Agenda

+ Operations Analysis
+ Estimated Procurement Timelines
  • Vehicles
  • Infrastructure
+ Life Cycle Cost Analysis
+ Market Options
+ Community Considerations
+ Key Takeaways & Next Steps
+ Questions
Operations Modeling: The Fixed Routes

Route Configuration

Route Geography and Traffic Patterns

Energy Consumption per Trip

Data Processing & Drive Cycle Generation

Drive Cycle Simulation & Energy Calculation
Operations Modeling: TheFixed-Route Vehicles

Transit Bus
Nominal Energy: 492 kWh
-20% for aging
-20% margin + battery health
Usable Energy: 315 kWh
Usable Range: 156 mi

Cutaway
Nominal Energy: 157 kWh
-20% for aging
-20% margin + battery health
Usable Energy: 100 kWh
Usable Range: 79 mi

Trolley
Nominal Energy: 127 kWh
-20% for aging
-20% margin + battery health
Usable Energy: 81 kWh
Usable Range: 54 mi
Operations Modeling: The Fixed-Route Service Patterns

Energy Consumption per Trip

Operating Blocks

Energy Consumption per Day

Energy per trip, over all trips... → ...yields energy needed per day
EV Operations Strategies:
- Shorter blocks (more vehicles)
- On-route charging
- Use of diesel or hybrid vehicles

Assumption: no changes to passenger-facing schedules
Operations Modeling: The Fixed Routes

• Key Hubs:
Operations Modeling: Demand-Response

Cutaway Vehicle
Nominal Energy: 157 kWh
-20% for aging
-20% margin + battery health
Usable Energy: 100 kWh
Usable Range: 92 mi

Typical Routes
Miles/day: 87, 120, 130, 175
Midday breaks: on some routes

EV Operations Strategies:
- More (shorter) runs
- Lunchtime charging
- Some ICE vehicles retained
## Operations Modeling: Demand-Response Sample Runs

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Miles</th>
<th>kWh Req</th>
<th>Lunch Break Duration</th>
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<tbody>
<tr>
<td>B16</td>
<td>87</td>
<td>95</td>
<td>49 min</td>
</tr>
<tr>
<td>B27</td>
<td>120</td>
<td>130</td>
<td>55 min</td>
</tr>
<tr>
<td>B51</td>
<td>130</td>
<td>141</td>
<td>96 min</td>
</tr>
<tr>
<td>B54</td>
<td>175</td>
<td>190</td>
<td>64 min</td>
</tr>
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</table>

### Assumptions:
- 50% of lunch break time can be used for charging at nearby charging station
- DC fast charging (80 kW)
- Representative sample
# Operations Modeling: Demand-Response Sample Runs

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Miles</th>
<th>kWh Req</th>
<th>Lunch Break Duration</th>
<th>kWh Gained During Lunch</th>
<th>Reduced kWh Req</th>
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<tr>
<td>B16</td>
<td>87</td>
<td>95</td>
<td>49 min</td>
<td>33</td>
<td>62</td>
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<td>B27</td>
<td>120</td>
<td>130</td>
<td>55 min</td>
<td>37</td>
<td>93</td>
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<tr>
<td>B51</td>
<td>130</td>
<td>141</td>
<td>96 min</td>
<td>64</td>
<td>77</td>
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<tr>
<td>B54</td>
<td>175</td>
<td>190</td>
<td>64 min</td>
<td>43</td>
<td>147</td>
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![Demand-Response: kWh Requirements](chart.png)
Operations Modeling: Demand-Response (Fleet-Wide)

Peak Service Vehicles
- Cutaway: 36
- Caravans: 6
On-Route Charging

- Key Hubs:
  - Mashpee
  - Hyannis
  - Orleans
  - Falmouth
On-Route Charging

- Key Hubs:
On-Route Charging

Use of Third-Party Charging Station

On-Route Charging Station

Depot
On-Route Charging: Assumed Locations

- Mashpee
- Provincetown (Midday & Overnight)
- Falmouth – Palmer Parking Lot (Midday)
- Hyannis (Midday)

Use of Third-Party Charging Station

On-Route Charging Station

Route Terminal
Peak fleet requirement increases by four (8%):  
- 2 cutaways: Sandwich  
- 1 cutaway: Bourne  
- 1 transit bus: Flex  

Alternatively, schedule changes (longer layovers at charging locations) could reduce this need
Estimated Procurement Timelines
Vehicle Procurement Timeline

- **2 Gas DART Cutaways**
- **3 Gas DART Cutaways**
- **4 Gas DART Cutaways**
- **7 Gas DART Cutaways**

<table>
<thead>
<tr>
<th>Year</th>
<th>Fixed Route Gillig</th>
<th>Fixed Route Cutaway</th>
<th>Trolleys</th>
<th>DART Cutaway</th>
<th>Caravans</th>
<th>Total</th>
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<td>3</td>
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<td>4</td>
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<td>4</td>
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<td>2035</td>
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<td></td>
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<td></td>
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</tr>
</tbody>
</table>

**2023-2035**

- **Fixed Route Gillig**
- **Fixed Route Cutaway**
- **Trolleys**
- **DART Cutaway**
- **Caravans**
- **Total**

**2023-2035**

- **Electric**
- **Fossil**
## Charger Procurement Timeline

### Depots
- **Total, 25**
  - **2023**: 2
  - **2024**: 3
  - **2025**: 5
  - **2026**: 15
  - **2027**: 11
  - **2028**: 1
  - **2029**: 1
  - **2030**: 1
  - **2031**: 1
  - **2032**: 3
  - **2033**: 2
  - **2034**: 0
  - **2035**: 0

### Provincetown & Mashpee
- **Total, 24**
  - **2023**: 2
  - **2024**: 3
  - **2025**: 5
  - **2026**: 15
  - **2027**: 11
  - **2028**: 1
  - **2029**: 1
  - **2030**: 1
  - **2031**: 1
  - **2032**: 3
  - **2033**: 2
  - **2034**: 0
  - **2035**: 0

### Charger Types
- **19.2 kW Level 2**
- **150 kW DCFC (3 Dispensers)**
- **100 kW DCFC (Single Dispenser)**
- **300 kW DCFC (Single Dispenser)**
# Charger Distribution

<table>
<thead>
<tr>
<th></th>
<th>Depot</th>
<th>HTC</th>
<th>Provincetown</th>
<th>Mashpee</th>
<th>Total</th>
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<tbody>
<tr>
<td>19.2 kW Level 2</td>
<td>101</td>
<td></td>
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<td></td>
<td>101</td>
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<tr>
<td>150 kW DCFC (3 Dispensers)</td>
<td>15</td>
<td>2</td>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>100 kW DCFC (Single Dispenser)</td>
<td>3</td>
<td></td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>300 kW DCFC (Single Dispenser)</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>116</strong></td>
<td><strong>5</strong></td>
<td><strong>3</strong></td>
<td><strong>5</strong></td>
<td><strong>23</strong></td>
</tr>
</tbody>
</table>

Notes:
- 15 - 150 kW DCFC will equal to a total of 45 dispensers at the depot
- 2 - 150 kW DCFC will equal to 6 dispensers at the Provincetown
- The chargers at Falmouth are assumed to be public chargers and hence are not included in CCRTA’s capital plan
Lifecycle Cost Analysis & Capital Plan
Capital Plan

$79 million

2023  2024  2025  2026  2027  2028  2029  2030  2031  2032  2033  2034  2035

$-  $21,197,400  $2,901,562  $1,546,209  $7,169,491  $5,628,276  $6,435,942  $8,461,532  $7,587,953  $11,540,719  $5,966,989  $-  $-
Assumptions for Lifecycle Cost Analysis

- **General**
  - 3% inflation
  - 12-year life for Buses
  - 7-year life for all other vehicles
- **Fixed Route Vehicle**
  - $75,000 battery warranty cost assumed
  - Diesel vehicle maintenance cost: $1.3/mile
  - Electric vehicle maintenance cost: $0.96/mile
- **DART Vehicle**
  - Gasoline vehicle maintenance cost: $1.25/mile
  - Electric vehicle maintenance cost: $0.92/mile
- **Operator hourly cost**: 43$/hour
- **Charging**
  - Construction costs were assumed to be covered by Eversource
Total Cost of Ownership

- Fossil Baseline Fixed Route
  - Operations Cost: $139M
  - Infrastructure: $40M
  - Maintenance: $80M
  - Capital: $200M
  - 139% increase in Vehicle Capital

- Future Fleet
  - Operations Cost: $140M
  - Infrastructure: $40M
  - Maintenance: $80M
  - Capital: $200M
  - 8% increase in TCO

- Fossil Baseline DART
  - Operations Cost: $160M
  - Infrastructure: $40M
  - Maintenance: $80M
  - Capital: $200M
  - 164% increase in Vehicle Capital

- Future Fleet DART
  - Operations Cost: $170M
  - Infrastructure: $40M
  - Maintenance: $80M
  - Capital: $200M
  - 14% increase in TCO
Annual CO2 Emissions (kg)

- Fossil Baseline
- Future Fleet

Well-to-Tank
Tank-to-Wheel
Grid

66%
Market Options
# Electric Vehicle Options

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Electric Equivalent</th>
<th>Example(s)</th>
<th>Approx. Unit Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>30’, 35’ Bus</td>
<td>Gillig/New Flyer</td>
<td>$960,000</td>
</tr>
<tr>
<td>Cutaway/Minibus</td>
<td>Large, mid, and small-sized cutaways</td>
<td>Ford E Transit Cutaway/Lightning eMotors ZEV 3 &amp; 4 Van/Ford Transit 350HD Passenger Van</td>
<td>$295,000, $170,000, $125,000</td>
</tr>
<tr>
<td>Caravan</td>
<td>SUV</td>
<td>Chevy Electric Equinox EV/Rivian R1S</td>
<td>$70,000</td>
</tr>
<tr>
<td>Trolley</td>
<td>Electric trolley</td>
<td>Hometown Villager/Streetcar</td>
<td>$800,000</td>
</tr>
</tbody>
</table>
Charging Equipment Options

- **19.2 kW Level 2**: $7,500
- **150 kW DCFC (3 Dispensers)**: $150,000
- **100 kW DCFC (Single Dispensers)**: $110,000
- **300 kW DCFC (Single Dispensers)**: $200,000
Community Considerations
Findings: Justice40

10,000 residents (or 5%)

- health (heart diseases & asthma)
- costs of living (spend more on housing and energy)
- income (low median income)
- traffic proximity (near major roads)
- educational attainment
Key Takeaways
Key Takeaways

- Fixed route is feasible for full fleet electrification
- Demand response appears feasible for 75% electrification
  - Continued monitoring of the market
- Start procurement process for Depot and HTC
- Continued Utility coordination
- Strategize charging at Mashpee/Provincetown/Woods Hole
  - Negotiations with local landowners
  - Where/layout
  - Coordination with Steamship Authority
- LCC – 11% Increase
- CO₂ Emissions – 66% Decrease
Next Steps

- Depot space proofing, planning, and utility coordination
- Begin outreach for workforce training
- Strategize around charging infrastructure at identified locations and additional charging opportunities
Questions

For more information, please visit www.hatch.com