Electric Transportation Characteristics and Charging Infrastructure

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Why electric transportation?

- Opportunities for operation, control, performance
- Energy reduction and energy flexibility
- Operating cost reduction
- Emissions reduction

Some results are based on survey information and charging operating history at the University of Illinois at Urbana-Champaign

Photos by the author unless shown otherwise
Are the problems still the same as 100 years ago?

- Limited range. Where can I charge up?
- Battery performance, cost, and life.
- Refueling time.
- Other stuff people hate.
  - Cargo limits
  - Heavy cars
  - Energy for comfort

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“An electric car will need to match everything we can do with a conventional (fueled) car.”

-- Differentiation is common in transportation markets.

“People will not buy a car just for commuting.”

-- Actually, this is not unusual.

“Fast charging is a must.”

-- This needs more thought.

“Range is everything.”

…
People value personal mobility.

• How do we enable *mobility for everyone*?
• Transportation electrification must meet fundamental needs rather than matching existing thinking.
• Electric transportation is a potential beneficial partner for the electricity grid.

• Data on actual vehicle usage is essential.
Hybrid and electric aircraft are emerging
• Large fuel and emissions reductions.
• High impact on airport infrastructure and loads.
• Enormous emerging energy opportunity.

Hinetics.com
Hybrid electric aircraft charging, O’Hare case study

- Usage depends on a relative electrification factor (a motor factor $MF$).
- It also depends on enhancements to batteries (battery storage density $BSED$).
Charging infrastructure is considered a major barrier to plug-in vehicle adoption.

A mix of issues:

- Safety and safety perception
- Charge rate
- Desire to emulate fueled vehicles

But conventional outlets meet most of the needs in many locations.

A shift to outlet provisioning can save much of the cost.

Courtesy of Alicia Tomaszewski
In practice, owners do not emulate fueled cars

- Owners of EVs and PHEVs typically do not prefer a fuel-emulation approach.
- They seek simplicity and convenience.
- U.S. daily car travel average is 29 miles\(^1\).
- Less than 5% of trips exceed 31 miles\(^2\).

\(^1\)Bureau of Transportation Statistics, updated May 2017.  
\(^2\)http://nhts.ornl.gov/vehicle-trips
• The usual view: few EV charging points exist (less than 80,000 in the US, for instance).
• Fact: hundreds of millions of electrical outlets provide ready access to energy.

• Make conventional outlets into ubiquitous charging infrastructure.
• This does not meet needs for long-distance driving, but that is taken here as a separate issue.
• To accomplish this, low-level V2I (vehicle-to-infrastructure) interfaces must be in place.
• Vehicle communicates for billing and grid interfacing.
• Vehicle uses onboard charger for active safety management.
• The communication needs are minimal, e.g. a few messages per hour each way.
Safety can be an issue of perception, even though emerging codes address concerns.

Some of these block heaters are rated to 1500 W.

An EV owner sees a forest of Level 1 chargers.
Power electronics for in-vehicle chargers can implement extensive protection:

- Comprehensive handshaking
- Continuous monitoring for ground faults
- Current limits
- Various lockouts
- Monitor moisture
- Delay or coordinate charging times.
- …
What about Level 1?

Consider these:

- Level 1, 120 V at 12 A (or 16 A).
- Level “1A,” 240V at 12 A.

These exist in most of the world as conventional single-phase outlets.
Level 1 and 1A

Well designed EV uses about 250 Wh per mile (160 Wh/km) in city operation

Level 1 – 1.4 kW, about 8 km/h, 5 mph

Seems like not very much, but a car is parked many hours a day, and 60 km (38 miles) one way is plausible.

Level 1A – 2.9 kW, about 16 km/h, 10 mph

What about Level 2?

Level 2 (typically 6 to 7 kW)
*This is about 40 km per hour, 25 mph*
Not sufficient for distance driving
Not necessary for most commuting

Level 3 (fast charge) is
the alternative that
supports distance
driving – separate issue
Many infrastructure projects address Level 2

Expensive charging stations

*Instead*
A 240 V, 12 A outlet supports a one-way commute of 100 km with less than 8 hours of charge time.

Even less relevance for plug-in hybrids

*A plug-in hybrid with 60 km electric range can charge fully during a work day at Level 1*

Illinois campus experience: Level 2 usage 8 hr/month, Level 1 daily
Published data suggest that more than 95% of U.S. commuters drive less than 120 km round trip.

Actual usage is covered by Level 1 chargers.

**Usage cases**

1. Extended connection time. Enough time for charge, plus flexibility.
2. Defined time. No extra time for flexibility.
3. True opportunity charging.
4. Non-routine locations (hotel, shopping mall, relative’s home, etc.).

Courtesy of R. Fritz
“It takes a long time to charge an EV at Level 1.”

-- It takes a long connection time.
-- The driver’s time is a different story!

Owners of plug-in hybrids seem to hate gas stations.
The case for flexibility

Long connection time, limited need

*Sell flexibility to the grid*

Charge is delivered per a contract, but at times and rates determined to meet grid-related needs.

*Optimize for cost*

*Optimize for lowest grid stress*

*Or set the lowest charge current consistent with meeting energy target*

This Level 1 interface accessory does not support “universal” power input (it does not adapt to voltage).

The box must generate a 1 kHz square wave to meet SAE J1772.
Plug in and charge

Cost is retail or perhaps a premium

*But retailers might offer free connections.*

The vehicle manages billing services, and pays for energy unless the facility owner allows otherwise.

Notice two outlet database possibilities:

1. “Bill to” information.
2. Outlet capacity information.

This EVSE cable interface supports 120 V or 240 V.
Vehicles:

Measuring and metering
*The vehicle tracks usage and communicates billing*
Need not be real-time unless extra services are being sold. Secured within the vehicle.

Safety and handshaking
*The vehicle will not activate charging unless all attributes check out*
Test for safety ground, for valid connection.
Infrastructure:

Provisioning
Outlet is unintelligent, but could be entered into a database that lists capacity and payer. Parking provider installs outlets.

Utility
Pricing signals, updated “user pays” energy billing. Aggregator could manage a “parked fleet:” flexible timing, pricing schedules, and other capabilities.
Less than 10% of charging energy is likely to be at high rate.

Energy cost will carry a large premium
But still cheaper than fuel.

Interstate highway rest areas, vicinity of exits
Tesla is building up on these models.

Roadways?
Wireless roadbed charging – mainly on rural interstate highways?
Sliding contact chargers?

Battery swaps?
Conclusions

- About 95% of EV commuting needs can be supported by Level 1 charging.
- Level 1 infrastructure is routine, low cost.
- Readily provisioned in new construction.
- Easy to add to existing parking garages.
- Feasible for surface and street spaces.

- The vehicle can manage safety, billing, measurement, and other attributes.

Courtesy of R. Fritz
THANK YOU!

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