GHG Impacts of End-of-Trip Bike Commute Facilities

Intent

This research is intended to provide a defensible estimate of the cost and greenhouse gas (GHG) emissions impacts of building 'end of trip' showering and changing facilities for bicycle commuters at urban commercial buildings in King County.

Cost was estimated for installation of bike racks, for short-term parking, as well as for facility construction. Estimates are provided for both new construction (in new buildings) and remodel of existing buildings to construct end of trip facilities.

GHG impacts were estimated for the construction of the facilities; this estimate is based on the embodied lifecycle carbon of the major construction materials, and does not include minor materials (such as paint, dispensers, etc). It also does not include any emissions from construction activities, such as use of heavy equipment, tools, or generators; finally, it does not include an analysis of the demolition waste from the renovation option.

Finally, this analysis estimates the beneficial GHG emissions impact of building end of trip facilities for bicycle commuters. This analysis assumes that a minimum of 20 people – based on the provision of 20 bike racks – ride a bicycle to work every workday of the year. It also assumes that all 20 of those people would otherwise have driven cars. Car availability is well demonstrated in our region; according to the a survey conducted as part of the Seattle bicycle Master Plan, over 90 percent of survey respondents had a car available to them to make trips.[1] While some bike commuters may have otherwise commuted on transit, their decision to ride a bicycle frees up space on the transit system for other commuters. Furthermore, many commuters in our region combine transit and bicycles in their commute.[2]

Baseline assumptions

This analysis uses the following thresholds and assumptions:

- Two (2) shower/changing facilities, one for men and one for women, with a shared wall. 200 square feet (SF) is the room total for both facilities.
- Steel frame parking for 20 bicycles;
- Daily commute:
    - Distance = 10 miles round trip[3] [4]
    - Working days per year = 250

Results

The results are presented in order of cost, GHG impacts of major materials, operations and maintenance impacts, and GHG benefits of biking to work in lieu of driving.

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[1] City of Seattle Bicycle Master Plan. 2007. http://www.seattle.gov/transportation/docs/bmp/final/AppendixA.pdf
[2] Cascade Bicycle Coalition. http://cbcef.org/bike-commuting-statistics.html
[3] King County Metro Rider / Non-Rider Survey Final Report, 2007. http://metro.kingcounty.gov/am/reports/2006/2006-RNRFinal.pdf
[4] FHWA *National Bicycling and Walking Study*, 1994. http://ntl.bts.gov/lib/6000/6300/6341/CASE1.pdf

Construction Cost Estimate

The cost estimate, provided by the estimation team at BNBuilders, is as follows:

Bike racks	$4,643
New construction	$55,231
Renovation	$68,078

The increased cost for renovation is from increased labor for demolition, and the associated increased time on site for the whole building team. This also increases total taxes for the job. Note that the construction cost estimates do not include the concrete floor, since it is presumed that the floor would be poured regardless of whether these facilities are constructed. However, these costs do include a non-slip finish for the concrete floor (rather than being covered with another material).

Embodied GHG in Materials Used

The materials analyzed are as follows:

- Concrete – this is measured proportional to the total space. In other words, only the amount of concrete under the floor of these facilities is counted (200 SF).
- Gypsum wallboard (GWB) – this is assumed to be the wall surface on all walls, including a shared wall between the two facilities. It is also the ceiling surface, suspended from steel studs.
- Steel beams/studs – 16" on center framing for both the interior walls and the ceiling (with suspended GWB).
- Polymer solid surface (i.e. Corian) countertops in both facilities (8 SF each).
- Steel partitions – this measures the total steel content of stall and urinal partitions and screens. It assumes two stalls in the women's facility and one stall and one screen in the men's facility.

The total embodied GHG emissions from the materials measured is 3.0 metric tons CO_2 (2.7 MT with a 25% flyash concrete mix). Removing concrete from the analysis altogether (in line with the cost estimate) yields total materials emissions of 1.9 MT. Emissions by material are broken out in the following table.

Material	Amount	GHG (kg CO_2)
Concrete[5]	200 SF (@ 6" thick)	1082 kg CO_2 847 kg CO_2 (25% flyash)
Gypsum wallboard (GWB) & steel studs[6]	900 SF (@ 5/8")	1629 kg CO_2
Steel beams/studs	16" on center	Included in GWB output
Polymer solid surface (i.e. Corian) countertops[7]	16 SF (@ 0.5" thick)	5.5 kg CO_2
Steel partition walls[8]	~342 SF (20 gauge steel)	239 kg
TOTAL	**2,955 kg (3.0 metric tons) CO_2** **2,720 kg (2.7 metric tons) CO_2 (25% flyash)** **1,873 kg (1.9 metric tons) CO_2 (no concrete)**	

[5] Inventory of Carbon & Energy (ICE), Version 1.6a. Prof. Geoff Hammond & Craig Jones, Sustainable Energy Research Team (SERT); Department of Mechanical Engineering. University of Bath, UK. http://perigordvacance.typepad.com/files/inventoryofcarbonandenergy.pdf

[6] Buildings Energy Data Book: 1.6 Embodied Energy of Building Assemblies. March 2012. Generated using Athena Institute EcoCalculator for Assemblies. http://buildingsdatabook.eren.doe.gov/docs/xls_pdf/1.6.6.pdf

[7] 2010 Concrete Technology Forum, National Ready Mixed Concrete Association. http://www.concretetechnologyforum.org/2010cscproceedings/documents/Gentry%20Presentation%204-14-10.pdf

[8] Steel weight from cableorganizer.com Learning Center: http://www.cableorganizer.com/articles/gauge-metal-sheet.html. Emissions data from CA Air Resources Board: http://www.arb.ca.gov/cc/protocols/localgov/pubs/recycling_method.pdf.

Note: The cost and materials GHG emissions information can both be revised to estimate impact from construction of just one unisex facility, instead of two separated. One facility is estimated at approximately ***75 percent*** of the both total costs and total emissions provided here.

Operations & Maintenance Impacts

Some long-term operations and maintenance (O&M) demands from installing end of trip facilities can have a measurable impact; we estimated GHG emissions from increased energy use[9] – demand that would not exist in the absence of these facilities. This includes increased hot water demand for showers, an exhaust fan to vent steam, and room-specific lighting needs. We also estimated the net increase in building water use, at approximately **113 gallons per day**. It is worth noting that most bike commuters will utilize end of trip shower facilities instead of – rather than in addition to – showering at home, so there is likely no net increase in hot water use at the community scale.

We did not include emissions estimates for any systems or maintenance processes for which demand is unlikely to go up as a result of providing these facilities. Systems and impacts not analyzed include:

- Sink and toilet water use, which is simply displacing use somewhere else in the building;
- Provision and treatment of water to the building, and moving water within the building. These would already be necessary, and would not require a larger system just from adding these facilities;
- Energy for conditioning or ventilating the space, for the same reason as above – these facilities would not increase the existing system size or demand;
- Materials replacement: the major materials analyzed in this report should last for the lifetime of the building; most replacement would be done on finishes and sealants, which were not analyzed[10];
- Fugitive emissions from sealants and finishes were likewise not analyzed;
- Ongoing maintenance: regular maintenance is not likely to require any greater use of GHG producing substances or practices than would already be required by the needs of the space were it in another use.

The estimated annual GHG impacts of the systems analyzed are as follows:

Material	Amount	GHG (kg CO_2e)
Hot Water[11]	113 gallons/day	1293 kg CO_2e
Exhaust Fan[12]	21 kWh/year	4.6 kg CO_2e
Lighting[13]		
Shower facilities	450 kWh/year	99 kg CO_2e
Lobby	650 kWh/year	143 kg CO_2e
Storage	150 kWh/year	33 kg CO_2e
TOTAL	**1396 kg (1.40 metric tons) CO_2 (Shower facilities)** **1440 kg (1.44 metric tons) CO_2 (Lobby)** **1330 kg (1.33 metric tons) CO_2 (Storage)**	

[9] GHG emissions are based on electricity use, at 0.22 kg CO_2e/kWh, as per the *2008 King County GHG Emissions Inventory*. http://your.kingcounty.gov/dnrp/library/dnrp-directors-office/climate/2008-emissions-inventory/ghg-inventory-summary.pdf

[10] It is certainly possible that the facilities would be remodeled; however estimating that likelihood is beyond the scope of this research.

[11] Assuming 5 minutes showers (LEED standard) and all 20 commuters taking showers every day (while the latter is probably unrealistic, it provides the largest possible water use estimate).

[12] Assumes fan is on 10 hours per day, eight hours on default 'low' setting, and two hours per day on 'high' setting (while showers are in use).

[13] Presumably, in the absence of these facilities, the square footage would simply be used for another purpose. For purposes of comparison, this analysis selected either more lobby space, or more storage space. Therefore lighting values reflect the lighting levels (as per ASHRAE 90.1 standards) of these three potential uses for the space.

Far and away the most significant GHG impact of providing these facilities is the increase in hot water use; more specifically the energy required to heat the water. Of an estimated annual O&M emissions impact of 1.4 metric tons CO_2e, hot water represents 1.3 metric tons, or 93 percent. The impacts of the exhaust fan and the lighting are negligible, and the lighting may even be a lower energy use than if the space were simply part of a larger lobby.

GHG Emissions Benefits from Mode Shift to Bicycle

Using the baseline assumptions below to calculate the total GHG emissions benefit from bicycle commuting instead of automobile commuting, the result was a net reduction of over **22 metric tons** of CO_2 per year. This is based on a calculation that 20 people driving 10 miles per day burn roughly 2,500 gallons of gas per year in their commute to work.

Baseline assumptions

Total annual GHG emissions from automobile commute in King County assumes the following:

Fleet average (US)	20 MPG
Total daily commute distance (KC)[14]	10 Miles
GHG emissions per gallon of gasoline	20 lbs
Number of vehicles replaced by mode switch	20
Annual workdays	250

The emissions reduction from bicycle commuting is 5-7 times greater than the impacts from the materials and operations, which range from **3.3 to 4.4 metric tons** of CO_2 per year. Even though not all impacts were measured, it is unlikely that the total emissions from constructing these facilities would even come close to the projected savings from lower automobile use. The net benefit of building these facilities would appear to far outweigh the impacts, from a GHG emissions perspective.

Impacts of End of Trip Facilities on Commute Mode

Finally, although it is slightly outside the scope of this research, it is a worthwhile follow-up inquiry to ask to what extent building end of trip facilities impacts the decision to commute by bicycle. Reviewing some of the existing research suggests that there is a statistically significantly increase in willingness to commute via bicycle when end-of trip facilities are provided. Although the data is old, the first FHWA *National Bicycling and Walking Study* found that of **active cyclists**, 15 percent of respondents in Seattle (12 percent in Portland) chose not to commute by bicycle due to "Lack of facilities". This was greater than any other reason given except danger or distance.[15] A 2007 study, *Factors Influencing the Propensity to Cycle to Work*, estimated that end of use facilities, combined with bicycle parking, increased bike commuting by 22 percent.[16] Finally, the Sacramento Air Quality Management District, in their rules for providing bicycle facilities as part of a Transportation Demand Management Strategy, allots equal weight to four components of bicycle commuting: Short-term Parking, Long-term Parking, End of Trip Facilities, and Proximity to Bike-specific Infrastructure (e.g. bike paths).[17] It is reasonable to assume that all four of these components complement each other in encouraging bicycle commuting.

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[14] Note that while the average auto commute distance in King County is closer to 20 miles round trip, we held the number the same as the distance for bicycle commuters. This reflects an assumption that people living closer to work are more likely to commute by bicycle, as well as maintaining the 1-for-1 commute mode replacement.

[15] FHWA; *National Bicycling and Walking Study*. 1994. http://ntl.bts.gov/lib/6000/6300/6341/CASE1.pdf

[16] Wardman et al. *Factors Influencing the Propensity to Cycle to Work*. 2007. http://eprints.whiterose.ac.uk/2448/1/ITS2119-actors_infl_to_cycle_uploadable.pdf. Cited in Pucher et al. *Infrastructure, programs, and policies to increase bicycling: An international review*. 2009. http://policy.rutgers.edu/faculty/pucher/pucher_dill_handy10.pdf#bib216

[17] http://www.airquality.org/climatechange/AQMDGuidanceForGHGReduction.pdf