OPPORTUNITY FOR EV MASS ADOPTION

Gain insight on benefits of DCFC hardware adoption

Abstract

The Direct-current fast charger (DCFC), otherwise known as a Level 3 DC charging source, is a powerful and efficient device that intends to charge electric vehicles batteries in the span of a few minutes. The unique benefits associated with the DCFC's hardware adoption include positive environmental impacts such as reducing air pollution, saving on time, fuel costs and reducing the security risks associated with the usage of gasoline or diesel as fuel for any transportation vehicle. By owning a DCFC station, you will be able to take part in a long-term solution that is the closest in terms of re-fill speed to internal combustion engines (ICE) recharging stations.

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Contents

1. Charging infrastructure

1.1. Will Charging Infrastructure Support EV Adoption?

The success of EVs will depend on the availability of charging infrastructure, whether at home or in public, which is accessible, easy to use, and relatively inexpensive. Currently, a range of charging technologies are available and is likely to emerge within the next 10 years.

A range of charger types is currently available, including slower AC chargers (Level 1-2) that are best suited for home and office use, as well as much faster DCFC for rapid recharging in public places, which are best suited for longer journeys (Level 3-5).
In other words, it takes 26 hours for the slowest AC charger to add 100 miles of range, while it takes six minutes for the fastest DCFC charger, which is still much slower than the 300 miles-per-minute enjoyed by an ICE that travels 30 miles per gallon. This means that installation, utilities, transformers, and equipment are fixed (infrastructure costs), while electricity charges are variable (infrastructure costs).

It is important to take in consideration that demand charges are commonly a major factor in the operating costs of chargers on commercial electricity tariffs. Therefore, power costs for fast-charging stations are higher than the slower residential chargers, unless the latter can reach sufficiently high utilization rates.

Consequently, modeling different types of charging infrastructure and comparing them with the operating costs of ICEs shows that simple home charging can compete with today's more efficient gasoline cars, and could be significantly cheaper if time-of-use electricity tariffs enable lower prices during off-peak hours. The price of more powerful home charging is sensitive to capital costs, but it is competitive with moderately efficient ICEs and substantially cheaper under a time-of-use tariff.

For commercial chargers (Levels 3-5), the electricity price required for the system to break even, falls sharply as utilization rates rise. All variants are cheaper to fuel at 30% utilization than an average ICE. Therefore, they are competitive at 40% utilization.

1.2 DCFC Fast Charging Solutions

The lack of infrastructure that can recharge an EV in a reasonable amount of time would discourage most motorists from buying EVs, even if they are cheaper and perform better. While the risk of being stranded without power is slim, it remains a hazard that today's drivers have never experienced with the vehicles they use.

Therefore, in order for electric vehicles to succeed, charging infrastructure must be accessible, convenient, and relatively inexpensive.

Even though there are many charging technologies available today and more are on the horizon, there is uncertainty about how an effective infrastructure will emerge thirty years from now. In fact, there is less certainty today than there was six years ago, when the battery electric vehicle (BEV) batteries were smaller and easier to charge. For example, an evening charge of a 24 kWh Nissan Leaf at a "Level 1" 1.4 kW residential outlet would recharge the battery by half, require no additional capital expenditure, and will cost approximately $60 per month assuming that the vehicle is charged every day.

In addition to the Level 2 systems, heavy users can install a 220-volt (6.6 kW) system for approximatively $1,500-$2,200 to charge up their Leaf in seven hours. However, these options become less attractive as the BEV industry attempts to overcome consumer range anxiety. As a result, A 70 kWh Tesla Model S would need fifty hours to charge from a normal wall outlet, and almost eleven hours on a 220-volt, 6.6 kW line.

Due to this, Tesla has developed residential chargers that can triple the power output of a 220-volt line, reducing battery-charging time to under four hours. The installation cost varies depending on the buyer's requirements.

In addition, for electric vehicles to be competitive with gasoline-powered transport, residential charging technology will need to improve dramatically or commercial fast-charging stations will need to be widely deployed. Our DCFC roll out will fill the gap between range anxiety and time-consuming charging.

EVDC's DCFC network provides convenience to BEV users by allowing them to locate nearby infrastructures and charge in under 20 minutes. The deployment of EVDC DCFC facilities at scale will give easy access to electric vehicles of all kinds.

2. EV charging equipment

Several charging options are currently available. It is crucial to keep in mind that multiple options could and, most probably, will emerge in the future. In this section, we will discuss the financial model affecting all EV charging equipment, the types of EV charging and the viability of each charging infrastructure.

2.1 EV charging equipment major economic factors

In general, the major economic factors impacting the EV chargers are the capital and variable costs. The capital costs regroup the cost of property/ space occupation and the cost of installation of the charging equipment. The variable costs are the cost of electrical power supply, the cost of the time spent for the project to generate revenue and the revenue required from the infrastructure to break even.

2.2 Types of EV charging equipment

2.2.1 Level 1 and 2: Alternating Current (AC)

Electric Vehicle Supply Equipment (EVSE) at Level 1 and Level 2 are powered by alternating current (AC). To put it another way, the energy can be sourced by local distribution systems to obtain electricity. BEVs and Plug-in hybrid electric vehicles (PHEV)s both have an onboard inverter with a limited capacity that converts AC power into (DC) in order to charge the battery.

As a reference, In the United States, Level 1 generates 1.4 kW of power, operates from a standard outlet, and does not require any additional wiring, other than the adapters needed to connect the EV to the outlet. It will take around 40 hours to charge a 70kw battery from empty to full using Level 1.

Level 1 charging can occur anywhere. However, because of the time needed to charge using a Level 1 charger, most electric vehicle owners only use Level 1 chargers at home.

Following the previous reference, in the United States, Level 2 begins at a power rating of 6.6 kW and can reach 19.2 kW depending on the circuitry supporting it. It will take between 4 to 7 hours to charge a 70kw battery from empty to full using Level 2.

Because the onboard inverters that are installed are not capable of handling much more than the current level, the 6.6-kW limit applies to most residential and commercial Level 2 chargers. Moreover, boosting the current generally requires the installation of more expensive higher-capacity circuitry.

Level 2 charging utilizes upgraded 220-volt outlets and is runs the same outlet used by washing machines and clothes dryers. Any certified electrician can install it. These outlets are typically found in modern and new residences, whereas older houses may require electrical upgrades.

Level 2 charging is also available in public spaces like offices, hotels, malls, parking lots and on-street parking as well as anywhere vehicles could be parked for an extended period of time.

2.2.2 Level 3 and above: Direct Current (DC)

Electric Vehicle Supply Equipment (EVSE) at Level 3 and above operates on DC power, without the use of an inverter and charges the battery directly allowing much greater power output. DC and AC charging otherwise differ only in terms of voltage.

In general, a level 3 unit generates 50 kW of power, Level 4 generates 150 kW and Level 5 generates 350 kW. It will take from 45 minutes up to 1 hour to charge a 70kw battery from empty to full using Level 3, up to 20 minutes using Level 4 and around 10 minutes using Level 5.

Level 3 and above require heavy-duty insulation equipment and a qualified electrician to install it.

Level 3 chargers and above are normally reserved for commercial use only. Although studies have shown that consistently high DCFC usage accelerates battery degradation over time, in most cases battery degradation is more closely associated with overall usage than specific charging patterns. In fact, the battery's thermal management system matters more.

2.3 Viability of each charging infrastructure

Level 1 charging is a viable option for users who do not require long-range charging on a regular basis. Furthermore, charging at Level 1 occasionally will extend the battery's lifespan compared to regularly using Level 3 or above.

Level 2 charging is the most viable. Unless it is for a road trip, for a longer trip than average, or if you are constantly on the move, most EV users will not need a faster charger. A great amount of charging is done on Level 2 since they are mostly everywhere and are the cheapest to use and most of them are free.

Level 3 and above charging is viable because of the charge speed and because it’s time efficient. They are vital for road trips, longer trip than average, or if you are constantly on the move.

3. EV charging equipment comparison

Table 1: AC and DC current type differences

Charger Type	Current Type	Average Power Delivered (kW)	Time taken to replenish daily usage (13.65 kW)	Time taken to charge 100 miles (37 kWh)	Range added per minute (miles)
Level 1	AC	1.4	9h 45m	26h 26m	0.06
Level 2 [standard]	AC	6.6	2h 4m	5h 36m	0.30
Level 2 [maximum]	AC	19.2	43m	1h 55m	0.86
Level 3	DC	50.0	16m	44m	2.25
Level 4	DC	150.0	5m	15m	6.76
Level 5	DC	350.0	2m	6m	15.77

*Note. Reprinted from "Belfer Center for Science and International Affairs", by Henry Lee Harvard Kennedy School, and Alex Clark Climate Policy Initiative, 2018, September. Retrieved from https://www.hks.harvard.edu/research-insights/publications?f%5B0%5D=publication_types%3A121

Table 1: AC and DC current type differences present each charger type, its nominal power rating (in kW), the time taken to recharge a battery with 13.65 kWh of usage on average, the time taken to charge a battery of 75 kWh and the miles of range added per minute of charging.

It is assumed that charging time depends solely on the charger's power rating, however technical limitations on the battery, electricity supply, and inverter capacity (for AC charging) can lengthen the process. In most cases, the rate of charging is linear (this means, it does not slow down significantly throughout the session.).

As a result, this is an appropriate simplifying assumption since the rate of charging does not diminish until the battery reaches approximately 90% of its capacity, and most public charging sessions involve only partial battery recharging rather than full.

Users of EVGo’s Level 3 network in California, for instance, average just 5-12 kWh per session (or enough to drive an additional 15-36 miles) this means in city supercharging usually is just a top-up, enough to complete a trip and plug into a home charger’’.47 The reference battery size of 75 kWh reflects a reasonable expectation of the average battery size of BEVs over the next five years—larger than the current Chevrolet Bolt (60kW) and smaller than the top-end Tesla Models S and X (90-100 kWh).

Even ultra-fast Level 5 charging takes six minutes to half-fill a 75 kWh battery; a full charge would take 12 minutes or longer. These charging times will increase as batteries become larger, moving towards 100-150 kW.

Level 5 charging can increase range by 15.8 miles per minute, but the time needed to recharge an EV is still shorter than conventional gasoline refuelling.

It would require a charger 19 times more powerful, or 6.7 MW, to reduce range refuelling time to the 300 miles per minute enjoyed by a 30 mpg ICE refuelling at 10 gallons per minute.

It is beyond the scope of what is achievable today and likely to remain so for many years to come.

In almost every case, charging an electric vehicle will take longer than fueling an internal combustion engine.
At least one charging stop will be required for journeys over 300 miles. Adding just 100 miles of range with a Level 4 charger would take at least fifteen minutes. Filling up completely (about 300 miles) would require about 45 minutes.

Additionally, the flow of vehicles through gasoline stations is much higher due to the rapidity of refuelling. The wait for a 100-mile charge can take 30 minutes or longer in areas with overcrowded charging stations or stations where drivers typically wait while doing something else (such as shopping). The only way to solve this issue would be more stations per location.

4. Understanding Charging Economics

Electric vehicles have two types of costs: equipment required to recharge the vehicle (fixed costs) and the electricity consumed (variable costs). Several types of fixed costs are associated with electric vehicle supply equipment.
(EVSE) have three main components:
1) Installation and preparation of the site, if applicable;
(2) The cost of utility system improvements, such as transformers. Both of these can be referred to as "make-ready" infrastructure, which includes everything except the charging equipment itself.
(3) The cost of the charging equipment;

4.1 Installation and preparation of the site costs

Installation and site preparation (including electrical service extension, permits, labour costs, and trenching for laying cables) are the first components.

If the installation of new circuitry is required, these costs are generally non-existent for Level 1 and minimal for Level 2. Installation costs are much higher for Level 2 chargers used in public areas, which typically consist of a physical "tower," like a gasoline dispenser or a parking ticket machine.

Commercial Level 2 EVSE usually require some form of wiring extension, installation of signage, and trenching to provide additional grid connections. Because each EVSE has specific requirements, installation costs vary based on location. This causes a wide range of estimated costs.

Installing a Level 2 system (both residential and commercial) can vary from $600-$12,700 and installing a DCFC system can range from $4,000-$51,000. If labour costs are included in the installation costs, they account for 55-60%.
An experienced installation partner could potentially save you approximately 25% of the installation cost for each unit.

Table 2: Capital costs differences between Residential and Commercial

Capital Costs	Residential		Commercial			
	Level 1	Level 2	Level 2	Level 3	Level 4	Level 5
Installation (per charger)[A]	$0	$1,354	$3,108	$22,626	$22,626	$22,626
Site preparation (per charger)	0	0	3,000[B]	12,500[C]	12,500	12,500
Utility service (per station)	0	0	4,000	17,500[D]	17,500	17,500
Transformer (per station)	0	0	5,698[E]	32,500[F]	40,000[G]	40,000
Equipment (per charger)	0	1,000[H]	3,842[I]	35,000[J]	50,000	100,000

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4.2 Utility system improvements costs

The second major cost (where a number of chargers are typically connected to the same local network and transformer) is to upgrade the utility infrastructure to provide power to the chargers.

These upgrades may not be necessary in some cases; in others, they may be necessary.
Costs associated with them will make up a large portion of the total. In cases where more than one charger is present, the infrastructure requirements will also be higher, since the peak demand will be greater. One Level 2 EVSE is unlikely to require a transformer upgrade, but multiple ones operating simultaneously (such as several EV owners charging their vehicles at the same time) may overload the existing transformer, and require an upgrade.

Certain utilities will need to upgrade their distribution infrastructure as EV penetration increases.

To optimize the temporal demand on the system, the design of the tariff schedule and the commercial penetration of smart-charging systems will affect the investment rate. Chargers at Level 3-5 will cost considerably more than those at lower levels.

In the case of these facilities, the cost of a new transformer can range from $30,500 to $45,000, although the cost of a transformer per charger can be reduced to $10,000 to $25,000, and the cost of service extensions to $3,500 to $9,500.

4.3 Charging equipment costs

The third cost is for the equipment itself (i.e. the EVSE). Once again, there are several estimates of these costs available for various charger types. A typical Level 1 home charger does not require additional equipment. Commercial Level 2 EVSE towers can cost up to $3,000-$4,000 with an electronic interface, payment system, and network connection. The DCFC (Level 3-5) EVSE is significantly more expensive; a single-port charger typically costs $30,000-$40,000, whereas dual-port chargers typically cost $50,000-$60,000. Depending on the manufacturer and specifications, costs can vary widely.

Applied Energy Systems estimates the total cost of a four-DCFC system at $205,000, budgeting approximately $30k per unit, $20,000 for installation, $17,500 for utility service extensions, and $4000 for a 500kVA transformer. According to other estimates, the installation and equipment costs could be even higher. For larger DCFCs organized into multi-charger stations, returns to scale are possible, but these returns would depend largely on the ability to sustain sufficiently high utilization rates (the percentage of time the EVSEs actually dispensing electricity) to make the investment in each additional charger worth it.

Gas stations in the United States, many of which feature multiple pumps, are typically utilized at approximately 34%, whereas commercial EVSE are typically utilized at approximately 25%. Having a twenty-five percent utilization rate for an asset costing $160,000 is a financially viable proposition, as the following example illustrates. To maintain a high level of utilization, charging events is proportional to the number of chargers at a given station. When a car has completed charging and remains idly plugged into the charging cable, there is no electricity used, but there are idle fees charged (sometimes up to 1.5 dollars a minute) based on usage and immediate demand.

Therefore, achieving even a modest utilization target of 40% on a daily basis may prove to be profitable in areas with high EV penetration.

5. Commercial Charging

Chargers used by commercial entities are generally metered using commercial and industrial electricity rates, which in most cases combine a per-peak-kW demand charge with a volumetric per-kWh energy tariff. Compared to residential rates, commercial tariffs offer lower volumetric charges (an average of $0.145 per kWh in 2016 versus $0.1759), but also charge roughly $10- $17 per peak kW (based on the highest rate of usage during any 15-minute period over an entire month).

In both the system and local distribution levels, demand charges reflect the projected cost of providing generation and distribution infrastructure to meet peak demand. Utility upgrade costs are not a penalty, but rather a way to recover the utility's fixed costs of supplying that customer. These are the same costs discussed in the previous section.

DCFCs usually demand short bursts of high power, which is usually penalized by the charge based on maximum, not average, load. Flexible on-demand and energy charges are of greater significance the more powerful the charging device is, since full demand charges are based on a single instance of high usage, regardless of the average level of use.

The demand charges can be higher in the summer, as well as layered into non-coincidental charges (reflecting maximum demand at any time) to recover distribution costs; and to recover the infrastructure and generation costs incurred in meeting demand during peak times.

In the U.S., the average peak demand charge for commercial customers is $8.62 per kW. The investor-owned utility Southern California Edison (SCE) charges $3.70 per KW for EV-specific demand; Pacific Gas and Electric (PG&E) charges $10.47 for winter peak demand and $17.84 for summer peak demand. According to an independent study, EVSE operators face an average demand charge of $13 per kW. A Level 3 50 kW charger at a commercial station and a Level 4 150 kW charger would incur monthly charges of $650, $1,950, and $4,550, respectively (see *Table 3: Demand vs electricity cost*).

Table 3: Demand vs electricity cost

Charger Type	Power (kW)	Total demand charge ($/month) at U.S. general avg. of $8.62/kW	Total demand Charge ($/month) at U.S. EVSE avg. of $13/kW
Level 2 (standard)	6.6	57	86
Level 2 (maximum)	19.2	166	250
Level 3	50.0	431	650
Level 4	150.0	1,293	1,950
Level 5	350.0	3,017	4,550

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Due to the fact that it only depends on maximum demand, the demand charge increases proportionally for additional chargers. Considering that all four EVSE are delivering maximum power simultaneously once a month (200 kW), four 50kW EVSE will incur a charge of $1,724. A total of $1,724 would be incurred by four 50kW EVSE with different contracts operating in different locations at separate locations, each incurring a demand charge of $531. The demand charges alone for a Level 5 installation with ten charging poles that are all in use for at least 15 minutes per month would amount to $45,500 per month or $546,040 per year.

An EVSE owner who also purchases electricity for other purposes on the same contract faces a more complex marginal cost. For this, it is important to know the difference between what would be incurred without the EVSE (i.e. during the owner's regular operations), and what would be incurred with it.

Peak demand for the site host with and without the EVSE is determined by whether the two coincide. Consider an EVSE that reaches peak capacity at least once a month that was recently installed. Assuming that the EVSE peak demand and peak demand from other operations are coincident (Figure 2.1a), the site host would simply add 50kW to its peak demand. If it is not just a coincidence, because charging is only allowed outside of business hours or on days when air conditioning is not used, the marginal demand charge would likely be less, or even zero, if the peak demand with an EVSE is less than the peak demand without it. Consequently, the site host might lose revenue if they limit charging to off-peak periods, but our model assumes the marginal demand at 100%, but this may not always be the case and the cost impact may actually be lower.

In most cases, commercial EVSEs are self-service devices, which include a secure authentication and payment system, as well as Internet/network connectivity (which provides real-time data to the equipment operator and/or utility). The cost of these services varies from $100-$900 per charger, per year, based on the manufacturer, type, and service provider of the charger and the network connection fees.

The cost of maintenance and warranty/insurance may also vary depending on the charger type and location. It is estimated that Level 2 chargers are subject to both warranty and maintenance costs of about $400 per year, according to documentation from EV Connect and NRG. For faster, commercial chargers with more physically demanding components that are more vulnerable to vandalism, maintenance and warranties are typically more expensive. Annual DCFC maintenance costs range from $300 to $3000, averaging $2500. Charge-Point documentation places the cost of a five-year warranty and maintenance package for nine DCFCs and eight Level 2 chargers at $269,269. Documentation from Recargo puts maintenance for 11 DCFC and 7 Level 2 chargers at $95,000 over 5 years, implying $19,000 per year and $1,473 per DCFC. Given the substantial variations, this analysis assumes DCFCs have a relatively high maintenance, warranty, and insurance costs of $2,500 each per year.

When demand, electricity, network fees, insurance, and maintenance are taken into account, making an operating profit on EVSE (i.e. excluding capital costs) can require significantly increasing the price of electricity per kWh at the point of sale. Life-cycle profitability (including capital costs) will require a further markup to cover installation, equipment, and utility upgrade costs. Despite facilities having a greater number of chargers incurring higher demand charges, a multi-charger station may incur lower per-charger capital costs than a standalone facility, since utility extensions and transformer upgrades will typically only be required once for the entire facility.

Unless fast-charging stations are able to drive up utilization rates and maintain those rates across time, the cost of power generated by fast-charging stations will be higher than from a Level One or Level 2 unit.

6. Break-even kWh and Positive ROI

In the next section, we will examine the economics of charging with a simple financial model. We estimate fixed costs based on information in the literature and variable costs based on actual electricity rates. Estimated revenue is based on utilization rates and load profiles, measured in dollars per kWh. It is important to note that not all EVSE operators will bill their customers by kWh. As an example, they may charge an hourly fee, or offer a monthly subscription service, or both. Because variable electricity costs are expressed in $ per kWh terms, however, revenues are also denoted in this way. EVSE owners mark up each kWh of electricity at the point of sale. To break even, the EVSE owner will need to charge a minimum price of $0.27 per kWh. For example, if electricity costs $0.14 per kWh on average and the markup required for the project is $0.13 per kWh.

6.1 Projected earnings

Our Base price per kWh is $0.79. Generating a net of $0.52 per kWh after covering the costs of ownership, maintenance, warranty and marketing.

The average customer will plug in for 6 minutes on a DCFC Super-fast unit.
At a rate of 5.83 kWh per minute.
$27.63/ 6 Minute.
Including a 5-minute un-plug grace period.
At a utilization of 30% each unit generates $82.90 per hour.

At a utilization of 100% each unit generates $276.33 per hour.

These rates are calculated on a 350KW unit.

7. APPENDICE

Table 4: Cost of Operation (COO)

The table 4 is an average of the financial situation related to electric vehicle.

Cost of capital	8%
Electricity price, annual increase	3%
Demand charge, annual increase	0%
Fuel price, annual increase	3%

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The capital is the invested cost to acquire to the hardware and installation of each unit.

Table 5: Residential and commercial electricity costs peak and off-peak

Electricity Prices ($/kWh)[85]

Residential[A]	0.1759
Commercial[B]	0.1447
Residential time-of-use (off-peak)	0.0800
Residential time-of-use (peak May-October)	0.3500
Residential time-of-use (peak November-April)	0.2700
Residential time-of-use (partial peak May-October)	0.2200
Residential time-of-use (partial peak November-April)	0.1759

A, B Energy Information Administration. 2017. "Electricity data browser."

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Table 6: Capital cost breakdown per unit

EV Charger Specifications, cont.

Capital Costs ($)	L1 Res.	L2 Res.	L2 Comm.	L3 Comm.	L4 Comm.	L5 Comm.
Equipment (per charger)	0	1,000[A]	3,842[B]	35,000[C]	50,000	100,000
Installation (per charger)[16]	0	1,354	3,108	22,626	22,626	22,626
Site preparation (per charger)	0	0	3,000[D]	12,500[E]	12,500	12,500
Utility service	0	0	4,000	17,500[F]	17,500	17,500
Transformer	0	0	5,698[G]	32,500[H]	40,000[I]	40,000

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Table 7: Average load (utilization) per unit

Load Profile	L1 Res.	L2 Res.	L2 Comm.	L3 Comm.	L4 Comm.	L5 Comm.
12am-6am	25%	25%	0%	0%	0%	0%
6am-9am	0%	0%	5%	5%	5%	5%
9am-12pm	0%	0%	10%	10%	10%	10%
12pm-3pm	0%	0%	15%	15%	15%	15%
3pm-5pm	0%	0%	15%	15%	15%	15%
5pm-7pm	25%	25%	30%	30%	30%	30%
7pm-9pm	25%	25%	20%	20%	20%	20%
9pm-12am	25%	25%	5%	5%	5%	5%

*Note. Reprinted from "Belfer Center for Science and International Affairs", by Henry Lee Harvard Kennedy School, and Alex Clark Climate Policy Initiative, 2018, September. Retrieved from https://www.hks.harvard.edu/research-insights/publications?f%5B0%5D=publication_types%3A121

Table 8: Variable costs breakdown per units

Variable Costs ($)	L1 Res.	L2 Res.	L2 Comm.	L3 Comm.	L4 Comm.	L5 Comm.
Maintenance (per year)	0	0	400	2,500	2,500	2,500
Insurance (per year)	0	0	400	2,500	2,500	2,500

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