demand, with an even greater impact in colder climates. In many cases, this load can be reduced by using more efficient equipment, like **air-source and ground-source heat pumps**.

The following sections outline PED strategies for two different system types:

- **Per-dwelling systems** which serve individual dwelling units and are commonly found in ground-oriented buildings such as single-family homes, rowhouses, and low-rise MURBs, though they can also be used in apartments. In Québec, where electricity is inexpensive, these systems are also prevalent even in new high-rise apartments.
- **Central systems** provide space conditioning to multiple units within a single building, and are almost exclusively used in apartment buildings.

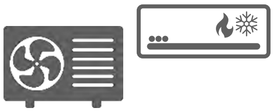
2.3.1 Per dwelling systems

The following section presents various PED strategies for space conditioning systems **contained within individual dwelling units**. These systems are commonly found in smaller residential buildings, such as single-family homes, rowhouses, and low-rise MURBs.

In larger apartments, per dwelling systems are more prevalent in regions with low electricity costs. In areas with higher electricity costs, it is often cost-effective to invest in a central system. However, the added expense and complexity of a central distribution system (e.g., piping, pumps) can be avoided by opting for per-dwelling systems, which are easier to implement and manage, particularly for units with independent owners (for example, condos).

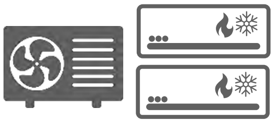
There are various configurations of heat pumps available for space heating, each suited to different building types and climate zones. In colder climates, some buildings may require gas or electric backup systems to supplement heat pumps when outdoor temperatures fall below the operating range of the chosen units. Properly sizing the equipment is crucial to ensure the heating load is met efficiently.

For each system, we will highlight its specific characteristics and the situations in which it is most suitable.



Single-head ductless mini-split air source heat pump, which consist of one exterior unit – generally installed on the ground, roof, or balcony – and one interior unit (or head) generally installed on a wall in a dwelling's main living area. Most manufacturers offer models ranging from ¾ ton to 2 tons, offering flexibility to closely match the heating and cooling loads, especially in smaller dwellings.

The fact that there is only one indoor unit generally means it will likely be combined with other heating equipment – baseboards in the bedrooms for instance – to ensure the heating load is met and occupant comfort is maintained. In retrofits, this type of system is ideal where there is no existing ductwork.



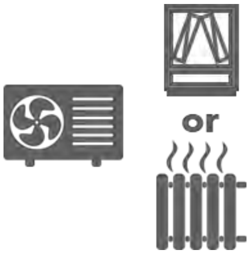
Multi-head ductless mini-split air source heat pumps, as the name implies, are mini-split heat pumps that can accommodate more than one indoor unit.

While this significantly reduces the space heating electrical load, most manufacturers only offer models ranging from 1.5 to 3 tons, a capacity that may exceed the requirements of smaller single dwelling units. The introduction of lower capacity systems is an important power efficiency, as well as energy efficiency, opportunity.

In retrofits, this type of system is ideal where there is no existing ductwork.

Single and multi-head split systems can also be provided with indoor unit types other than wall-mounted units, such as small ducted units, ceiling cassette and floor consoles.

Packaged terminal heat pumps (PTHPs) are compact, single-unit systems that do not require a separate outdoor unit. Installed through an exterior wall, these units directly provide heating or cooling to individual rooms or zones. Due to their localized nature, PTHPs are commonly used in apartments or multi-room spaces, where multiple units or a combination of PTHPs and electric baseboards may be needed to maintain comfort throughout the dwelling. Cold-climate models are available that can operate efficiently in temperatures as low as -15°C, making them suitable for moderate cold-weather regions.



Centrally ducted or hydronic air-source heat pumps are typically used in combination with an air or water distribution system. In many climate zones, they can meet the full heating load of a single dwelling unit without the need for supplementary heat. These systems are ideal for retrofits where existing ductwork or hydronic network is available – for example, when replacing fossil fuel forced-air furnaces or boilers. However, it is important to note that existing ductwork may not always be properly sized for the airflow required to efficiently heat and cool the entire home with a heat pump.

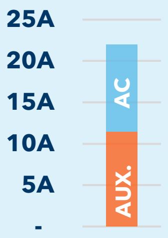
Due to the lower supply temperature from heat pumps, buildings' **existing heat distribution systems can be a bottleneck to deliver peak heating requirements**. In retrofits, combining electrification with heating load reduction measures (air-sealing, insulation or ventilation heat recovery) or combining a central system with ductless units in larger rooms can enable electrification without supplementary heating sources.

In milder climate, ASHPs can efficiently reduce the electrical service size

The following example is based on a typical **apartment dwelling** in a Vancouver MURB.

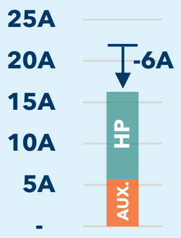
AC with baseboards

In this design, a **1 ton mini-split AC** in combination with electric resistance baseboards – covering the full heating load – are installed. No interlock prevents the simultaneous operation of both systems.



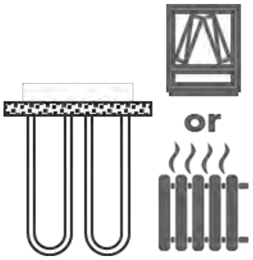
Single head mini-split with baseboards

In this design, a **1 ton single-head mini-split cold-climate ASHP** in combination with electric resistance baseboards – covering 50% of the heating load – are installed.



Overall, the higher efficiency of the heat pump covering most of the heating needs reduces electrical capacity requirements by **6 A at the dwelling level**.

The heating capacity of ASHPs decreases as outdoor temperatures drop. While some advanced ASHP models can operate in temperatures as low as -35°C, **colder regions with design temperatures below -20°C**, such as Montréal, **will likely be designed with supplementary heat sources** – like electric baseboards or duct heaters.



Centrally ducted or hydronic ground-source heat pumps are typically used in combination with an air or water distribution system. They use the stable temperatures of the ground as a heat source in winter and a heat sink in summer, thus maintaining a consistant efficiency throughout the year.

Depending on the design, they can meet the full heating and cooling demands of a single dwelling unit without the need for supplementary heating. In colder climates, this capability can **meaningfully reduce the space conditioning load calculation.** Furthermore, avoiding electrical supplementary heating can reduce utility system-wide winter peaks.

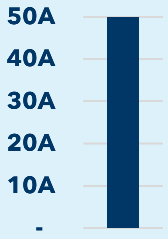
Most manufacturers offer models ranging from 2 to 6 tons, which may exceed the requirements for smaller single dwelling units. Although possible, using ground-source heat pumps for retrofits challenging, even when ductwork is present, because of the outdoor ground loop that must be added.

In colder climate, ground source heat pumps can efficiently reduce the electrical service size

The following example is based on an **single family home** using a ducted central system in Montréal.

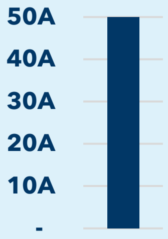
Electric resistance heating

In this design, an electric furnace with **two 5kW heating strips** – covering the full heating load – are installed.



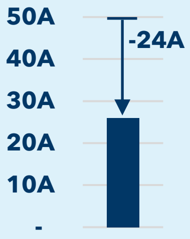
ASHP with electric backup

In this design, a **2T ASHP** and a furnace with **two 5kW supplementary heating strips** – covering the full heating load – are installed.



GSHP without backup

In this design, a **3T GSHP** and a furnace with **no backup heating strips** are installed.



Overall, the consistent efficiency of the GSHP reduces electrical capacity requirements **24 A**, roughly half the initial requirement. Given the significant on electrical peak, winter peaking utilities, like Hydro-Québec, through it's LogisVert program, offers significant incentives for this heating system, around 9000$/ton in residential buildings.

In **existing buildings with gas heating systems**, installing a heat pump and **using the gas system** as a backup during winter peak **can effectively electrify a significant portion of heating**.

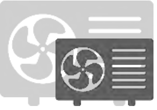
This approach can minimize the need for service upgrades while enhancing energy efficiency and reduce GHG emissions.

2.3.1.1 Equipment sizing

When selecting space conditioning equipment, it is crucial to **accurately assess the load and select the appropriate equipment** for optimal performance

Small apartments and small bedrooms are the most at risk of heat pump **oversizing,** which can cause the following issues with ASHPs:

- **Short cycling or constant on/off cycling**, reducing system efficiency and potentially leading to premature failure.
- **Increased electrical requirements,** potentially resulting in costly and unnecessary electrical upgrades.
- **Defrost issues** in heating mode, where short run times may prevent the defrost cycle from activating, causing ice build-up on the outdoor unit.
- **Dehumidification issues** in cooling mode, where short cycles may fail to adequately remove humidity from the living space.
- **Higher upfront capital costs** and increased monthly energy bills.



Dwellings in less efficient buildings and colder climate zones are the most at risk of heat pump **undersizing,** which can lead to the following issues with ASHPs:

- **Unmet heating demand,** leading to discomfort and complaints from occupants.
- **Increased reliance on supplemental heat,** which is generally more costly to operate.
- **Accelerated wear and tear** due to a constant operation at maximum capacity.

The risk of installing heat pumps that are over or under sized can be reduced by taking a few important steps:

Complete a heat load calculation to determine the right amount of heating needed for the space. A greater accuracy, than approximations or rules-of-thumb, is needed.

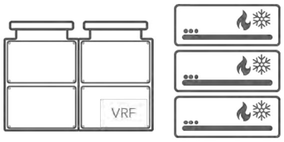
Many contractors in smaller residential projects still use floor area to size heat pumps, even though heat loads can vary widely between buildings and dwellings within the same building, influenced by factors such as building location, efficiency, and orientation. For example, top and ground floor dwellings can have over twice the heating load of those on middle floors.

Choose a **right sized heat pump** that can **adjust its capacity based** on heating needs. For example, some variable capacity heat pumps can reduce their heating capacity to as low as 25% of their maximum output. Variable capacity output allows the heat pump to run efficiently without constantly turning on and off, which is especially helpful in rooms that don't require as much heat.

To optimize service capacity, the CE Code, Part I, **Rule 8-200** could explicitly mention that electric space-heating loads should not be greater than those calculated in accordance with **CSA F280-12:** Determining the required capacity of residential space heating and cooling appliances.

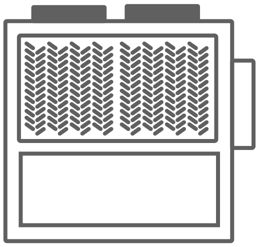
2.3.2 Centralized systems

Space heating can also be accomplished with one or more large central ASHP/GSHP systems. In retrofit contexts, some central systems utilize the existing hydronic piping in the building, making them more suitable for buildings where the piping is in good condition. In centralized systems, the central heat pumps connect to the common building meter, and the new zone terminals connect to each individual suite meter. Zone terminals in each suite may need to be replaced in some cases, as high-temperature hydronic zone terminals are usually not compatible with central heat pump systems. Central heat pumps offer efficient heating and cooling, contributing to energy savings and emissions reductions. Depending on the climate zone, some buildings may require supplementary gas or electric heating for providing effective heating during very cold temperatures.



Variable refrigerant flow (VRF) systems feature one or more outdoor heat pump units – depending on the building size – and multiple indoor units (or heads) connected by refrigerant lines. The central outdoor heat pump can be installed on the roof, ground, or other suitable locations depending on the site.

These systems are like split-system air-source heat pumps (see section 2.3.1) but require fewer outdoor units, centralizing the equipment. They can also allow for heat recovery between zones that are in cooling and heating mode. However, they introduce added significant complexity in installation, operation, and maintenance due to the additional controls and refrigerant lines required.



Air-to-water heat pump feature a large, central, ASHP that replaces, or supplements, a central gas or electric heating system. The central outdoor heat pump can be installed on the roof, ground, or other locations depending on the site.

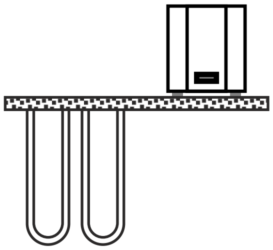
When used with **zone water source heat pumps**, zone terminals in the suites are water source heat pumps that actively heat or cool each individual room or the zone where they are placed. Water-source heat pumps are equipped with a small compressor, integrated controls, and a fan to deliver supply air to the room. This system can be more complex compared to decentralized systems.

When used with **zone terminals**, low-temperature zone terminals, like radiant floors and fan coils, can be directly connected to the hydronic loop. In a retrofit context, the existing distribution can be used if the terminals and the hydronic piping in the building are in good condition. Some terminals – like older hydronic baseboards – will require hotter system temperatures which necessitates central boilers to provide "top-up" heating. Providing cooling with this type of system is not recommended because pipe condensation can lead to mold, pipe corrosion and leaks. When suitable, however, this retrofit minimizes disruptions to tenants by limiting the need for work within suites.

The heating capacity of ASHPs decreases as outdoor temperatures drop.

In milder climates like Vancouver (design temperature of -7°C), most ASHPs can meet the full heating demand at the heating design temperature, typically without requiring auxiliary heating.

While some advanced ASHP models can operate efficiently in temperatures as low as -35°C, **colder regions with design temperatures below -20°C**, such as Montréal, **will likely be designed with supplementary heat sources** – like electric baseboards or duct heaters.



Ground-source heat pumps systems feature a central heat pump that uses the stable temperatures of the ground to replace or supplement a central gas or electric heating system. The central GSHP unit can be installed indoors, typically in a mechanical room, with a ground loop buried in vertical boreholes.

When paired with zone water-source heat pumps or zone terminals, the operation is identical to the air-to-water heat pump.

Heating efficiency and capacity is more consistent with GSHP systems than with air-source alternatives due to the stable ground temperatures. Although possible, using ground-source heat pumps for retrofits challenging, even when ductwork is present, because of the outdoor ground loop that must be added.

In **existing buildings with gas heating systems**, installing a heat pump and using the gas system as a backup during winter peak can effectively electrify a significant portion of heating, while reducing the potential for supplementary electrical heat to increase calculated loads and trigger service upgrades or other undesirable electrical works.

When implementing a dual-fuel system, **it is crucial to ensure the operation prioritizes maximizing the use of the HP**. The effectiveness of such systems heavily depends on the controls used for switching from the HP to the natural gas system. Improper configuration can lead to the NG system unintentionally becomes the primary heating source rather than serving as a backup.

Interestingly, stakeholders involved in this study noted that in new construction projects, **even with incentives covering up to 80% of the cost of the additional electric heating system**, such as those in Québec, dual-fuel systems are not generally cost-effective compared to per-dwelling systems in large apartment buildings. This is primarily due to the additional distribution costs associated with central systems.

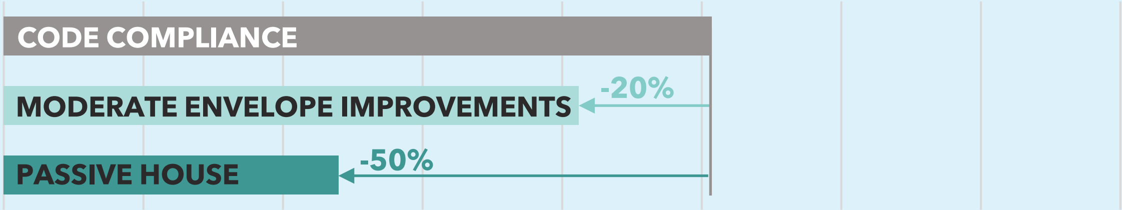
2.4 Building Efficiency

2.4.1 Envelope Improvement

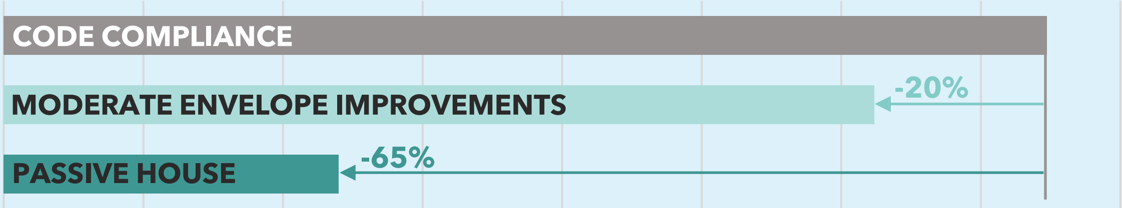
Another method of reducing a building's heating load is through envelope improvements. In addition to reducing annual energy use, envelope improvements allow for the use of smaller capacity heating equipment. Performance targets that address the heating and cooling load specifically – such as Passive House – are likely to have the biggest impact in optimizing the electrical service size.

How much can an improved envelope reduce peak heating?

In a milder climate like Vancouver, enhancing the building envelope in new construction can lower peak heating loads by an average of 20% compared to minimum code requirements. Opting for high-performance construction standards, such as Passive House, which focuses specifically on reducing heating demand, can achieve even more—potentially halving the heating load.



The impact is even more pronounced in colder climates. As discussed in Section 5, colder weather significantly increases heating loads, making envelope improvements even more critical. In these regions, high performance construction standards, like Passive House standards not only deliver greater potential reductions but also address a much larger initial heating demand.



Research indicates that achieving a high-performance building envelope in new construction can be accomplished with little to no increase in cost.[7]. When considering long-term energy savings and durability, the investment often proves cost-effective. This conclusion is further strengthened when this improvement results in a reduction of the electrical service size.

In **existing buildings**, upgrading the envelope before its end of service life can be costly. However, when such an opportunity arises, it is essential to assess its feasibility as improving the building envelope can free up electrical capacity, reduce the size of required heating equipment, and lower overall operating costs

In many cases, replacing low-performing windows is a low-hanging fruit, providing energy savings and better comfort to occupants.

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[7] Addressing the Cost of Efficiency (2021), Scaling Up Passive House Multifamily: The Massachusetts Story (2022), Does High Performance Construction Cost More?, BC Housing (2024)

2.5 Low Power DHW

Although water heating energy consumption is substantial in residential and many non-residential buildings, its overall effect on load calculations is usually relatively less significant. However, certain PED strategies can effectively reduce demand enough to achieve a smaller service capacity increment, particularly when the calculated load approaches the threshold for a reduced service size. In many instances, this load can be minimized by utilizing more energy-efficient electric resistance equipment or heat pumps (especially when the climate does not require supplementary heat).

The following sections outline PED strategies for two system types:

- **Per-dwelling systems** which serve individual dwelling units and are commonly found in ground-oriented buildings such as single-family homes, rowhouses, and low-rise MURBs, though they can also be used in apartments. In Québec, where electricity is inexpensive, these systems are also prevalent even in new high-rise apartments.
- **Central systems** serve multiple units within a single building and are almost exclusively used in apartments and non-residential buildings.

Electric tankless water heaters were excluded from this report due to their significantly higher power draw compared to storage systems, which conflicts with the goal of optimizing electric load calculations.

As such, utilities like BC Hydro include special conditions in rates without demand charges to discouraged their use.

In new construction, per-dwelling systems or central systems can both be implemented in power efficient ways, and the most power efficient approach depends on the building. While per-dwelling systems may lead to a higher overall nameplate load, the CE Code allows for considerable diversity in these designs. On the other side, central systems can be optimized to account for this diversity, but the CE Code specifies a lower diversity factor in this case.

Per-dwelling systems offer advantages, such as straightforward billing, since each unit has its own system, as well as lower construction costs – when using traditional electric resistance water heaters – by eliminating the need for a distributed hot water and recirculation loops. However, central systems enable a more cost-effective and space-efficient implementation of heat pump water heaters.

In systems being retrofitted, it is generally recommended to follow the existing configuration.

2.5.1 Per dwelling systems

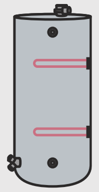
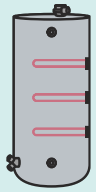
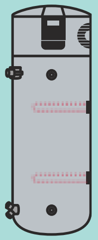
This section focuses on typical water heaters installed on a per-unit basis, typically found in smaller ground-oriented buildings.

- **Traditional electric resistance storage water heaters** use two electric resistance elements to heat water. Typically, the heating elements require 4500 W each, but the overall nameplate rating is also 4500 W, as they cannot operate simultaneously. This system is the most power-intensive, leading to higher electrical service requirements.
- **Power efficient electric resistance storage water heaters** reduce power requirements by distributing the heating load **across three smaller elements** (3800, 3000 and 800 W).

This design lowers the instantaneous power draw, typically to 3800 W, helping to optimize electrical service sizing. The system delivers comparable water heating capacity but with better demand management.

- **Hybrid heat pump water heaters** (HPWH) are highly efficient, consuming about one-third of the power of traditional electric resistance water heaters, using a compressor rather that resistive elements to heat the water. A typical hybrid-HPWH may require only 1 to 2 kW of power to operate, hot water recovery times are generally longer. While larger storage tanks are a solution to meet peak hot water demands, “off the shelf” products typically come with auxiliary heating elements (2300 to 4500 W) to speed up recovery time and ensure occupant satisfaction. This has a limited impact on energy efficiency, but a significant one on power efficiency. These units are like conventional in-suite electric resistance storage tanks but are approximately 18 inches taller. For optimal performance, HPWHs should be vented outdoors (in which case outdoor air temperature might affect performance) or into the return air duct of a central forced air system; however, they can still function adequately even if outdoor venting is not feasible.

> To **enabling greater hot water output the same equipment**, **drain water heat recovery** systems – a water-to-water heat exchanger to capture waste heat from drain lines and preheat cold water entering the storage tank.

	Traditional electric resistance storage water heaters 	**Power efficient electric resistance storage water heaters** 	**Hybrid heat pump storage water heaters** 
Voltage	240V 1-Phase AC	240V 1-Phase AC	240V 1-Phase AC*
Amps (min. breaker size)	12 to 20 A (20 to 25 A)	16 A (20 A)	8 to 20 A (15 to 25 A)
Load	3 to 4.5 kW	3.8 kW	1.8 to 4.5 kW
Tank Size	30 to 60 gal.	60 gal.	40 to 80 gal.
Examples of Manufacturers	Giant AO Smith Rheem	Giant	AO Smith Rheem SANDEN

* In the US, 120V “retrofit ready” models are entering the market to facilitate the replacement of gas water heaters. At the time this report was published, none of the manufacturers had those models on their Canadian websites. This alternative have benefits from a power efficiency standpoint, but faces barriers similar to the HPWH shown above.

When calculating a building's required service capacity under the latest version of the CE Code, **electric water heater loads must be accounted for using a 25% demand factor** with two exceptions:

1. If the load is under 1500 W, it does not need to be included in the load calculation.
2. In ground-oriented buildings only, if the dwelling does not include an electric range, a 100% demand factor might be required.

In single dwellings, per CE Code, Part I, Rule **8-200 1) vii)**, "any loads provided for that have a rating in excess of 1500W [shall be considered] at A) 25% of the rating of each load, if an electric range has been provided for; or B) 100% of the combined load up to 6000W, plus 25% of the combined load that exceeds 6000W, if an electric range has not been provided for".

The same approach is used in apartments is similar under **Rule 8-202 1) viii)** except when an electric range has not been provided for, in which case "25% of the rating of each load with a rating in excess of 1500W [has to be considered] plus 6000W".

When an electrical service supplies more than a single dwelling unit, additional diversity is accounted for in the load calculations. This means as more units are included, the total calculated load for water heaters is less than the sum of the individual loads. This also means that, as the number of dwellings increases, the relative savings from using power-efficient water heaters diminishes.

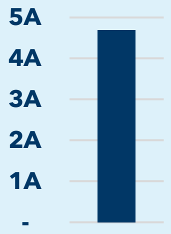
Per CE Code, Part I, if multiple dwellings are served by a single service, **Rule 8-202 3)** allows for a progressively lower demand factor to be used, from 100% in the first unit, to 10% after the 20th unit.

Let's see how the different approaches compare in terms of electrical load.

To do so, we will compare the three (3) design approaches to water heating.

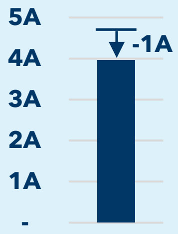
Electric resistance water heater

Giant 172STE 60 gal. tank
4,500 W nameplate rating



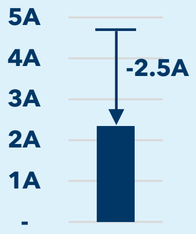
Power efficient electric resistance water heater

Giant 172EPS 60 gal. tank
3,800 W nameplate rating



Hybrid heat pump water heater

Rheem XE65T10H22U1 65 gal. tank
2250 W nameplate rating



Overall, this reduces the required electrical capacity by **2.5 A at the dwelling level**. The impact is limited because only 25% of the water heater's nameplate rating is used in the load calculation, which reduces the potential savings from power-efficient models. As said before, many HPWHs have regular sized heating elements (4500 W). In this case, there would not be any electrical capacity savings versus a traditional electric resistance water heater.

! Smaller 30 or 40 gal. electric resistance water heater also have smaller **3,000 W** nameplate ratings. Thus, selecting the right equipment size also impacts the electrical load calculation.

2.5.2 Centralized systems

This section focuses on central water heaters installed on a per-building basis, typically found in larger apartment buildings.

- **Electric resistance storage water heaters** use electric resistance elements to heat water inside a storage tank. While this technology has been in use for decades and may have lower upfront costs, it is important to note that these heaters consume 2-3 times more electricity than heat pump systems and generate higher peak demand, resulting in lower overall energy savings. Those centralized systems tend to be larger and are typically located in a common area of buildings, allowing for the distribution of hot water to multiple suites, compared to decentralized systems, which are smaller and installed within individual units.
- **Modular heat pump water heaters** consist of modular arrays of outdoor heat pump units mounted together and connected through potable water lines to the storage tanks. Installation of additional storage tanks is usually required as the storage for heat pump domestic hot water systems is larger than typical gas systems. The storage tanks are typically located indoors, but can also be located outdoors. All refrigerant is contained inside the outdoor heat pump units. Modular systems offer flexible placement of outdoor units and scalability, allowing for conservative initial designs with space for future expansion, unlike large central systems. Key limiting factors are the availability of space for mounting arrays of the outdoor units, and location for the additional storage tanks given space constraints in existing mechanical rooms and roof structural capacity limitations.
- **Large heat pump water heaters** consist of an outdoor heat pump unit connected through potable water lines to the storage tanks. Installation of additional storage tanks is usually required as the storage for heat pump domestic hot water systems is larger than typical gas systems. The storage tanks are typically located indoors, but can also be located outdoors. All refrigerant is contained inside the outdoor heat pump unit. Although these large heat pumps are typically louder, heavier, and more difficult to place than modular systems, they can be suitable for larger size systems.

! **Heat pump water heaters** models are available with CO_2 refrigerant, which has lower global warming potential than other refrigerants and can operate down to -25°C without the need of auxiliary heating.

When calculating a building's required service capacity under the latest version of the CE Code, **central electric water heater loads must be accounted for using a 75% demand factor**.

Per **8-202 3) e)** "any lighting, heating, and other power loads not located in dwelling units shall be added with a demand factor of 75%".

While this approach may appear more stringent compared to the progressively lower demand factors used for distributed water heaters (section 2.5.1), the diversity of the load –

from multiple dwellings being served by the central system – is typically already considered in the system design.

! In larger buildings, **wastewater-source heat pumps** can be used to reclaim heat from a building's waster water – potentially preheating the domestic hot water.

2.6 Low Power Clothes Dryer

In Canada, most people use traditional electric dryers.

These dryers operate on 240V circuits and have power draw between 4,000 and 6,000 W. While they provide quick drying times, power draw is the highest amongst the available technologies. There are typically two alternatives that are more power efficient:

- **Condensing dryers** work without the need for external ventilation. Instead, they condense the moisture from the air inside the drum into water, which is then drained away. These dryers generally use slightly less power than traditional electric dryers but still have a significant power draw.
- **Heat pump dryers** (which often come as washer and dryer combos) are the most power efficient option, using a heat pump to dry the laundry. Although they take longer to dry clothes, this method reduces power draw substantially, to the point that some models will not need to be included in the electrical load calculation.

	Traditional dryer	**Condensing dryer**	**Heat-pump dryer (or combo)**
Voltage	240V 1-Phase AC	240V 1-Phase AC	120-240V 1-Phase AC
Amps (min. breaker size)	16 to 25 A (20 to 30 A)	10 to 16 A (15 to 20 A)	4 to 12 A (typically 15 A)
Load	4 to 6 kW	2.5 to 4 kW	900 W to 1.4 kW
Examples of Manufacturers and Models		Bosch WTG86403UC	120 V: Miele TWI180WP 240 V: Bosch WQB245AXUC

When calculating a building's required service capacity under the latest version of the CE Code, **clothes dryer loads must be accounted for using a 25% demand factor** with two exceptions:

5. If the load is under 1500 W, it does not need to be included in the load calculation.
6. In ground-oriented buildings only, if the dwelling does not include an electric range, a 100% demand factor might be required.

In single dwellings, per CE Code, Part I, Rule **8-200 1) vii)**, "any loads provided for that have a rating in excess of 1500W [shall be considered] at A) 25% of the rating of each load, if an electric range has been provided for; or B) 100% of the combined load up to 6000W, plus 25% of the combined load that exceeds 6000W, if an electric range has not been provided for".

The same approach is used in apartments is similar under **Rule 8-202 1) viii)** except when an electric range has not been provided for, in which case "25% of the rating of each load with a rating in excess of 1500W [has to be considered] plus 6000W".

When an electrical service supplies more than a single dwelling unit, additional diversity is accounted for in the load calculations. This means as more units are included, the total calculated load for dryers is less than the sum of the individual loads. This also means that, as the number of dwellings increases, the relative savings from using power-efficient dryers diminishes.

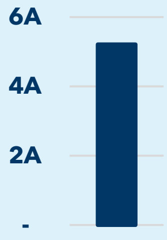
Per CE Code, Part I, if multiple dwellings are served by a single service, **Rule 8-202 3)** allows for a progressively lower demand factor to be used, from 100% in the first unit, to 10% after the 20th unit.

Let's see how the different approaches compare in terms of electrical load.

To do so, we will compare the three (3) dryer types.

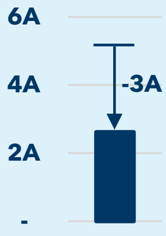
Traditional electric dryer

Regular appliance with a **5,000 W** nameplate rating.



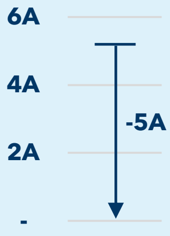
Condensing dryer

Bosch WTG86403UC with a **2,520 W** nameplate rating



Heat pump dryer (or combo)

Bosch WQB245AXUC with a **900 W** nameplate rating



Overall, the condensing dryer reduces the required electrical capacity by **3 A at the dwelling level.** The impact is limited because only 25% of the water heater's nameplate rating is used in the load calculation, which reduces the potential savings from power-efficient models.

Crucially, **since the HP dryer has a nameplate rating under 1500W, it does not have to be included** in the electrical load calculation which reduces the required electrical capacity by **5 A at the dwelling level**.

There are two primary barriers adoption of more efficient dryers:

1. **Cost:** The price of heat pump dryers is generally around twice that of traditional electric dryers.

2. **Drying Time:** The drying cycles of heat pump dryers are longer than traditional dryers, which may lead to dissatisfaction among users. This can be mitigated by educating consumers on the cost saving benefits.

On the other hand, it's worth noting that **condensing and HP dryers** eliminate the need for venting moist air, thereby:

- **Avoid the requirement for a building envelope penetration**, which reduces the risk of water ingress and also minimizes air infiltration.
- **Prevents building depressurization**, which removes the need for make-up air – if required by code.

2.7 Battery Integrated Appliances (BIA)

Battery-integrated appliances (BIAs) function similarly to conventional appliances but **incorporate an internal battery system to power the device** during operation. This built-in battery is recharged during periods of inactivity.

While the total energy consumption of the appliance remains the same, the integrated battery system reduces power demand by distributing the load over a longer period. Instead of drawing high power all at once, the appliance relies on stored energy. This can also allow power-intensive appliances (e.g. electric range) to use a smaller 120V circuit, rather than a typical 240V circuit, and offer resilience during an outage.

Currently, two products are planned to be introduced in the US market. To the best of our knowledge, none are currently available in Canada – and projected prices are 4 to 5 times higher than those of a traditional electric range.

	Traditional electric range	**Battery integrated electric range**
Voltage	240V 1-Phase AC	120V 1-Phase AC
Amps (min. breaker size)	Depends on model (Typically 40 A)	12 A (15 A)
Examples of Manufacturers and Models	various	COPPER Copper Induction Range IMPULSE Impulse Cooktop

These technologies are **not explicitly addressed in the CE Code**. As a result, they would not permit a reduction in electrical service size compared to a typical electric range. Currently, if an electric range is installed, a minimum of 6,000W is added to the load calculation.

> In single dwellings, per CE Code, Part I, Rule **8-200 1) a) iv)** "6000W for a single range plus 40% of any amount by which the rating exceeds 12 kW". Identical in apartments per Rule **8-202 1) a) v)**.

Even if a gas range is installed, the CE Code accounts for a provision (up to 6,000W in apartments).

> In single dwellings, per CE Code, Part I, Rule **8-200 1) a) vii) B)**, the load has to be accounted for at "100% of the combined load up to 6000W, plus 25% of the combined load that exceeds 6000W, if an electric range has not been provided for". In apartments, per Rule **8-202 1) a) viii)**, while the load is considered at 25%, a provision of 6000W is automatically added.

Enabling implementation of BIAs for the purpose of service capacity optimization requires updates to the CE Code.

> Section 0 of the CE Code could explicitly define an **electric range** and a **battery-integrated electric range**. Articles **8-200** and **8-202** could allow for a load to be considered if using the latter.

STRATEGY 3

Energy Management Systems

3. Energy Management Systems

Energy management systems (EMS) can monitor and control electrical loads so as not to exceed power thresholds. By controlling electrical loads in this way, they can be used to avoid a building or facility exceeding capacity limits. Likewise, EMS can be used to control loads for other purposes, such as avoiding utility demand charges, responding to time varying electrical rate price signals, and utility demand response, among others.

This chapter first summarizes several archetypal EMS control schemes and the associated electrical configurations that they can enable, including:

- Circuit switching (Section 3.1).
- Dynamic energy management (Section 6.2)
- Service and feeder monitoring (Section 6.3)

Section 6.4 then summarizes treatment of these strategies in the CE Code, Part I, noting that electric vehicle energy management systems (EVEMS) are generally well enabled in the CE Code, but that there is an **opportunity for electrical codes and standards to further enable EMS** for other types of electrical loads (i.e. non-EV loads). EV loads are particularly large and controllable. Thus, for many building types, EV loads are the most important load to be able to control for the purposes PED. However, several stakeholders noted that it would be valuable for CE Code load calculation methodologies to reflect that EMS can dynamically control non-EV loads, as well as use service and feeder monitoring to control non-EV loads.

3.1 Circuit Switching

A **circuit switching device** (Figure 7) deactivates a "secondary load" on a branch circuit when a "priority load" is turned on, thereby staying within the capacity limits of the circuit. Most circuit switching devices allow the secondary load (for example, an EV charger) to operate only when the power drawn by the priority load falls below a specified threshold (e.g., 250 W). The priority load (e.g., an oven or dryer) typically remains powered to ensure user-controlled features, such as clocks and custom settings, are not disrupted.

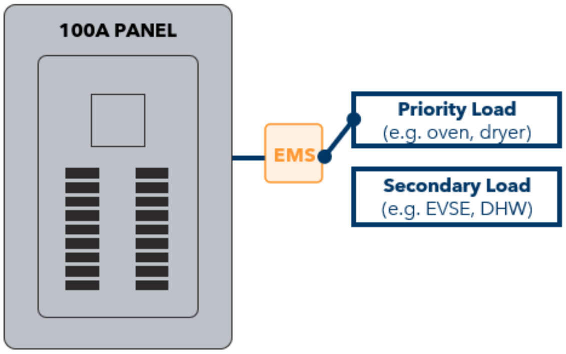


Figure 7: A branch circuit switching EMS.

When circuit switching devices are used, only the highest load is considered in demand load calculations. This can effectively reduce demand loads for both a single dwelling's feeder/panel, as well as buildings' services. The CE Code, Part I, enables such switching devices.

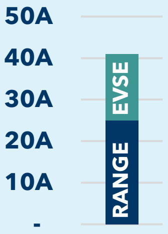
CE Code, Part I, **Rule 8-106 (2)** specifies that where two or more loads are installed so that only one can be used at any one time, the one providing the greatest demand shall be used in determining the calculated demand.

Using a circuit switcher will reduce the impact of EVSE on the electrical service

The following example shows the impact of installing a 20A Level 2 EVSE with and without circuit switching.

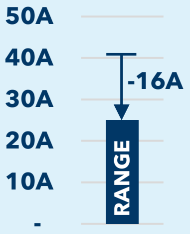
Without circuit switching

In the design, adding the 20 A Level 2 EVSE adds a 16 A load on top of the allocation for the electric range.



Circuit switching with the oven

In this design, only the largest load – here the electric range allocation – is considered.



Overall, this reduces electrical capacity requirements by **16 A at the dwelling level**. The exact load reduction will vary based on the magnitude of the loads used for circuit switching.

There are **two typical configurations** for circuit switching devices:

- **Hard-wired devices** require installation by an electrician, which offer a more permanent and seamless integration.
- **Plug-in devices** connect directly to an existing power outlet (typically for appliances like an oven or dryer), eliminating the need for an electrician. This relative simplicity makes them particularly suitable for electrification projects in existing buildings.

	Hard-wired devices	**Plug-in devices**
Voltage	240V 1-Phase AC	240V 1-Phase AC
Max circuit amps	Up to 60 A	Up to 50 A
Examples of Manufacturers and Models	DANDY LOADMISER simpleSwitch CANADA simpleSwitch LOADSHARE TECHNOLOGIES DIVVEE	NeoCharge Smart Splitter BSA Electric Range Buddy SPLITVOLT Splitter Switches

Figure 8: Circuit switching device configurations.

Branch circuit switching could theoretically interact with multiple different devices. However, **many devices are not appropriate to switch on/off regularly** (i.e. be the secondary load). For example, switching heat pumps on/off can interrupt compressor cycles and lead to inefficiencies and potential wear (see page 36). Product warranties may be void if a branch circuit switching device is used.

EV chargers are the most common secondary load, and can be paired with primary loads including an electric range/oven, electric dryer, and potentially domestic hot water equipment.

Electric resistance domestic hot water (DHW) equipment or hot tubs have also been used as secondary equipment in limited circumstances. However, DHW heaters need to be able to maintain safe temperatures over sufficient time periods to prevent *Legionella* contamination risk. However, it is worth noting several utility demand response programs are predicated on switching DHW tanks on/off, apparently without ill effect; further study of appropriate designs for use of DHW as the secondary load is warranted.

3.2 Dynamic Energy Management Systems

"Dynamic" EMS involve electrical equipment (e.g. an EV charger, or potentially some other load) that can incrementally adjust power consumption up and down to stay within the electrical capacity of a circuit, as opposed to simply switching circuits on or off. An example of such dynamic load sharing is when two or more "smart" 50A EV chargers are installed on the same 50A branch circuit. If only one EV is plugged in and charging, it can be allocated the full capacity of the circuit; however, if another EV is plugged in while the first is still charging, then the EMS communicates to reallocate capacity between the chargers. Both then charge at half capacity, ensuring the limit of the circuit is not exceeded.

Using such a dynamic control scheme generally requires "smart" end use equipment that are capable of wireless (e.g., Wi-Fi, cellular) or wired (e.g., ethernet cable) communications to receive and/or send messages and control power consumption of the equipment. The EMS is programmed to ensure that equipment collectively do not exceed the capacity of the circuit.

Several electrical configurations are possible using dynamic EMS, including:

- **Branch circuit sharing** where multiple flexible loads controlled by an EMS sharing one branch circuit (Figure 9).
- **Panel sharing** where flexible loads are controlled so as not to exceed the capacity of the panel (Figure 10).
- **Service/feeder monitor with dynamic controls** involves monitoring the instantaneous current on a service or feeder (as described in Section 6.3 below), and dynamically controlling loads so as not to exceed the capacity of those services or feeders.

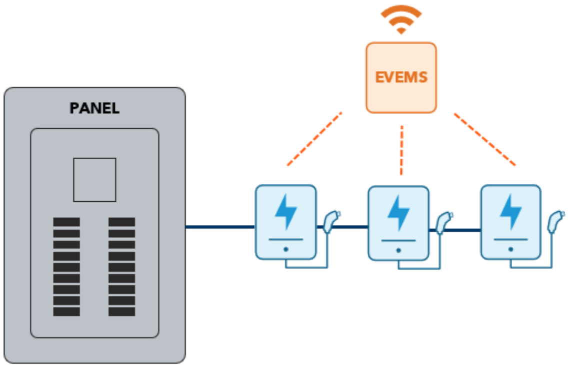


Figure 9: Branch circuit dynamic EMS controlling EV chargers.

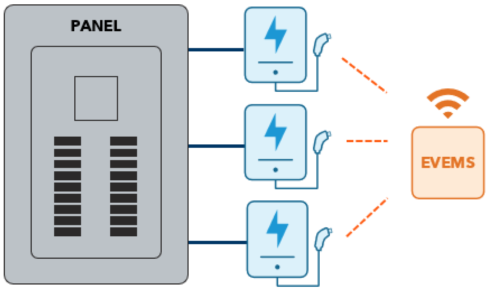


Figure 10: Panel sharing dynamic EMS controlling EV chargers.

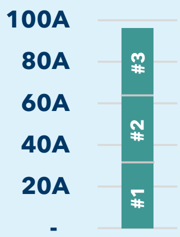
A dynamic EMS control scheme is commonly used to control EV charging loads. Such a control scheme could also theoretically be used to control other household loads – e.g., heat pumps with variable speed compressors, electric water heaters, pool heaters, lights with dimming capability, and any other device that can operate with reduced power consumption when capacity constraints are present. However, as discussed in Section 3.4 below, the CE Code only enables EV energy management systems (EVEMS), and dynamic control of non-EV loads, as a means of reducing calculated loads.

Using an EMS will reduce the impact of EVSE on the electrical service

The following example shows the impact of installing three 40A Level 2 EVSE on the same electrical panel with and without a dynamic EMS.

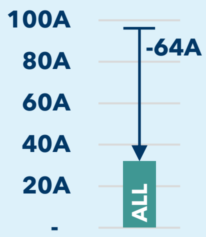
Without dynamic EMS

In the design, adding the three 40 A Level 2 EVSE adds a 96 A load.



Dynamic EMS

In this design, only the largest load allowed by the EMS is considered.



Overall, this reduces electrical capacity requirements by **64 A at the panel and service** level. The exact load reduction will vary based the number of chargers and the minimum load allowed by the EMS.

3.3 Service and Feeder Monitoring

A **monitoring EMS control scheme** involves implementing equipment – e.g., current transformers (CTs) – that monitor the real-time capacity of circuits in a building or facility, and control an electrical load depending whether there is sufficient capacity. Controls may switch loads' circuit breakers on/off; alternately, dynamic EMS may be used to communicate with "smart" networked devices, allowing them to incrementally adjust power up or down depending on the available capacity.

Monitoring EMS may be installed on a feeder serving a panel, controlling a device on that panel (see Figure 11). Likewise, it can be installed on a service to a building. EMS can also involve multiple monitoring devices on both services and feeders (see Figure 12).

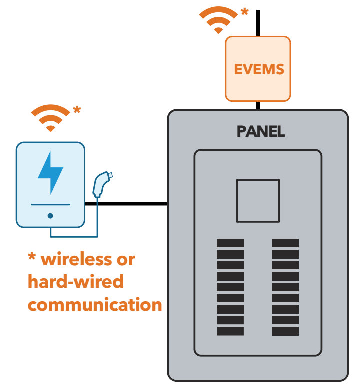


Figure 11: Feeder monitoring EMS controlling an EV charger.

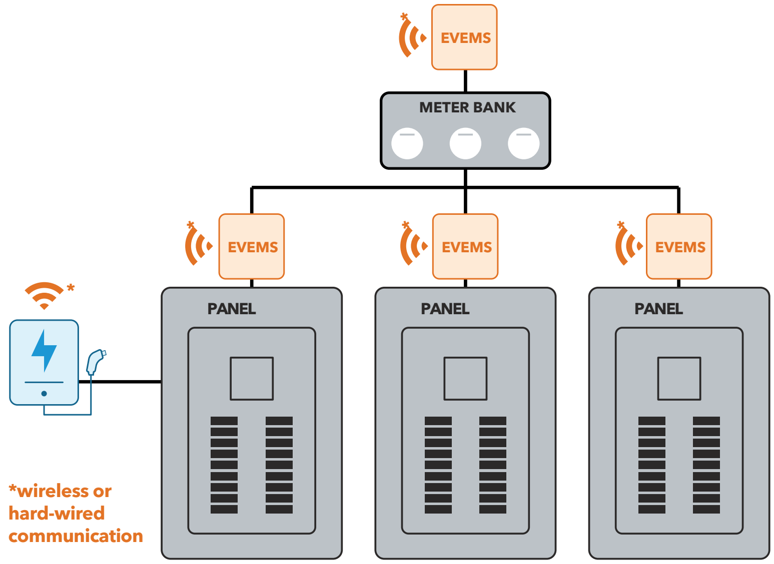


Figure 12: Feeder and service monitoring EVEMS controlling an EV charger.

Feeder/service monitoring is a potent PED strategy. It can enable EV charging to be added without increasing calculated loads. Likewise, it can be leveraged to enable more energy on a service/feeder to be devoted to EV charging, by monitoring available capacity and controlling EV loads accordingly (see Figure 13). This can be very valuable in retrofit applications. Similarly, new construction can benefit by negating EV loads from load calculations, allowing buildings to be served from smaller service sizes.

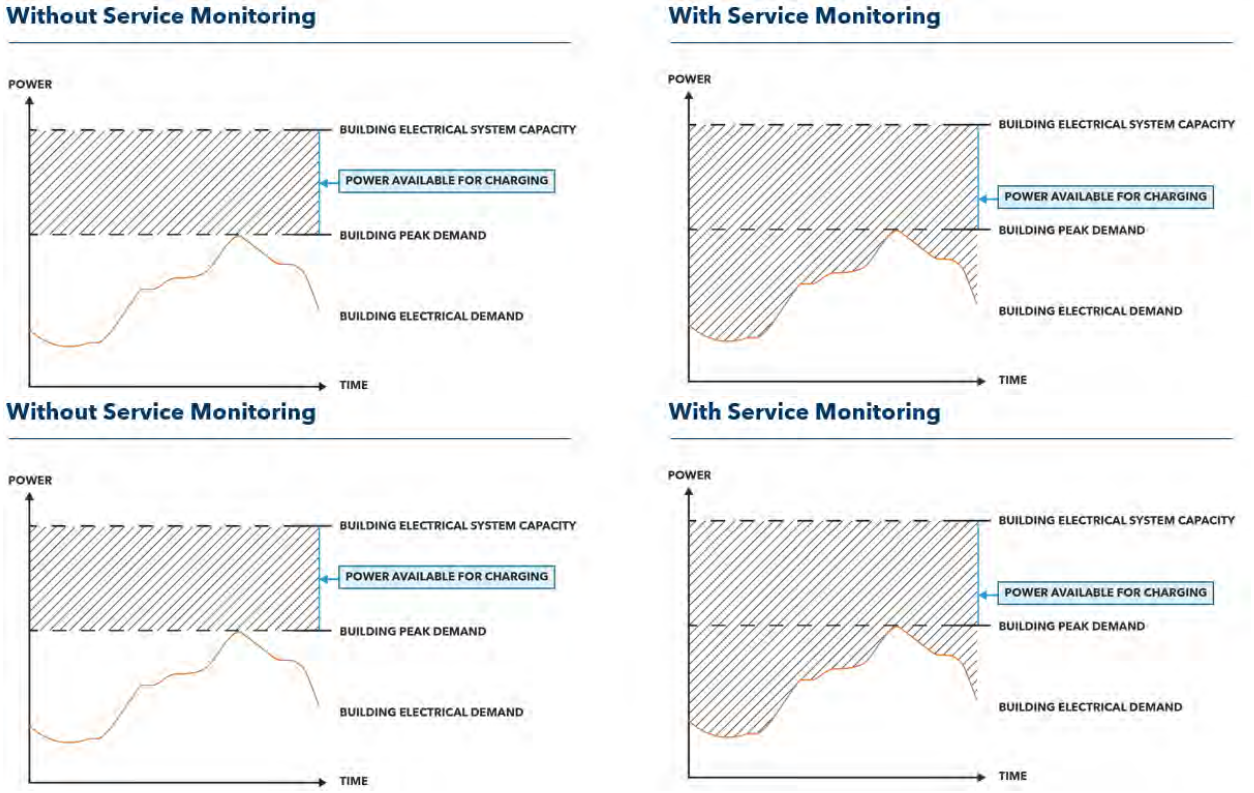


Figure 13: The additional electricity available for use for EV charging (or other end use equipment) when using service monitoring EMS. Derived from: BC Institute of Technology. 2019.

As noted in Section 6.5 below, the CE Code, Part I, only clearly enables EVEMS to perform dynamic energy management and/or service/feeder monitoring. While managing EV loads represents the largest PED strategy in many buildings and facilities, several stakeholders noted that such EMS control strategies can be valuable for other loads, and should therefore be better enabled in electrical codes.

For example, one stakeholder noted the value of programming commercial or large multifamily buildings' air handling units (AHUs) or rooftop units (RTUs) to stay within service or feeder limits. While this can be programmed in building energy management systems, it is not recognized in the CE Code. As a result, electrical safety authorities must provide variances for these applications, a process which can be uncertain and more expensive and time-consuming depending on jurisdiction.

Similarly, other stakeholders speculated that as electrification increases, more technologies may be brought to market that can control networked equipment, such as household's space heating, DHW, and appliances. These stakeholders believe the electrical codes and related standards should enable dynamic control of these loads, in anticipation that it will enable such innovation in technologies and energy services.

Using a service and feeder monitoring EMS will reduce the impact of EVSE on individual panels and at the service level

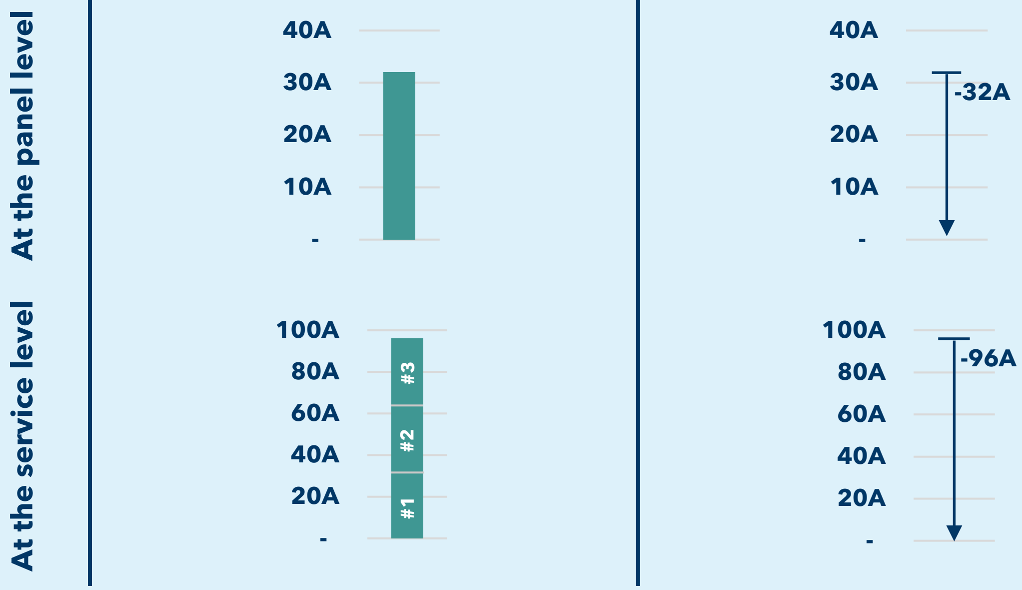
The following example shows the impact of installing a 40A Level 2 EVSE on three dwelling unit panels sharing an electrical service.

Without service and feeder monitoring

In the design, adding the 40 A Level 2 adds a 32 A load on each panel, which sums up to 96 A at the service level.

Service and feeder monitoring

In this design, since the service and feeder monitoring always ensure both the panel and the service are within their maximum capacity, no load EVSE load have to be considered.



Overall, this reduces electrical capacity requirements by **32 A at the panel** level and **96A at the service** level. While this approach is having an impressive impact, designers must ensure that sufficient spare capacity remains consistently available on the electrical service. Without it, the monitoring system will constantly throttle down the EVSEs, preventing them from delivering power when needed, undermining their functionality.

3.4 Energy Management Systems' Treatment in Electrical Codes and Standard

EV energy management system (EVEMS) is a defined term in the CE Code, Part I. This definition is broad and includes a wide variety of components and possible arrangements of electrical equipment. Equipment forming an EVEMS may be approved as a standalone product, or field assembled from approved products interconnected in accordance the CE Code. Subrules 8-106 (10) and (11) allow for an EVEMS to minimize or eliminate the load associated with EV supply equipment (EVSE, i.e. an EV charger) depending on the limits imposed on the EVSE by the EVEMS. So long as the arrangement of the equipment is such that only EVSE loads are controlled, any other types of loads may be monitored as input to the control scheme of the EVEMS.

The CE Code, Part I, **Rule 8-002** defines "electric vehicle energy management system" (EVEMS) as "a means used to control electric vehicle supply equipment loads through the process of connecting, disconnecting, increasing, or reducing electric power to the loads and consisting of any of the following: a monitor(s), communications equipment, a controller(s), a timer(s), and other applicable device(s)."

Rule 8-500 permits the use of EVEMS. **Rule 8-106** contains the following sub-rules:

> 10. Where electric vehicle supply equipment loads are controlled by an electric vehicle energy management system, the demand load for the electric vehicle supply equipment shall be equal to the maximum load allowed by the electric vehicle energy management system.
>
> 11. … The demand load for the electric vehicle supply equipment shall not be required to be considered in the determination of the calculated load where an electric vehicle energy management system as described in Subrule 10) performs the functions of
>
> > a. monitoring the consumer's service, feeders, and branch circuits; and
> >
> > b. controlling the electric vehicle supply equipment loads in accordance with Rule 8-500.

In contrast, the CE Code, Part I, does not include a definition of "energy management systems" (nor synonymous concepts). Accordingly, Section 8 does not include means for EMS to reduce calculated loads in the same manner as EVEMS.

Multiple interviewees noted amending the CE Code, Part I, to reference EMS in a similar manner as EVEMS as an opportunity to better enable PED. It was noted that the 2023 NFPA 70, *National Electrical Code* (referred to as "NEC 2023" in this document) includes Article 750 "Energy Management Systems", and enables EMS to control both EV charging and other end loads. This opportunity will be included in Dunsky's forthcoming CE Code, Part I, amendment proposals as part of the Consortium.

The CE Code, Part I, can be updated to **define "energy management systems"**, and enable their use to impact calculated loads.

3.4.1 EMS standards landscape overview

As noted in Section 3.4 above, the CE Code, Part I, requires that installed electrical equipment be certified to a product standard for its specific purpose. CSA Group is in the latter stages of developing an Electric Vehicle Energy Management System standard (CSA C22.2 No. 343), but it must be published before any devices can be listed as a certified EVEMS.[8] Until this issue is resolved, the approval of the products listed in this report as an EVEMS are subject to approvals processes established by electrical safety authorities having jurisdiction.

Likewise, there is no single product standard for EMS used for the purposes of controlling loads to avoid capacity thresholds for services, feeders, and other electrical circuits. In the absence of a consistent standard, manufacturers of equipment that can be used in such EMS applications have certified to various product standards, including (but not limited to):

- CSA 22.2 No.14 Standard for Industrial Control Equipment.
- CSA C22.2 No. 205-17 Standard for Signal Equipment.
- UL 508 Standard for Safety for Industrial Control Equipment.
- UL 916 Standard for Energy Management Equipment.

Likewise, it was noted that UL 3141 *Outline of Investigation for Power Control Systems* includes similar functionality.

The complicated standards landscape can make the regulatory path unclear for manufacturers and safety authorities. It was noted during interviews with certain vendors that they perceive barriers to entering the Canadian market due to the cost associated with certifying a product to multiple standards.

Again, pursuing updates to Section 8 of the CE Code to allow for the full range of EMS strategies is recommended. Likewise, Phase 1 of the Consortium for Power Efficiency's work program involves a separate report summarizing the scope of EMS standards and opportunities to rationalize the standards landscape, targeting a March 2025 delivery.

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[8] Likewise, CSA Group has published SPE-343:21, which provides guidance for design, manufacture, and testing of electrical equipment that comprises or forms a part of an EVEMS.

STRATEGY 4

Energy Storage

4. Energy Storage

Energy storage refers to technologies that enable the storage of energy for later use, whether by power system operators, utilities, developers, or customers. Energy storage strategies typically involve storing energy in the form of electricity (e.g. batteries) or heat or cold (e.g. water, heated rocks, bricks or other materials that can store heat for the purposes of later water heating, space heating or cooling). Behind-the-meter electrical storage is currently employed for improving grid resiliency and peak shaving, often as part of utility demand response programs or under favorable rate structures.[9, 10]

Theoretically, buildings could be designed to use electrical or thermal storage to meet peak loads while staying within electrical service limits. The electrical or thermal storage would be filled while building demand is low, then would serve space heating and/or hot water needs during periods of high building demand. This could, in certain circumstances, avoid the need for a larger electrical service or feeder.

The CE Code currently does not enable the use of energy storage systems to reduce calculated loads and service sizes. While this could be a potential option under special permissions or in future iterations of the Code, it should not be regarded as a standard practice at this time. It is noted here for completeness only.

4.1 Battery Energy Storage

A battery energy storage system (BESS) is an electrochemical device that stores energy from the grid or a distributed generation (DG) system and discharges it later to provide electricity or other services. BESS systems can act as both a load (while charging) and a generation asset (while discharging), providing benefits to both the grid and customers. BTM BESS refers to stationary storage systems located on the customer side of the utility meter.

Currently, lithium-ion is the primary battery chemistry available for BTM applications, due to their cost-effectiveness, driven by steep price declines in recent decades. Key components of these systems include:

- **Battery Modules**: Contain individual cells that store energy chemically.
- **Inverters**: Convert stored DC energy into AC suitable for building use.
- **Control Systems**: Optimize charging and discharging to align with PED strategies and energy management goals.

The following products are examples of battery energy storage strategies.

	Battery storage	
Examples of Manufacturers and Models	TESLA	Powerwall
	GENERAC	PWRcell 2

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[9] Vermont's biggest utility dramatically expands home battery subsidies, Canary Media (2023)
[10] Hydro-Québec subsidizes thermal storage system to reduce winter peaks

Vehicle-to-Home (V2H) and Vehicle-to-Building (V2B) as BTM BESS

Bidirectional charging enables EVs to not only draw power from the grid to charge their batteries but also send stored energy back to a building (V2B) or home (V2H). This emerging technology allows EVs to function as mobile energy storage.

EV batteries are an attractive solution for on-site energy storage given their significant **storage capacity** and their **ubiquity**. Not only do many people already own EVs, but EV batteries can store substantially more energy than typical residential stationary storage solutions.

The landscape for V2H/V2B is rapidly evolving. Many automakers, including Nissan, Ford, Volvo, and others, are already offering bidirectional charging solutions. However, like other energy storage solutions, these technologies are not currently enabled by the CE Code to reduce calculated loads or service sizes.

Like other forms of BTM BESS, V2H and V2B systems could theoretically be used to meet peak loads and help buildings stay within capacity limits. However, a unique challenge of this application is that EVs are **mobile assets**; unlike stationary batteries, they may not always be available when the building requires energy storage support. As a result, the use of V2H/V2B for power efficiency may not be feasible, even as technology and policy evolve.

4.2 Thermal Energy Storage

Thermal energy storage (TES) systems capture and store thermal energy in the form of heat or cold for later use in space heating, cooling, or hot water production. These systems typically operate by using inexpensive or surplus electricity to store energy in a thermal medium such as water, ice, or phase-change materials. The stored energy is then released during peak periods to reduce reliance on active electrical heating or cooling systems. TES provides a cost-efficient way to manage energy demand without increasing electrical loads.

BTM TES systems are commonly deployed in domestic, commercial, and industrial buildings for applications such as water and space heating or cooling. They are often integrated with heat pumps to enhance energy efficiency and load flexibility.

The most prevalent form of BTM TES is **hot water storage** via **power-to-heat**, whereby electricity is converted into thermal energy by heating water stored in insulated tanks. The stored hot water is then typically used for DHW or space heating.

The following products are examples of thermal storage strategies for residential applications:

	Thermal storage	
Examples of Manufacturers and Models	STEFFES	Serenity (forced air) Comfort Plus (hydronic)
	Wilsons MECHANICAL	Room units and forced air furnaces

While TES offers significant advantages, there are some limitations. One key challenge is **space requirements,** as large thermal storage tanks or materials can require substantial space, making them impractical for smaller buildings or densely populated urban settings. Additionally, **efficiency losses** due to heat dissipation over time can reduce overall system performance, necessitating the use of well-insulated systems to maintain effectiveness.

The CE Code, Part I, does not currently enable energy storage to reduce calculated loads. Updating the CE Code to enable energy management systems (as noted in the previous section of this report) presents an opportunity to include energy storage systems as means of controlling calculated loads and avoiding system thresholds. This would enable services to offer the ability to avoid electrical service upgrades as an additional source of value for energy storage.

Discussion and Conclusion

Discussion and Conclusion

Key Takeaways

- **There are a variety of PED strategies**, including updating calculation methodologies for estimating electricity needs, reducing electricity demand through right-sized equipment and improved building efficiency, managing and controlling power use to stay within specified limits, and using stored energy to provide buildings' peak loads.
- **PED often offers a low-cost alternative to costly and complex electrical service upgrades** and other electrical works. Beyond avoiding the cost associated with such upgrades, many PED strategies can also reduce utility system-wide peak loads and provide demand response.
- **There are several barriers to PED which must be addressed,** including current electrical codes that do not fully support PED strategies, a complicated standards landscape for equipment to be certified to, limited industry and customer awareness, and sporadic access to appropriate utility data.
- **PED can be effectively deployed across a broad range of building types.** However, the feasibility and effectiveness of individual PED strategies may vary between building types, including between retrofits and new construction, and between single family, multifamily, and commercial building types. A summary of PED strategies and their applicability across building applications is presented in Table 2.

Table 2: PED Strategies Across Different Building Applications

Strategy		Retrofit	New Builds	Single Family	Multifamily	Commercial
Optimizing Load Calculations	Historical Load Calculations	✓		✓	✓	✓
Building Efficiency and Right-Sizing Loads	EVSE	✓	✓	✓	✓	✓
	Space conditioning	✓	✓	✓	✓	✓
	Building efficiency	(✓)	✓	✓	✓	✓
	DHW	✓	✓	✓	✓	(✓)
	Low-power / battery appliances	✓	✓	✓	✓	(✓)
Energy Management Systems	Circuit Switching	✓	✓	✓	(✓)	
	Dynamic Energy Management Systems	✓	✓	✓	✓	✓
	Service and Feeder Monitoring	✓	✓	✓	✓	✓
Energy Storage	Battery Storage	**?**	**?**	**?**	**?**	**?**
	Thermal Storage	**?**	**?**	**?**	**?**	**?**

Note: ✓: Clear application. (✓): potential application. **?**: Uncertain market application

Opportunities to Enable PED

The findings from the research summarized in this report suggest several opportunities to advance the practice of power efficient design

CE Code Amendments

Amendments to the Canadian Electrical Code (CE Code) represent one of the most impactful ways to enable PED.

Several opportunities to update the CE Code to better enable PED have been identified (Table 3). Dunsky is currently drafting these and other CE Code amendment proposals on behalf of the Consortium.

Table 3: Summary of Proposed CE Code Amendments

Topic	Rule(s)[11]	Summary of Proposed Amendments
Energy Management Systems	Section 0, Section 8	• Enable EMS to monitor & control non-EV loads (currently only management of EVs is enabled).
Electric Space Heat	62-118, 8-106 2) and 3)	• Consider how best to reflect that heat pumps can function as non-continuous loads, potentially requiring less buffer. • Clarify and better enable use of controls and physical interlocks for multiple heating and/or cooling systems, to reflect that not all leads need be summed in appropriate circumstances. • Omit/reduce redundant electric heating loads in appropriate circumstances (e.g. do not necessarily require that additional load capacity be added when an air-source heat pump is implemented to displace an existing buildings' electric resistance heat).
Prescribed Loads for Cooking and "Basic Loads" (Lighting & Receptacles)	8-200 1) a) iv) and vii) A) &B)	• Accommodate low power and battery-integrated cooking appliances by using their actual load (not a prescribed minimum) if these electrical cooking appliances are implemented in an all-electric building.
	8-200 1) a) i) and ii)	• Provide an alternative compliance pathway, whereby "basic load" (i.e. lighting and receptacles) can be calculated using values determined in accordance with energy codes.
Optimizing Historic Load Calculations	8-106(8)	• Adjust historic loads to reflect removed loads. • Specify the time internal (i.e. 15 minute max) between measurements that is considered acceptable for historic load calculations. • Consider specifying appropriate multipliers to translate 1-hour load data (and potentially other intervals) to 15-minute load calculations.
Service Metering	Section 6	• Propose a requirement for master metering on electrical services, to better enable historic load calculations.

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[11] This column notes the primary rule impacted. It is not intended to be comprehensive; other rules/sections may be included in the detailed CE Code amendment proposals.

Energy Management Standards

Canada lacks a unified EMS standard for the purposes of PED and electrical codes' compliance. The standards landscape for these technologies is relatively fragmented and confusing. This complexity can discourage vendors from entering the Canadian market, create regulatory uncertainty, increase approvals time, create inconsistency between jurisdictions, and drive up costs.

Efforts are underway to address these challenges. CSA Group is finalizing a standard for Electric Vehicle Energy Management Systems (CSA C22.2 No. 343), which could streamline approvals for EV-specific EMS products once published. Additionally, the Consortium is preparing a report to identify opportunities to simplify and align EMS standards, with recommendations expected by March 2025.

Education and Capacity Building

Building industry knowledge and skills is critical to enabling PED strategies. Electrification and densification are relatively new trends, and technologies are evolving quickly. Many contractors, designers, and building owners are not yet familiar with these PED strategies, so there is a need to share best practices and provide practical tools and resources to help them understand and adopt these approaches.

To address this need, the Consortium is currently developing a **PED Guide for Electrification Retrofits** focused on single-family homes. This guide will help contractors and households apply PED strategies to avoid costly electrical service upgrades during retrofits.

Additionally, the Consortium is developing a **Power Efficient Electrification Calculator** (PEEC). This Excel-based tool will help homeowners and contractors plan for electrification, showing how to prioritize equipment upgrades while staying within electrical capacity limits.

Going forward, additional guides and calculators should be developed for other building types and applications, such as new buildings, multifamily units (e.g., apartments subject to Rule 8-202), and non-residential properties. Expanding these resources will empower industry stakeholders with the knowledge and tools to implement PED strategies effectively across a wider range of projects.

Optimizing Utility and Electrical Safety Authority Processes

Utilities can take several actions to better enable determination of historic loads and evaluation of electrification projects, including:

- **Historical Load Data:** Utilities can provide readier access to peak historical load data to customers with single meters, and establish automated systems to provide aggregated load data across multiple meters for multifamily and commercial facilities.
- **Upstream Infrastructure Capacity Data:** Utilities can share information on the available capacity of upstream electrical infrastructure (e.g. distribution grid circuits) to accommodate electrification.

Likewise, electrical safety authorities can review their processes opportunities to better support PED and other technologies that are important for decarbonization and other societal goals – For example, in 2022, Technical Safety BC commissioned a comprehensive review of how best to optimize their processes to support low carbon technologies, including energy management systems.

PED Cost-Benefit Analysis Across Applications

To support effective prioritization of PED strategies, there is an opportunity to conduct a comprehensive cost-benefit analysis (CBA) to identify the most impactful approaches across different building types and applications. This analysis would evaluate a wide range of PED strategies across various building archetypes, including single-family homes, multifamily units, and non-residential buildings, and assess these strategies based on factors including cost-effectiveness, energy savings, peak demand reduction, and feasibility.

The study could leverage real-world utility data to ensure accuracy and relevance, or it could rely on detailed modeling for diverse building types and electrification scenarios. By incorporating multi-parametric optimization, the analysis could highlight the best combinations of PED strategies for specific contexts, such as retrofits versus new construction, or single dwelling versus multi-unit buildings. This approach would provide clear guidance for policymakers, utilities, and industry stakeholders, ensuring that resources are directed toward the most effective solutions to support widespread adoption of PED.

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