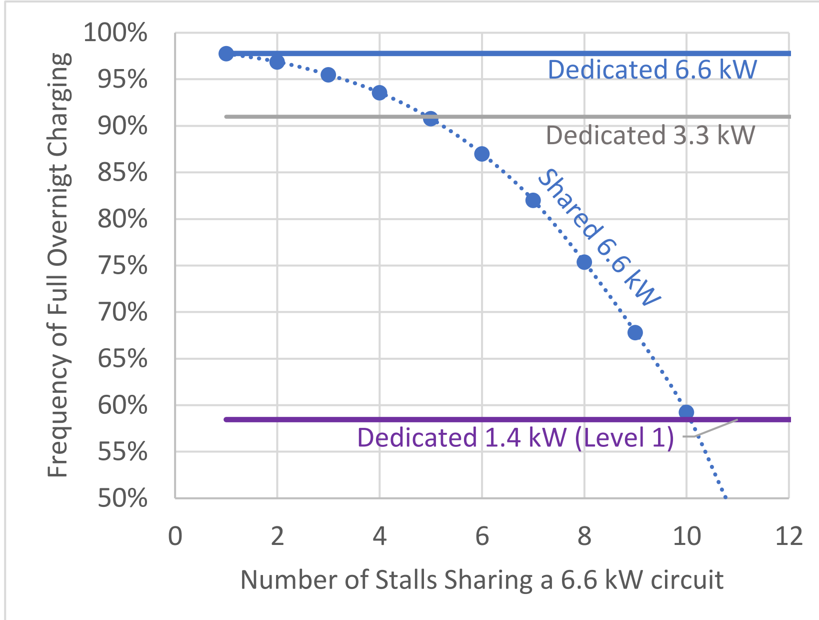
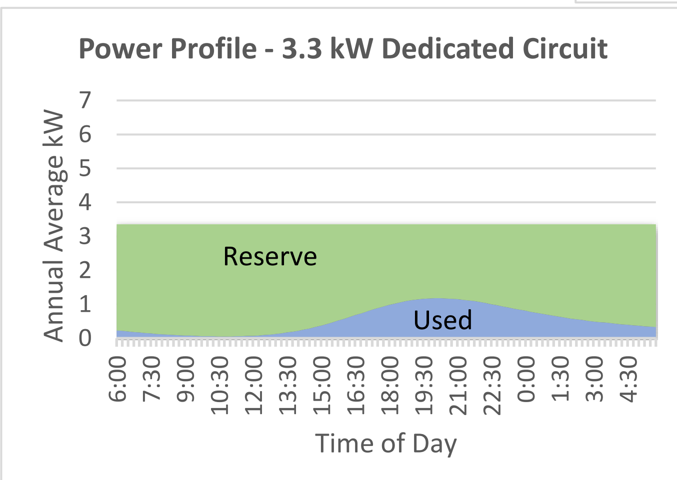
The Power of Sharing

How much power does it take to charge electric vehicles? A lot less than you think, according to new research. But only if the power is shared. If electrical engineers and contractors, utilities and policymakers ignore the potential of load-sharing opportunities, they will grossly overbuild the residential infrastructure required for electric vehicles. Contrary to common belief, planning for electric vehicles should rarely require expansion of the residential distribution grid or incoming service to multi-unit residential buildings.

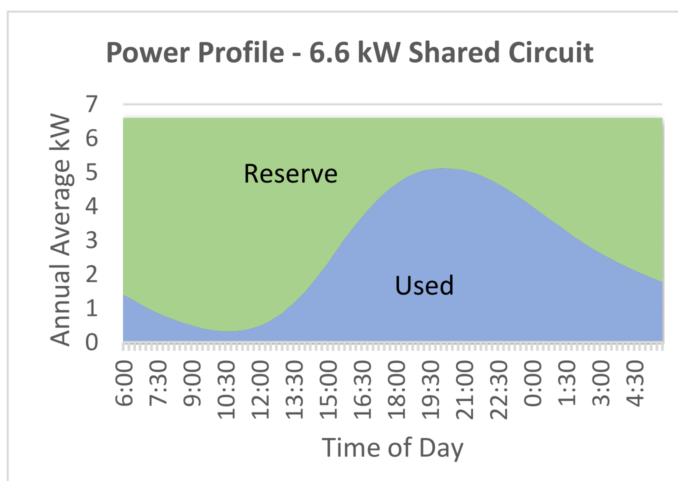


The graph shows that in a representative setting, five vehicles can share a Level 2 circuit with less average power per stall than Level 1 but achieve performance comparable to a smaller Level 2 circuit. Alternatively, ten vehicles can share a Level 2 circuit that is just as effective as Level 1 with half as much power per stall.



How are these sorts of power reductions possible? They come from efficiency – using a larger percentage of the available power.

A circuit that is dedicated to a single parking stall is idle most of the day. At times it is operating at capacity but, even in the early evening, only about a third of the vehicles will be charging at one time. Overall efficiency of smaller dedicated circuits is only 17%, with the rest of the available power maintained in reserve for times when all vehicles are home and charging.



When five stalls share a Level 2 circuit, charging starts as soon as the first vehicle arrives home for the day and continues overnight until all vehicles are fully charged. Since each vehicle can use all the power when it is the only one charging, more power is used in the off-peak hours than with a smaller circuit. The peak of the parking garage power profile at 7:30 pm is actually a bit lower (per stall) than with dedicated circuits, because some vehicles will already be fully charged before that time. Overall efficiency is 41%.

Restricting power for charging to times when the power is not needed elsewhere in the home can enable electric vehicle charging in single family residences without increasing the panel size. Similarly, if power for electric vehicle charging in a multi-unit residential setting is capped during peak building demand hours, more power will be used during off-peak hours[1]. Large shared circuits will still be more effective than smaller dedicated circuits in delivering full overnight charging within existing building power supplies.

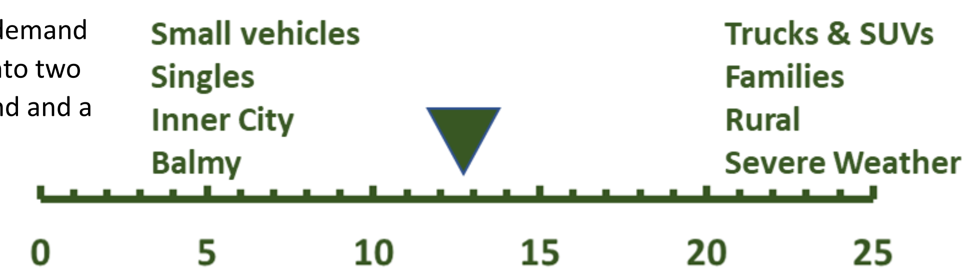
Planning Ahead

It is reasonable to expect that at some point before 2050, all of the stalls in a residential parking garage will be used for electric vehicles and the owners will want to be able to meet their daily driving needs through overnight charging. But we have little practical experience to use as a guide. It will be years before all or almost all personal-use vehicles are fully electric. Nonetheless, despite the uncertainties, electrical designers must make a best effort today to address this future need. Retrofitting transformers and other electrical equipment is far more expensive than including them in original construction or as part of a major renovation.

Estimating Power Requirements

Of course, electric vehicle charging requirements depend on the circumstances of each building. The physical layout of the parking stalls might limit load-sharing opportunities. In some situations, large vehicles, extreme temperatures and long driving distances from bedroom communities will require more charging to achieve satisfactory overnight results. Level 1 charging would be totally inadequate and a smaller dedicated Level 2 circuit might be less than satisfactory in these situations. With higher rated circuits (and on-board chargers), load-sharing could still achieve large reductions in power demand without compromising effectiveness. Careful evaluation of expected demand and time available for charging is required to ensure satisfactory results.

All of the factors involved in demand analysis can be synthesized into two variables: daily energy demand and a reserve requirement. This is illustrated in the sample estimation of power required per stall below.



Daily energy demand is simply the product of daily driving distance and average vehicle energy consumption, with adjustments for local conditions and power losses. While 12.7 kWh per electric vehicle per day might be representative, the range of daily energy demands illustrated in the scale is quite wide. Different buildings within the same municipality could have higher or lower expected energy demands because of their target demographic, wire length or proximity to the urban core.

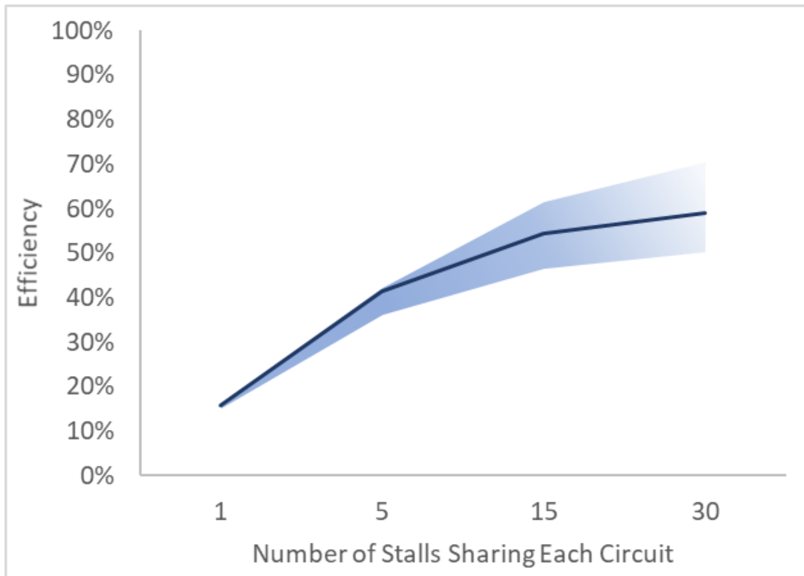
[1] Chandler, Don. *Power to Charge* Presentation at EV/VE 2019, Electric Mobility Canada. May 2019.

For dedicated circuits, the most common cause of inadequate overnight charging is unusually long driving distances. For shared circuits, variations in driving distance from day to day are important but the mix of short-distance and long-distance drivers is less important. Differences between drivers can be accommodated without customizing for individual needs and without excessive reserves for short-distance drivers. Factors that affect all the overall daily energy demand in the parking lot take on a more important role in the design of shared circuits. These factors include daily temperature, day of the week and season.

Sample Estimation of Power Required per Stall

A	**Average driving distance**	**35 km/day**
B	Average rated vehicle energy consumption	228 Wh/km
C	Adjustment for prairie temperatures and seasonal driving patterns	1.36
D	Adjustment for losses in on-board charger and building electrical equipment	1.17
E	Averaged demand (A x B/1000 x C x D)	12.7 kWh/day
F	Efficiency after reserve required to meet performance standard with 5 sharing	40%
G	Power requirement (E/F/24hrs)	1.3 kW

The reserve requirement depends on the number of vehicles sharing each circuit and the performance target – how often residents can accept less than a full overnight charge. The relationship between these factors is illustrated in the graph, showing how the reserve required to achieve a 90% frequency of full overnight charging declines and efficient use of the available power improves as sharing increases. There is a range of efficiency ratings for shared configurations because the reserve requirement also depends on:



- the variability of daily driving distances,
- when residents typically arrive home and when they leave for work the next day, and
- the relationship between the maximum capacity of the circuit and the maximum capacity of each vehicle's on-board charger.

To date, designs for electrification of parking garages have typically limited load management to sharing four vehicles on a 40A circuit. While it may be true that power must be maintained above a minimum level for some vehicle chargers to operate, testing by manufacturers of load management equipment has demonstrated that lower power per stall can be implemented through existing technology that combines time-switching and power level adjustments.

Simulations show that overnight charging performance targets can be met in low-demand scenarios with as little as 20% of the average power per stall that would be required for Level 1 charging and half of the average power that would be required for four sharing[2]. At the other extreme, in unfavourable conditions where Level 1 charging would clearly be inadequate (cold winters, long commutes, big vehicles), load sharing with larger groups can provide significant improvements in efficiency and bring average power requirements down close to Level 1.

Reducing the reserve requirement by increasing the number of vehicles sharing each circuit saves on building infrastructure. Monitoring building power consumption and controlling electric vehicle charging rates can save even more on building infrastructure, while still achieving overnight charging performance targets. These savings inside the building have the added benefit of flattening the power demand profile for the building and reducing infrastructure requirements for the residential power grid. In contrast, efforts by utility companies to flatten demand through pricing do not guarantee lower peak demand and so do not generate the same savings on infrastructure in the building or in the grid.

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[2] Chandler, Doug. Statistical Modelling of Load-Managed Charging for Electric Vehicles in Mult-Unit Residential Parking. May 2020. researchgate.net/publication/341763845 DOI 10.13140/RG.2.2.21028.09608