Evaluating Cost-Effectiveness of CO2 Emissions Abatement Transit Strategies

Jeffrey Tumlin, Nelson\Nygaard
For Val Menotti, BART
October 29, 2008
CO2 Emissions Abatement Transit Strategies

**BART Basics**

- Rapid transit system
- Trains all-electric; majority clean hydro power
- 104 miles
- 43 stations
- 360,000 daily riders
- 1.3 billion annual passenger miles
CO2 Emissions Abatement Transit Strategies

California Policy Context

- **AB32 Global Warming Solutions Act (2006)**
  - 1990 emissions levels by 2020

- **Governor's Executive Order (2005)**
  - 80% below 1990 emissions by 2050

- **SB375 Sustainable Communities Strategy (2008)**
  - Regional GHG Emission Targets for Autos / Light Trucks
CO2 Emissions Abatement Transit Strategies

Transit’s Role in Transport Sector

Transportation Sector
Transit

Current Greenhouse Gas Emissions

Transportation Sector
Transit

Future Greenhouse Gas Emissions
1. State / Federal Policy & Regulation
2. GHG Inventory / Footprint
3. Carbon Markets
4. Partnerships
5. Climate Action Plan (scoping)
6. Cost-Effectiveness
CO2 Emissions Abatement Transit Strategies

McKinsey – Economy Wide Study

GHG reduction opportunities widely distributed – 2030 mid-range case

Cost
Real 2005 dollars per ton CO2e

-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
120
230

Residential electronics
Residential buildings Lighting
Fuel economy packages – Light trucks
Industrial process improvements
Coal mining – Methane mgmt
Residential buildings Shell retrofits
Active forest management
Distributed solar PV
Commercial buildings HVAC equipment efficiency
Residential buildings HVAC equipment efficiency

Potential
Gigatons/year

0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2

Commercial electronics
Cellulosic biofuels
Commercial buildings New shell improvements
Conservation tillage
Manufacturing HFCs mgmt

“What we do in the next 10-20 years can have a profound effect on the climate in the second half of the century and in the next.”

Nicholas Stern, The Stern Review
CO2 Emissions Abatement Transit Strategies

Analysis Considerations

- Sense of Urgency: “Early Actions”

- BART Early Action Strategies:
  - Service Frequency
  - Station Access
  - Fares
  - Marketing

- Other BART Strategies

- Transportation Sector Strategies
Additional Considerations

- Did not compare to roadway investments
- Did not examine life-cycle costs
- Only analyzed GHG emissions
- Transit projects have multiple objectives that need to be balanced
- Capacity improvements hard to quantify
- Considered “transit multiplier” for some investments (shorter trips, more walk/bike)
- Considered public costs, not private costs
CO2 Emissions Abatement Transit Strategies

Assumptions

• Existing transit capacity
• Average BART trip = 13 miles
• BART 2/3 clean hydroelectricity
• Average BART trip = 14% of GHG of equivalent auto trip.
• Average auto drive access = 3.8 miles
CO2 Emissions Abatement Transit Strategies

Cost-Effectiveness Comparison

Cost per Metric Ton of CO2 Emissions Abatement (Bart Strategy)

- Off-peak Frequency Firsharments: $1,600
- Structural Parking: $1,305
- Surface Parking: $1,100
- TOD with Full Replacement: Parking: $1,100
- BART Extension: $1,000
- Attended Parking: $1,000
- Unlimited Ride Pass: $125
- Renewable Energy: $100
- Kids Ride Free: $10
- Fuel Shuttle Service: $10
- Train Efficiency Improvements: $25
- TOD with Partial Replacement: $37
- TOD without Replacement: $2,210

Cost per Ton of CO2 Emissions Abatement

- 1 - Lower Potential (< 20,000 Tons)
- 2 - Moderate Potential (20,001 - 50,000 Tons)
- 3 - High Potential (50,000 - 100,000 Tons)
- 4 - Very High Potential (> 100,000 Tons)
CO2 Emissions Abatement Transit Strategies

Service: Off-Peak Frequency

- BART improved off-peak frequencies (evening and Sundays) in FY08
- More frequent transit service can attract travelers out of their cars.
- Considered additional costs for traction power and rolling stock
- BART’s recent off-peak frequency enhancements lower system productivity; not cost effective for CO2 abatement alone.

<table>
<thead>
<tr>
<th>Improve off-peak frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Reduced:</td>
</tr>
<tr>
<td>Cost:</td>
</tr>
<tr>
<td>Max Potential:</td>
</tr>
</tbody>
</table>
Shuttle programs can bridge the last mile to destinations and reduce the need for new parking. Employers may contribute part of the cost of operation. Including new fare revenue generated for BART, feeder shuttles can be revenue positive under the right conditions.

**Feeder Shuttle Access**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Reduced (Metric Tons)</td>
<td>3,600</td>
</tr>
<tr>
<td>Annual Cost</td>
<td>-$150,000 to $570,000</td>
</tr>
<tr>
<td>Cost Efficiency ($ per metric ton)</td>
<td>-$80 to $320</td>
</tr>
<tr>
<td>Max Potential (Metric Tons)</td>
<td>3,600</td>
</tr>
</tbody>
</table>
CO2 Emissions Abatement Transit Strategies

Access: Commuter Park-n-Ride

- More parking may allow more people to access a BART station by car; shorter auto trips.
- Capital costs are very high.
- Cost effectiveness low.

### BART Station Parking

<table>
<thead>
<tr>
<th>Surface Parking</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Reduced:</td>
<td>240 to 431 Metric Tons per Project</td>
</tr>
<tr>
<td>Cost:</td>
<td>$520 to $1,400 per ton</td>
</tr>
<tr>
<td>Max Potential:</td>
<td>4,800 to 8,600 Metric Tons (Projects at 20 BART Stations)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structured Parking</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Reduced:</td>
<td>700 to 1,200 Metric Tons per Project</td>
</tr>
<tr>
<td>Cost:</td>
<td>$2,204 to $4,700 per ton</td>
</tr>
<tr>
<td>Max Potential:</td>
<td>14,400 to 25,900 Metric Tons (Projects at 20 BART Stations)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attended Parking (In Structure)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Reduced:</td>
<td>800 to 1,400 Metric tons per Project</td>
</tr>
<tr>
<td>Cost:</td>
<td>$2,200 to $4,700 per ton</td>
</tr>
<tr>
<td>Max Potential:</td>
<td>15,300 to 27,600 Metric Tons (Projects at 20 BART Stations)</td>
</tr>
</tbody>
</table>
Fares: Special Promotions

- Fare programs have the potential to encourage off-peak ridership.
- Could be cost-effective way to reduce emissions. Requires further study and possibly outside funding.

<table>
<thead>
<tr>
<th>Kids Ride Free</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Reduced</td>
<td>1,500</td>
</tr>
<tr>
<td>(Metric Tons)</td>
<td></td>
</tr>
<tr>
<td>Annual Cost</td>
<td>-$20,400 to $286,000</td>
</tr>
<tr>
<td>Cost Efficiency (per metric ton)</td>
<td>-$10 to $185</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unlimited Ride Passes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Reduced</td>
<td>85,000</td>
</tr>
<tr>
<td>(Metric Tons)</td>
<td></td>
</tr>
<tr>
<td>Annual Cost</td>
<td>$10,000,000</td>
</tr>
<tr>
<td>Cost Efficiency ($ per metric ton)</td>
<td>$120</td>
</tr>
<tr>
<td>Max Potential (Metric Tons)</td>
<td>85,000</td>
</tr>
</tbody>
</table>
Marketing programs may include either BART advertising on its own or investing in outreach programs run by other agencies.

TravelChoice outreach has been successful and cost effective at attracting people to transit.

Return on Investment varies widely for BART’s own marketing projects.

**TravelChoice Outreach**

<table>
<thead>
<tr>
<th>Emissions Reduced:</th>
<th>6,600 Metric tons per year for 10,000 households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost:</td>
<td>$60 per ton.</td>
</tr>
<tr>
<td>Max Potential:</td>
<td>66,000 metric tons per year (100,000 households)</td>
</tr>
</tbody>
</table>
CO2 Emissions Abatement Transit Strategies

**Energy: Expand to 100% Renewable**

- BART power already 2/3rds hydroelectric.
- Replace energy from fossil fuels with emissions-free renewable energy eliminates CO2 emissions.
- Questionable whether sufficient reliable, baseline green power can be acquired.

**BART Power Supply**

<table>
<thead>
<tr>
<th>Emissions Reduced:</th>
<th>72,000 Metric tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost:</td>
<td>$110 per ton</td>
</tr>
<tr>
<td>Max Potential:</td>
<td>72,000 Metric tons</td>
</tr>
</tbody>
</table>
Improvements to BART train car efficiency were identified in a recent PG&E audit. Could reduce the energy needed for trains by more than half: -$250 per ton/CO2.

<table>
<thead>
<tr>
<th>Improvement</th>
<th>Electricity Savings (kW/h/Year)</th>
<th>Initial Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use Ultracapacitors for Regenerative Braking Energy Storage</td>
<td>82,948,688</td>
<td>$88,038,753</td>
</tr>
<tr>
<td>Use Permanent Magnet (PM) Motors for Car Propulsion</td>
<td>38,905,029</td>
<td>$51,344,198</td>
</tr>
<tr>
<td>Install Variable Frequency Drives on HVAC Supply Fans</td>
<td>3,206,292</td>
<td>$1,475,000</td>
</tr>
<tr>
<td>Direct Cooler Air to the Inlet of HVAC Condensers</td>
<td>1,717,819</td>
<td>$100,000</td>
</tr>
<tr>
<td>Optimize Outside Air Intake into Cars</td>
<td>1,444,334</td>
<td>$847,793</td>
</tr>
<tr>
<td>Install Daylight Controls on the Fluorescent Lamps</td>
<td>837,433</td>
<td>$2,820,270</td>
</tr>
<tr>
<td>Install Higher Efficiency HVAC Units on C Cars and New Cars</td>
<td>413,021</td>
<td>$632,177</td>
</tr>
</tbody>
</table>

Two benefits for CO2: Attracts passengers to BART and creates residential developments that encourage walking, biking, and short trips.

Bay Area TOD residents generate half VMT compared to regional average.

Revenue-positive: can maximize value of BART property.

Wide range of cost effectiveness, depending on station and replacement parking requirements.

<table>
<thead>
<tr>
<th>BART Station Transit Oriented Development</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOD with full replacement parking</strong></td>
</tr>
<tr>
<td>Emissions Reduced: 800 to 2,000 Metric Tons per Project</td>
</tr>
<tr>
<td>Cost: $480 to $770 per ton</td>
</tr>
<tr>
<td>Max Potential: 16,000 to 40,000 Metric Tons (Projects at 20 BART Stations)</td>
</tr>
<tr>
<td><strong>TOD with partial replacement parking</strong></td>
</tr>
<tr>
<td>Emissions Reduced: 900 to 2,500 Metric Tons per Project</td>
</tr>
<tr>
<td>Cost: Negative $400 to positive $148 per ton</td>
</tr>
<tr>
<td>Max Potential: 13,000 to 50,000 Metric Tons (Projects at 20 BART Stations)</td>
</tr>
<tr>
<td><strong>TOD without replacement parking</strong></td>
</tr>
<tr>
<td>Emissions Reduced: 650 to 2,300 Metric Tons per Project</td>
</tr>
<tr>
<td>Cost: Negative $800 to negative $1,400 per ton</td>
</tr>
<tr>
<td>Max Potential: 13,000 to 48,000 Metric Tons (Projects at 20 BART Stations)</td>
</tr>
</tbody>
</table>
Extending BART attract new passengers; some may currently take long auto trips.

Extensions in isolation have very high capital costs, and lower productivity may mean that extensions may not be cost effective for CO2 abatement.

Extensions effectiveness significantly improves when considering the “transit multiplier” where transit enables a more compact land use pattern (shorter trips, more walk/bike).

**BART Extensions**

<table>
<thead>
<tr>
<th>Emissions Reduced:</th>
<th>30,000 Metric tons; 79,000 including land use impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost:</td>
<td>$2,000 per ton; $285 per ton including land use impacts</td>
</tr>
<tr>
<td>Max Potential:</td>
<td>Not Estimated.</td>
</tr>
</tbody>
</table>
In the coming decades BART will increasingly face capacity challenges for peak-hour, peak direction travel. The analysis does not account for the additional costs from the need to add capacity. Some strategies, such as fare incentives and TOD, tend to generate off-peak ridership.
CO2 Emissions Abatement Transit Strategies

Cost-Effectiveness Comparison

Cost per Metric Ton of CO2 Emissions Abatement (Bart Strategy)

- Off-peak Frequency Enhancements
- Structural Parking
- Surface Parking
- TOD with Full Replacement: Parking
- BART Extension
- Attended Parking
- Unlimited Ride Pass
- Renewable Energy
- Kids Ride Free
- Feeder Shuttle Service
- Train Efficiency Improvements
- TOD with Partial Replacement
- TOD without Replacement

Cost per Ton of CO2 Emissions Abatement:

1 - Lower Potential (< 20,000 Tons)
2 - Moderate Potential (20,001 - 50,000 Tons)
3 - High Potential (50,001 - 100,000 Tons)
4 - Very High Potential (> 100,000 Tons)

Transportation Strategies
Energy Strategies
Other Strategies
## CO2 Emissions Abatement Transit Strategies

### Potential Impacts

<table>
<thead>
<tr>
<th>CO2 Emissions Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Potential (&lt;20,000 Tons)</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td><strong>Very Expensive ($&gt;800/Ton)</strong></td>
</tr>
<tr>
<td><strong>Expensive ($&gt;100/Ton)</strong></td>
</tr>
<tr>
<td><strong>Inexpensive ($&lt;100/Ton)</strong></td>
</tr>
<tr>
<td><strong>Revenue Neutral ($0/Ton)</strong></td>
</tr>
<tr>
<td><strong>Revenue Generating ($&lt;0/Ton)</strong></td>
</tr>
<tr>
<td><strong>Strongly Revenue Generating ($&lt;1000/Ton)</strong></td>
</tr>
</tbody>
</table>
CO2 Emissions Abatement Transit Strategies

Findings

Most cost-effective strategies:
- Fill empty seats
- Transit multiplier
- Energy strategies competitive
- Co-benefits
CO2 Emissions Abatement Transit Strategies

Finding the Right Balance

- Reduce VMT = Grow transit ridership
- Greener Transit
Evaluating Cost-Effectiveness of CO2 Emissions Abatement Transit Strategies

Jeffrey Tumlin, Nelson\Nygaard for Val Menotti, BART October 29, 2008