Energy Efficiency for Urban Transport - Continuing Programs in Distributed Transit

Submitted by: Toyota
Continuing Programs in Distributed Transit

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Agenda

Future Society
Future Energy
Future Vehicles
On One Hand: Growing Megacities (>10M)

Today – 2
- New York, NY 18.65M
- Los Angeles, CA 12.22M

4 Additional by 2050
- Atlanta, GA
- Chicago, IL
- Dallas – Fort Worth, TX
- Miami, FL

On the Other Hand: Populations are Spreading

2/3 of US jobs, 3/4 economic output, are within 35 mi of 98 largest central business districts (CBD). Increasingly, they are moving to a ring 10-35 mi from CBD. (Brookings Inst.)
Most Commutes Are Suburb to Suburb

Metropolitan Flow Map (Millions of Commuters)

Source: Brookings Inst.

Today’s Commuting Distances

Implication: A substantial segment of commuters is unavailable to an EV alternative

One-way Commuting Distance

Source: Brookings Inst.
**By 2020**

Economic Forecast (% of Total Jobs)

- Trade 19%
- Financial, Insurance, Real Estate 5%
- Government 11%
- Other 24%
- Services 41%

Implication: Increasing flexibility/mobility will be needed at workplace

148% Increase over 1994 Levels

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**Today**

A Need for Mobility at Work

- Don't Need a Vehicle at Work: 64%
- Need a Vehicle at Work: 36%

Implication: Growing dissatisfaction with commuting will not lead increased use of conventional alternatives
Congestion Continues to Grow

Figure ES.1 Congestion Has Grown Substantially in U.S. Cities over the Past 20 Years

Hours of Delay per Traveller

Population Area Size

Source: In their most recent annual report on the state of congestion in America's cities, the Texas Transportation Institute noted that congestion has grown substantially over the past 20 years. While the largest cities are the most congested, congestion occurs – and has grown – in cities of every size. A more complete discussion follows later in this section. (The 2003 Urban Mobility Report, http://mobility.tamu.edu.)

Sources of Congestion

Figure ES.2 The Sources of Congestion

Urban Mass Transport Solutions Require Last Mile Considerations

Future Trends will Focus on Distributed Mass Transit

- Congestion and air pollution is increasing
- Traditional solutions (i.e. more highways) are not sufficient
- Current mass transit doesn’t work in many American cities
  - Traditional rail service doesn’t match with suburban commuting patterns
  - Bus service inconvenient and has social stigma attached to it
- New Paradigm needed: Distributed Mass Transportation
Improving Transportation Systems

Distributed Mass Transit

“Station” Cars

• Typically, 2-seat battery electric vehicle
• Extension of mass transit
  • Provides instant, distributed mobility
  • Ideal for commuting and most local trips
• Each station car is used multiple times per day by different subscribers

Station cars alone are not sufficient; integration into a high-tech transportation “system” is critical
Station Car Systems: Enabling Technologies

**Reservation Management System**
Reservations from home and office PCs

**Location Management System**
Managing location information on vehicle in use

**Card System**
Membership card for vehicle use

**Real-time Information System**
Use of traffic information services

**Depot Management System**
Constant status checks on each vehicle's battery charge

**Charge Billing System**
Member billing

Station Car Flexibility Addresses Transit Rider Concerns

- **User Advantages**
  - Flexibility
  - Real alternative
  - “Free time”
  - No extra car

- **Community Advantages**
  - Air Pollution
  - Traffic Congestion
Potential Station Car Markets

20 Rail Corridor Systems

Potential Station Car Markets

New Urban Mobility – EV Concept

- Range: 50 miles
- Charge Time:
  - ~ 2.5hr/7.5hr (220V/110V)
- 2012
Car Sharing is Growing

Currently at 70+ U.S. college campuses

U.S. Car Sharing Growth Forecast

8 mm Potential

200k+ Current Members

Members (000s)

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000

2007 ~2020

Technology Enables New Possibilities

Wireless Technology Promotes Modal Diversity

Eco Technology Conserves Energy, Reduces CO₂

Convergence of:
- Wireless Computing
- Consumer Electronics
- Transportation
- Telematics
- Home Energy Management
- Eco-impact Metrics

Recommend optimal mode to minimize price & travel time

PEV ENABLERS

- Locate Mass Transit
- Locate Zipcar Available?
- Locate Charge Station
- Smarter Charging Stations
- Vehicle to Grid
- Monitor Charge Status
Transition in Personal Mobility

Transition will require:
1. Real-time Communication from Vehicle
   a) to customer (web portal, Smart Phone)
   b) to utilities
   c) to home energy management system
2. Shift to other modes of personal transportation
3. Partnerships

Mobility based on Multiple Modes
- Car Sharing
- Personal Rapid Transit
- Mass Rapid Transit
- Station Cars

Now Future
Agenda
- Future Society
- Future Energy
- Future Vehicles
Preliminary View of World Oil Supply

- Non-Opec crude oil
- Opec crude oil
- NGLs
- Canadian tar sands
- Biofuels

Source: Peter Wells

Reduction of Spare Capacity Opens the Door for Price Spikes

- Supply
- Price
- Demand
- Price spikes
- Price induced “new” supply or accelerated supply

Source: Peter Wells
There is no Single Solution
Plug in Hybrids For Medium Distance Commuting
Operation Specifications

Electric Vehicle Charger Assembly
Engine
Electric Motor
HV Battery
Cable Assembly
Household Outlet
AC 110 V to 220 V

Max. Output
<table>
<thead>
<tr>
<th>Engine</th>
<th>98 HP (73 kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MG2</td>
<td>80 HP (60 kW)</td>
</tr>
</tbody>
</table>

In EV Driving Mode
<table>
<thead>
<tr>
<th>Max. Speed</th>
<th>Approx. 62 mph (100 km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>Approx. 13 miles (21 km)</td>
</tr>
</tbody>
</table>

Power Source
Household Electrical Outlets

Charging Time
Approximately 3 hrs (110 V)

HV Battery Cooling
- Additional fans
- New ductwork
- 42 Temperature Sensors

HV Battery Temperature Sensors (for HV Battery Pack)

HV Battery Temperature Sensors (for Intake Air Duct)
Challenges: “What the Market will Bear”

2008 Midsize Car Prices

Source: PIN

Challenges: Battery Costs

Current/Developing Cost => even 10 mile AER is Too expensive
- 70% of total cost is from the battery cells
- Cost must be reduced – not just cells, but the entire PEV system
- Must consider the most balanced all electric range

Options for reducing PEV cost:
- Reduce battery cost per capacity
- Reduce All Electric Range
- Expand the Usable SOC

Battery Energy on board

~50% usable energy in actual operation

Cost of PEV System

- Cell Cost for 10 mile AER
- Battery Package w/o Cells
- Plug-in additional (Charger, Inlet, Cable)
PHV Role: EV Mode For Short Distance HV Mode for Longer Trips

U.S. Driving Patterns

Cumulative percentage of personal automobile trips
Cumulative percentage of travel distance energy

Approx. 20%
Approx. 35%
60% Trips

Average Daily Travel Distance per Vehicle (miles)

Source: 1990 Nationwide personal transportation survey

Ubiquitous Charging Increases Electric VMT

Utility Factor

All-electric range (miles)
Challenges: Key Infrastructure Issues Remain

Vehicle to Grid Communications
- Electric Utilities have excess electricity \textit{generation} capacity during off-peak hours – typically at night
- Even during off-peak times, however, there is insufficient electricity \textit{distribution} capacity for many PEVs to charge at the same time
- Communication between vehicle and "grid" is necessary to avoid negative impacts to distribution system (such as local outages)

Level 2 Charging Equipment
- The majority of customers, particularly larger-capacity BEVs (50+ miles), will need/want L2 (220V) charging at home and business
- The installation of L2 charging equipment is extremely challenging: high cost, lengthy time period, complex interactions among City, Utilities, Contractor, Customer, OEM and Dealer
- Resolving L2 installation issues will be critical for EV market adoption

Last Mile Grid System not Developed
- Old Transformers Cannot Accommodate Multiple EVs Charging in One Neighborhood
- Night Time Charging Limits Charging Hours
- Public Charging Not Assured

According to DOE Targets Fuel Cells Provide Most Efficient Packaging Over 100 Miles

Source: DOE
Fuel Cell Vehicles for Longer Trips And Challenges for FC Vehicles

- Durability
- Compactness & High Power Density
- High & Low Temperature Performance
- Cost
- Cruising Range

Over Time The Costs of Most Technologies Merge

Source: DOE
**Strong Regulatory Push: Reduce CO₂**

CARB 2050 Vision

- CARB expects BEV/FCV sales volume to surpass conventional gas by 2035 and reach 30% of mix by 2040.
- However, the above vision does not achieve the 80% reduction in GHG emissions from 1990 levels by 2050; ZEVs will need to reach 100% of vehicle sales by 2040, to meet the 80% goal.

**CARB Assumptions: Retail Price Increase Versus 2035 Hybrid**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Price Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>2035 Plug-in Hybrid (30 mile AER)</td>
<td>$3,400</td>
</tr>
<tr>
<td>2035 Battery Electric (100 mile range)</td>
<td>$5,500</td>
</tr>
<tr>
<td>2035 Fuel Cell</td>
<td>$2,800</td>
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</tbody>
</table>

**EV Costs vs CO₂ Reduction**

Electric vehicles, costing $140 to $230 per percentage point of CO₂ reduction (2020):

- **Plug-in hybrid (2009)**: $250 per percentage point
- **Electric vehicle**:
  - $350 per percentage point
  - Range extenders:
- **ICE optimization** (see the above graph):
- **Full Hybrid (2009)**: $150 per percentage point
- **Advanced gasoline**:
  - $70 per percentage point

Source: BGC analysis.

Note: Each label in the table represents a set of technologies.

ICE = internal combustion engine.

CO₂ is the charge compression ignition.

*CO₂ emission numbers refer to a base gasoline engine.

*Hence, the calculation assuming 138 grams per kilowatt-hour (grams) of carbon intensity from power generation.
Comparison of Vehicle Powertrain Technologies

<table>
<thead>
<tr>
<th></th>
<th>FC</th>
<th>HEV</th>
<th>PHEV-20</th>
<th>EV-40</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material production</td>
<td>17%</td>
<td>17%</td>
<td>20%</td>
<td>25%</td>
<td>11%</td>
</tr>
<tr>
<td>Vehicle assembly</td>
<td>3%</td>
<td>3%</td>
<td>4%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>Fuel production / transport</td>
<td>10%</td>
<td>10%</td>
<td>9%</td>
<td>5%</td>
<td>12%</td>
</tr>
<tr>
<td>Vehicle operation</td>
<td>63%</td>
<td>63%</td>
<td>59%</td>
<td>54%</td>
<td>71%</td>
</tr>
<tr>
<td>Vehicle maintenance</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Vehicle disposal</td>
<td>4%</td>
<td>4%</td>
<td>5%</td>
<td>7%</td>
<td>3%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Roles of EV/PHEV/FCV
Thank you for your kind attention

Apply existing technologies in new ways

Most of the technologies mentioned already exist, just not yet in the mobility space.

For now smaller battery approaches are more cost effective

Implies multiple charge periods throughout the day.

Fuel Cells are rapidly maturing

Multiple solutions for rapidly changing circumstances.

PEVs and FCs both face significant infrastructure hurdles.

At the end of the day, customer is king

All solutions must solve customers problems without creating new ones.

Charging solutions to manage the grid may be at odds with customer expectations.

Summary