

## MEMORANDUM

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To: Vicky Diede, City of Portland Office of Transportation  
Rick Gustafson, Shiels Obletz Johnsen

From: Eric Hovee

Subject: Portland Streetcar Economic Impacts – First Phase  
Carbon Footprint Benefits Modeling (Revised Draft)

Date: February 4, 2008

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This memorandum outlines and illustrates a methodology for modeling prospective benefits of reduced carbon emissions associated with Portland Streetcar as a form of *development oriented transit*. Topics covered by this first phase research and modeling process are:<sup>1</sup>

Summary Highlights	Carbon Footprint Methodology
Approach to Carbon Footprint Modeling	Illustrative Application
Background Review	Next Steps

*Appendix A* summarizes consultant-related experience. *Appendix B* covers project contacts and reference listing. *Appendix C* contains detailed illustrative model worksheets. In response to comments received in review of a preliminary draft of September 28, 2007, this memorandum serves as a *revised draft*, subject to further refinement based on added input received.

### SUMMARY HIGHLIGHTS

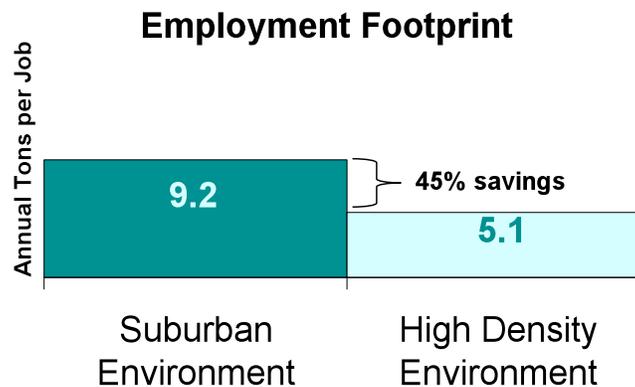
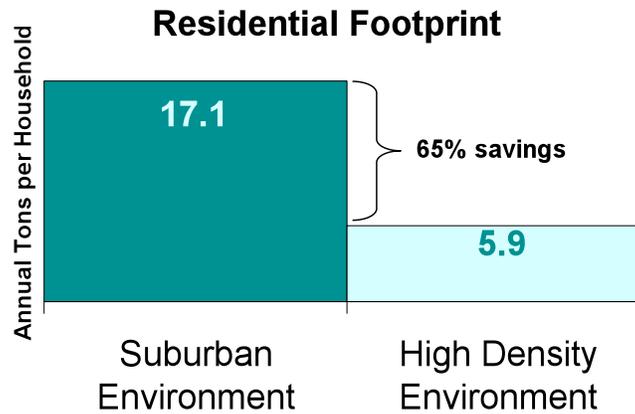
The modeling process outlined in this report illustrates carbon emissions associated with proposed extension of Portland Streetcar east of the Willamette River, distinguished between:

- *Transportation Footprint* – comparing increased use of non-auto modes and reduced vehicle miles traveled (VMT) with high density urban versus suburban development.
- *Development Footprint* – estimated separately for residential and employment uses potentially incited by extension of streetcar service to the east side of the Willamette.

An *illustrative example* provided with this initial modeling process indicates potential for a 60% overall savings in *carbon footprint* with high density urban development compared to a suburban alternative. This reflects a 76% savings in transportation and 46% in development footprint.

When viewed relative to *type of development*, the savings amounts to a 65% reduction in residential carbon footprint – covering both the transportation and development components of the residential use. With employment, a 45% reduction in carbon footprint is identified

## High Density / Suburban Carbon Footprint Comparisons



Source: E. D. Hovee & Company, LLC.

On a *per household* basis, the residential footprint goes from an estimated 17.1 tons of carbon dioxide (CO<sub>2</sub>) for each household in a suburban environment to 5.9 tons in a high density urban setting.

On a *per job* basis, the employment footprint goes from 9.2 annual tons of CO<sub>2</sub> for each employee in a typical suburban location to 5.1 tons in a higher density urban employment environment.

This summary illustrates a land use based approach taken throughout this benefits modeling process. The intent is to compare a suburban *base case* with low density, single purpose development and limited transit service (as a default alternative) vis-à-vis an urban high density option predicated on achieving good transit service and mixed use.

## APPROACH TO CARBON FOOTPRINT MODELING

This memorandum represents an initial attempt to bring together transportation and land use/development modeling to form a broad *landscape view* of reductions in carbon footprint achievable with urban versus suburban development. The organizing impetus for what can be termed *development oriented transit* is the reintroduction of streetcar service – which has proved itself as a major catalyst for increased density of urban development in Portland.

The *primary objective* addressed by this modeling process is to determine the effect that the streetcar-development linkage can have in reducing the carbon footprint associated with what has been the norm of suburban sprawl – both in this region and elsewhere. To address this objective, key steps taken with *first phase* carbon footprint research and modeling have included:

- Review of literature pertinent to carbon and greenhouse gas (GHG) modeling associated with transportation and development together with identification of data sources applicable in a streetcar-development context.
- Contacts with individuals knowledgeable and active in transportation, development and sustainability in the Portland metro area.
- Utilization of readily available information and projections made regarding streetcar in Portland (as for added development and auto travel reduction) together with industry sources for carbon footprint calculations typically associated with transportation and real estate development both locally and nationally.
- Illustrative application of development, transportation and carbon emission data to projections associated with eastside extension of streetcar service in Portland to form a Portland Streetcar Loop as currently planned.
- Characterization and quantification of potential carbon footprint savings resulting from urban development with *good transit and mixed use* versus an equivalent amount of suburban development in an environment offering limited transit and single purpose use.
- Circulation of a preliminary draft analysis for review with agencies and organizations actively involved with streetcar development and carbon footprint analysis – both locally and outside the Portland metro area.
- Revisions to address questions and suggestions received (with this *revised draft* memorandum).

The approach taken with this first phase of carbon footprint benefits modeling is intended to be *illustrative* rather than definitive in nature. The goal of this memorandum is to outline a possible framework for evaluating a transit-development investment strategy from a carbon perspective.

The modeling process outlined is based on readily available *off-the-shelf* information, including data from recognized carbon calculators. Methodology and data refinements can be expected as this framework is tested in a real world setting – whether in Portland or with other federally funded *Small Starts* streetcar and related circulator projects elsewhere in the U.S.

## BACKGROUND REVIEW

In Portland, as is increasingly the case throughout the U.S. and globally, there is growing impetus to understand and address the implications of carbon and greenhouse gases (GHGs) for a return to resource use and environmental sustainability. There is considerable documentation of alternatives for green development with standards such as Leadership in Energy and Environmental Design (or LEED) certification. The primary focus to date has been on site specific building design – although broader neighborhood standards (as with LEED-ND) are now coming into play.

Similar initiatives are occurring with transportation system planning to understand the relationship between such factors as auto usage, vehicle miles traveled, alternative modes and resulting carbon emission effects. These two lines of analysis are brought together with this research report – to outline an initial approach to understanding the transportation and economic development effects public transportation investment (as with streetcar) can have on reduced carbon footprint.

We begin this discussion with a review of pertinent background research including methodologies and data sources important to carbon footprint in both a transportation and development context. A more detailed description of carbon footprint methodological considerations related to streetcar system planning then follows this background review.

**Definitions.** A complete accounting of *carbon footprint* ideally represents the total amount of carbon dioxide (CO<sub>2</sub>) and related greenhouse gases emitted over the full life cycle of a product or service – as with transportation and real estate development.<sup>2</sup> For purposes of this report, the term *carbon neutral* refers to the objective of assuring that carbon released as a result of transportation or development activity is offset by reductions in carbon emissions from on- and off-site sources.<sup>3</sup>

Added residential and employment development within an area served by streetcar further enhances transit ridership, eliminating trips by auto and reducing vehicle miles traveled (VMT). Combining more intense development and VMT reduction also can serve to reduce net carbon footprint, especially when comparing the streetcar incentive to compact urban form versus the suburban alternative of low density development and higher auto usage.

**Portland Context.** Previous economic analysis has documented the remarkable impact that the streetcar has had on stimulating more intense urban development along and near streetcar corridors in Portland. Sites within just one block of streetcar now capture the majority of new development through downtown neighborhoods, versus less than 20% pre-streetcar.

The current Portland Streetcar alignment now extends on the westside from NW 23<sup>rd</sup> Street through the Pearl District to the West End of downtown Portland to the University District and, most recently, to the South Waterfront. Streetcar extension is proposed to the east side of the Willamette River, creating a complete streetcar loop encompassing the entire Central City area.

As has occurred west of the Willamette, eastside extension is expected to occur in conjunction with substantial redevelopment of residential and commercial/industrial property in the Lloyd and Central Eastside Districts.

**Overview Notes.** Any evaluation of potential carbon footprint benefits associated with Portland Streetcar development should appropriately account for *both transportation and development*-related benefits:

- While a range of greenhouse gases (GHGs) are identified as contributing to global warming, the overall GHG footprint is commonly expressed in *carbon dioxide (CO<sub>2</sub>e) equivalent* units.<sup>4</sup>
- Within *Multnomah County*, transportation accounts for an estimated 40% of carbon emissions. Total annual per capita carbon emissions are just over 14 metric tons CO<sub>2</sub>e.<sup>5</sup>
- Transportation accounts for a substantial (27%) share of the *nation's carbon footprint*; an even greater 48% of U.S. energy consumption is associated with buildings.<sup>6</sup>
- Nationally, the personal footprint of the typical U.S. resident has been estimated at approximately 10 tons of CO<sub>2</sub> equivalent per year. Including activities beyond personal (or household and transport) control, *total U.S. CO<sub>2</sub> equivalent emissions* annually equate to more than 20 tons per capita.<sup>7</sup>
- A concept gaining currency as an objective of the sustainable development movement is for *carbon neutral* – predicated on the concept that investments in human activity that create carbon emissions should be offset by carbon footprint reductions on- or off-site.<sup>8</sup>

From a methodological perspective, an issue critical to determining carbon footprint benefits is the creation of an *emissions baseline*, identifying the emissions that would have occurred in the absence of a transportation or development project. A credible approach is important to avoid an inflated baseline – the risk of suggesting that a specific project is yielding more offsets than is actually supportable.<sup>9</sup>

**Transportation Footprint.** Portland has encountered great success with the synergy created between transportation investments in streetcar and mixed use development. A 2005 impact study demonstrates that the Portland Streetcar has served to facilitate substantial investment along this transit corridor. Properties within one block of the streetcar are attracting the majority share of development in downtown Portland. Blocks closest to the streetcar corridor alignment also are realizing greatly increased density of construction.<sup>10</sup>

This combination of transit investment and associated development yields a related benefit – reduction in auto use, length of auto trips when taken, and resulting reduction in vehicle miles traveled (VMT). Reduced VMT offers substantial benefits for reduced carbon footprint.

*VMT Savings with Residential-Oriented Transit:*

- With its early 2006 application for funding of the Portland Streetcar Loop (extending to the eastside), the City of Portland provided an exhibit labeled *Template 14 – Economic Development Information and Supporting Documentation*. This template documented differences in non-auto mode share by transit orientation of land use type, based on Metro Travel Survey data. As depicted by the following chart, per capita daily VMT is approximately 55% less in a *good transit/mixed use* environment than in the remainder of the region (without good transit or mixed use development).

### Transportation Mode Share by Transit & Land Use Characteristics

Land Use Type	Mode Share (As % of Total)					Vehicle Miles per Day per Capita	Auto Ownership per household
	Auto	Walk	Transit	Bike	Other		
Good Transit/Mixed Use	58.1%	27.0%	11.5%	1.9%	1.5%	9.80	0.93
Good Transit Only	74.4%	15.2%	7.9%	1.4%	1.1%	12.38	1.50
Remainder of Multnomah County	81.5%	9.7%	3.5%	1.6%	3.7%	17.34	1.74
Remainder of Region	87.3%	6.1%	1.2%	0.8%	4.6%	21.79	1.93

Source: Metro 1994 Travel Survey

- Differential mode share data can be combined with associated *savings in vehicle miles traveled (VMT)* for added residential development in a high density environment (facilitated by streetcar investment) versus suburban environment. For the close-in eastside area, this is predicated on an added 3,432 residential units stimulated by streetcar – a figure that is above and beyond baseline development previously forecast by Metro.<sup>11</sup>
- In addition to the estimated 55% VMT reduction associated with higher density urban development facilitated by streetcar, *land required for urban development* is also 10 times less than the suburban alternative.
- Reduced VMT occurs as a result of reduced use of single occupancy vehicle trips, referred to as *the trip not taken*. Short distance transit (with streetcar) together with biking and walking become preferred modes when desired services are in close proximity to a place of residence (or work).
- In summary, the Metro *Travel Survey* data (as cited by Template 14) provides key transportation-related data and assumptions pertinent to the assessment of transportation-related carbon footprint benefits with this follow-on streetcar-related modeling process.<sup>12</sup>

#### *VMT Reductions with Employment-Oriented Transit:*

- While much of the streetcar-related forecast work has focused on the benefits of reduced VMT from urban versus suburban residential density, a similar case can be made for more urban *employment density*. Metro has forecast employment growth for eastside transportation analysis zones of an added 10,806 jobs (over the 2005-2025 time period).

- A *with-streetcar* added jobs projection has not been made to date because of methodology limitations in the Metro employment forecast.<sup>13</sup> However, more recent analysis conducted for the Central Eastside Industrial Area (a portion of the eastside excluding the Lloyd District) does begin to quantify added job potential with streetcar – including up to 18% more building rehabilitation and 45% more new construction within the Central Eastside Urban Renewal Area.<sup>14</sup>

*VMT Relationship to Carbon Footprint Savings:*

- A *Streetcar Circulator Initiative* has been recently drafted as a proposal for the federal government to select six demonstration cities across the U.S. for construction of streetcar circulators – based on ability to address criteria for development potential, greenhouse gas reduction, trip reduction, and counteraction of urban sprawl.  
With respect to greenhouse gases, the initiative proposal is that sponsors demonstrate a reduction in emissions based on projected higher density development along the streetcar corridor. This initiative provides additional impetus to the need to establish a conceptual framework for required carbon footprint benefits modeling.
- Various purveyors of carbon offsets offer *carbon calculators* suitable to estimate the carbon footprint associated with personal automobile use. Some calculators estimate carbon emissions using simplified factors such as car size, fuel efficiency and vehicle miles driven.<sup>15</sup>

For this analysis, the personal carbon calculator selected estimates annual carbon footprint based on factors of typical car size and vehicle miles traveled (VMT) per year. This approach coincides with VMT analysis provided for the eastside streetcar (to complete the Portland Streetcar Loop) as previously prepared with the initial Template 14 economic analysis.

**Development Footprint.** There are two components to the carbon footprint associated with the built environment:

- *Construction carbon* is also termed as embodied carbon – released when a building is constructed. This takes into account the manufacture, shipment and installation of building materials.
- *Operational carbon* is the carbon released annually to keep a building operating – as for heating, cooling, running electrical appliances, etc.

Construction carbon release is generally viewed as a one-time event in the economic and physical life of a site-specific real estate development project. However, from a district-wide (or regional) perspective, development can be assumed to occur on an incremental basis. The ultimate development build-out and later redevelopment/renewal can be expected to be phased in over a number of years.

For purposes of district-wide (or streetcar system) analysis, carbon impacts of construction can be converted to annualized equivalents. For example, if the average life of buildings in an urban or suburban environment is 40 years, the average annual equivalent of the construction (or embodied) carbon footprint could be viewed as 1/40<sup>th</sup> of the total carbon release per building project.<sup>16</sup>

Portions of a region with building stock capacity that have a longer average economic and physical life can be associated with a lower annualized carbon footprint. This is often the case for multi-level urban development, for example, if developed with green design standards emphasizing long-term sustainability.

A wide variety of approaches are currently advocated by various proponents of moving toward *carbon-neutral* development. *The Leadership in Energy and Environmental Design* (LEED) green rating system is being extended from certification of buildings to include a separate broader rating system for (ND) Neighborhood Development.

The intent of the ND rating system will be to “revitalize existing urban areas, reduce land consumption, reduce auto dependence, promote pedestrian activity, improve air quality, decrease polluted stormwater runoff, and build more livable, sustainable communities for people of all income levels.”<sup>17</sup> The proposed project checklist is organized around four categories of smart location and design, neighborhood pattern and design, green construction and technology, and innovation/design process.

Even more aggressive alternatives to the LEED system are also being pursued. Rather than offering options for design and resulting scoring, one alternative approach is to stipulate minimum thresholds or *prerequisites* necessary for “true sustainability.” This approach is being pursued by Portland’s Cascadia Region Green Building Council with *The Living Building Challenge* – set around 16 prerequisites all of which must be met to comply. Prerequisites relate to site design, energy, materials, water, indoor environmental quality, beauty and inspiration.<sup>18</sup>

As part of *The 2030 Challenge*, Architecture 2030 advocates a starting minimum standard for a 50% reduction in building-related fossil fuel use for new construction and existing buildings, increasing to 100% offsets or carbon-neutral effects for new buildings constructed by 2030. This 2030 Challenge has been adopted by the American Institute for Architects (AIA) and the U.S. Conference of Mayors.

Carbon neutrality (as advocated by Architecture 2030) has been defined to mean that there would be no need for fossil fuels to operate the building. This could be accomplished through a) design and innovation, b) new technology (as for solar, micro wind applications and energy management systems), and c) purchase of green renewable or certified green renewable energy credits (up to 1/5<sup>th</sup> of the total amount).<sup>19</sup>

As a final observation, it is noted that methodologies available for evaluating development footprint can be applied both to residential and employment-related uses. While the focus of

extension of Portland Streetcar, to date, has been on incremental residential development (as experienced on the westside), a similar though less empirically tested case can be made for increased employment opportunity. Both potentials are addressed with the carbon modeling methodology outlined in this first phase report.

**Indirect Footprint.** Indirect carbon and related GHG emissions result from activities of a particular project but from non-project sources owned or controlled by others. The most prominent example is electricity – for which emissions occur at the point where the power is generated rather than at the site of a development or transportation project.

There is general recognition that, while useful to understand, indirect benefits should not be construed as part of the core carbon analysis.<sup>20</sup> Another reason given for the separation of direct and indirect emissions is to ensure that different entities do not double-count the same emissions as indirect emissions – a greater problem for effects beyond the direct control of an individual project sponsor.<sup>21</sup>

A commonly cited indirect benefit of streetcar versus auto use is the opportunity to substitute clean hydropower for petroleum-based energy. *Green power* is often defined as electricity or heat generated from renewable resources, including wind, solar, geothermal, biomass, landfill gas and “certified low-impact hydro.”<sup>22</sup> However, larger scale hydro power is not as widely viewed as carbon neutral – with respect to either embodied energy or operations.<sup>23</sup>

While indirect, the emissions associated with electrical use differ in two important ways from other indirect emissions: a) they are easy to measure; and b) they are fully within the control of the end-user. Also noted is that, while hydropower accounts for an unusually large share of hydropower in the electricity mix of the Pacific Northwest, coal comprises about 40% of the regional mix with natural gas representing another 10-15%.<sup>24</sup> For these reasons, this analysis identifies and estimates the potential reduction in carbon footprint associated with purchase of *green power* for streetcar operation associated with proposed eastside extension.

**Related Regional Planning Activities.** As the regional government agency for the Oregon side of the Portland metropolitan area, Metro is currently involved in planning activities that will enable the region to better understand the carbon footprint implications of varied development and transportation measures. Two initiatives are of particular note:

- While Metro has not previously conducted carbon footprint modeling, the agency has planned to calculate anticipated greenhouse gas effects associated with the current update of the Regional Transportation Plan (RTP) – anticipated for release in early 2008.<sup>25</sup>
- As part of Metro’s *New Look at Regional Choices* to reexamine implementation of the 2040 Growth Concept, Metro is also working to identify or revamp existing funding tools for planning and infrastructure – including system development charges (SDCs). Steps being recommended to make SDCs more supportive of green design include “unbundling” the SDCs to separate cost elements, encouragement of best management practices, green design SDC discounts, and transition to “impact-based” SDCs (such as higher SDCs for

Greenfield than urban development to better accomplish real cost recovery objectives). Other factors that might be involved in differential (or location-based) SDCs could include reduced fees for higher density development with fewer occupants per unit and lower level of service (LOS) standards for urban area infrastructure as for transportation.

It is anticipated that the results of this initial Streetcar Loop footprint benefits modeling approach may subsequently be integrated with more comprehensive carbon modeling of transportation and development investments for the entire Portland metro region.

## CARBON FOOTPRINT METHODOLOGY

Based on this initial review, the following methodologies are suggested for purposes of evaluating and quantifying potential carbon benefits associated with eastside streetcar extension. As with the *Template 14* approach, this suggested model is focused on estimating the potential carbon emission savings resulting from high density urban versus lower density suburban development. Savings can be realized from residential and employment-related development.

**Transportation Footprint.** The *transportation-related* carbon footprint can be calculated based on the following factors:

- Annual Vehicle Miles Traveled per Development Unit  
(with units expressed in terms either of households or employees as occupants of commercial or industrial building space)
- CO<sub>2</sub> Emissions per Vehicle Miles Traveled  
(based on type of vehicle and fuel efficiency)
- Resulting CO<sub>2</sub> Emissions per Development Unit
- Number of Development Units  
(households or employees)

With this illustrative model, separate calculations are run for residential and employment-related transportation demands. The carbon footprints associated with both sources are then summed for a combined transportation footprint total.<sup>26</sup> The carbon footprint associated with a suburban development is compared with that of urban high density development – with the difference attributed to a *streetcar-driven* carbon benefit.

It is important to note that the transportation footprint approach taken with this analysis does not fully achieve the complete *life cycle* ideal of carbon accounting. This is because the transportation analysis (at this point) does not include the embodied energy associated with construction and maintenance of roads, streetcar alignments, vehicles and other transportation infrastructure.

Construction for streetcar in an urban high density environment can be expected to involve less embodied carbon impact than construction of added roadway to a similar level of housing and employment development in a low density suburban environment. However, this initial analysis does not attempt to quantify these effects due to the intricacies of the added analysis (and associated assumptions/data required).<sup>27</sup>

This means that the estimates of transportation-related carbon footprint savings achievable with high density development are greater than estimated with this more conservative analysis. Further analysis and projection of transportation construction effects from streetcar versus roadway development is suggested as a future phase refinement of carbon footprint modeling.<sup>28</sup>

**Development Footprint.** The *development-related* carbon footprint is calculated by multiplying the following two factors:

- CO<sub>2</sub> Emissions per Development Unit  
(with units expressed in terms either of households or employees)
- Number of Development Units  
(households or employees)

As noted, development-related carbon involves two distinct sources of carbon footprint – embodied carbon (as a one-time capital stock with construction) and operational carbon (as an ongoing annual source of emissions). For purposes of this initial illustrative analysis, capital stock impacts are translated into an annual average operating equivalent (by assuming an average life to the real estate investment before substantial replacement or renovation – of 40 years for low density suburban and 60 years for multi-level urban development).

As with transportation footprint modeling, separate calculations are also run for residential and employment-related development footprint demands. The carbon footprint from both sources is then summed to arrive at a total development footprint total. The carbon footprint associated with suburban development as experienced in the Portland metro area is compared with that of urban high density development – with the difference attributed to streetcar-induced carbon benefit.

**Indirect Footprint.** As noted, calculations of indirect footprint benefits are not included with initial streetcar-related modeling, with the exception of identifying potential benefits associated with purchase of green power for streetcar operations. Further analysis could address additional indirect footprint effects as appropriate categories of indirect carbon emission can be better characterized and quantified.

## ILLUSTRATIVE APPLICATION

This carbon footprint methodology is applied to the Portland Central City area east of the Willamette River most directly benefited by extension of streetcar service to form a Portland Streetcar Loop. With this illustrative application, carbon benefits are projected based on:

- *An estimated 3,432 added eastside households* – as the incremental development occurring over 20 years following streetcar investment, above and beyond prior Metro projections (assuming a pattern of residential development similar to that experienced post-streetcar on the westside).
- *Hypothetical projection of an added 2,593 streetcar incited jobs* – representing 30% of Metro’s eastside job projections after also discounting for the estimated 20% of workers who would also live in or near the area (based on projections recently completed for the Central Eastside Urban Renewal Area extrapolated to also cover the Lloyd District).<sup>29</sup>

The household projection is consistent with prior development analysis associated with the November 2005 report on *Portland Streetcar Development Impacts*. The employment projection (and associated streetcar projection) is subject to further refinement once a projection is prepared for the Lloyd District similar to analysis conducted for the Central Eastside.

Detailed calculation worksheets are provided with Appendix C to this memorandum. Summary results follow.

**Transportation & Development Footprint Results.** An overview estimate of carbon footprint results with this illustrative example is provided by the following chart. This example indicates potential for a 60% overall reduction in carbon footprint resulting from high density (eastside) development compared with a similar amount of housing and job development in a suburban Portland environment.

**Carbon Footprint Calculator**  
(Illustrative Example - Transportation & Development Footprints)

	Annual Tons of CO <sub>2</sub>		Comments
	High Density Environment	Suburban Environment	
<b>A. Development Assumptions</b>			
Added Households w/Streetcar	3,432	3,432	E.D. Hovee, <i>Portland Streetcar Development Impacts</i> , 2005
Added Employment w/Streetcar	2,593	2,593	E. D. Hovee hypothetical estimate, subject to further refinement
<b>B. Transportation Footprint</b>			
Residential Component	5,163	21,582	Metro 2004 <i>Travel Survey</i> & Climate Trust carbon calculator
Employment Component	3,902	16,309	Metro 2004 <i>Travel Survey</i> & Climate Trust carbon calculator
Subtotal Transportation Footprint	9,065	37,891	
Annualized High Density Savings	28,826		
% High Density Savings	76%		
<b>C. Development Footprint</b>			
Residential Component	15,201	37,234	Assumes concrete urban construction, wood frame suburban
Employment Component	9,268	7,853	High density premium for structured/below grade parking
Subtotal Development Footprint	24,469	45,087	Annualized sum of construction + operational carbon
Annualized High Density Savings	20,618		Mithun construction & Climate Trust operational calculators
% High Density Savings	46%		Added savings possible with high density <i>green design</i>
<b>D. Combined Footprint</b>			
Residential Component	20,364	58,817	Includes adjustment for urban vs suburban household size
Employment Component	13,170	24,162	Impacts for workers are live eastside are w/residential line item
Total Eastside/Streetcar Footprint	33,534	82,978	Refinements suggested for jobs increment w/streetcar
Annualized High Density Savings	49,444		Savings are benchmarked to suburban alternative
% High Density Savings	60%		

Note: Carbon footprint modeling calculations are for illustrative purposes only  
Estimates are preliminary and subject to revision  
Source: E. D. Hovee & Company, LLC  
Date: 4-Feb-08

Carbon savings are greatest with the *transportation component* of the total footprint – yielding a potential carbon reduction in the range of as much as 76%. Transportation savings are the combined result of higher non-auto mode split and associated reduction in vehicle miles traveled (VMT) – consistent with the Metro defined land use type of *good transit/mixed use*.

*Development footprint* savings are not as great – but a still substantial 46% reduction in carbon:

- *Residential* savings are attributed, in part, to the smaller typical size of urban households combined with smaller unit size.<sup>30</sup> On a per household basis, residential savings is estimated at 65%. This is adjusted to a 35% savings if considered on a per capita basis. Urban residential development is somewhat handicapped by concrete or steel-frame construction which has a higher embodied (or construction) carbon content than wood frame, single family suburban construction.<sup>31</sup> However, this can be offset by less site area disturbance coupled with the opportunity for longer lifespan of a multi-level high density urban structure versus shorter lifespan of a considerable portion of suburban structures – especially if developed to green (such as LEED) standards.
- The *employment* component of development footprint appears to offer a somewhat smaller advantage for urban development compared to the suburban prototype due in part to need for structured rather than surface lot parking to accommodate the same amount of employment space in an urban setting. Both initially and more so over time, the urban

disadvantage associated with site excavation (as for underground parking) can be reduced with lower parking ratios than for suburban development, as is assumed for this analysis. This materials-related *carbon price* for urban development can also be offset by extra impetus for green (e.g. LEED) development in an urban versus suburban setting – including opportunities ranging from district-wide heating and cooling systems to creating lasting structures with greater physical and economic longevity.

It is noted that the 60% reduction in carbon footprint associated with development in a high density versus suburban environment identified with this *revised draft* assessment is greater than the estimated 41% savings calculated with the initial draft run of September 28, 2007. As was described with the earlier draft, this greater savings is achieved by adjusting two key assumptions with this updated analysis: a) revising household size assumptions to better reflect smaller households typically associated with high density urban versus a lower density suburban environment (rather than applying the same average household size factor in both urban and suburban settings); and b) utilizing a 60-year average life span for construction with multi-level urban development versus 40-year life span with low-rise suburban development.

**Residential & Employment Footprints.** As an alternative to depicting savings organized by transportation and development footprint classifications, another way of portraying this information is to organize the data by residential and employment land use types.

**Carbon Footprint Calculator**  
(Illustrative Example - Residential & Employment Footprints)

	High Density Environment	Suburban Environment
<b>A. Residential Footprint</b>		
Annual Tons of CO <sub>2</sub> per Household	5.9	17.1
Annualized Per Household Savings	11.2	
Added Number of Eastside Households*	3,432	3,432
Annual Tons of CO <sub>2</sub>	20,364	58,817
Annualized High Density Savings	38,452	
% High Density Savings	65%	
<b>B. Employment Footprint</b>		
Annual Tons of CO <sub>2</sub> per Job	5.1	9.2
Annualized Per Job Savings	4.1	
Added Number of Eastside Jobs*	2,593	2,593
Annual Tons of CO <sub>2</sub>	13,170	24,162
Annual High Density Savings	10,992	
% High Density Savings	45%	
<b>C. Combined Footprint</b>		
Annual Tons of CO <sub>2</sub>	33,534	82,978
Annual High Density Savings	49,444	
% High Density Savings	60%	

\* Note: Added # assumed for streetcar  
For illustrative purposes only  
Source: E. D. Hovee & Company, LLC  
Date: 4-Feb-08

As is illustrated by the foregoing chart, this format rolls the transportation and development components of carbon footprint together under the major classifications of residential and employment footprint.

Residential use accounts for the majority (over 70%) of the combined base case (suburban) footprint. Employment use accounts for just under the remaining 30%.

Residential footprint savings associated with urban development also appear to be greater than is available for employment uses – in both absolute numerical as well as percentage terms. The potential reduction in carbon footprint indicated is 65% for residential (combining both transportation and development effects) and 45% for employment uses. As noted, the savings potentially associated with employment use can be substantially increased with a focus on green design with urban commercial and industrial-service development.

**Added Benefit of Green Streetcar Operation.** As with light rail (LRT), streetcars run on electric power while Portland’s bus system is reliant on fossil fuels. This means that streetcar technology will produce virtually no direct CO<sub>2</sub> although indirect emissions effects may be

associated with the purchase of off-site electric power. Because the Portland Streetcar Loop essentially represents net new service, no specific effects on existing bus service are anticipated.<sup>32</sup>

Of interest to Portland Streetcar, Inc. is the potential benefit of purchasing green power versus power from the grid with a combined hydro-petrochemical fuel source. Based on data from the draft Environmental Assessment for the streetcar loop project, the carbon-equivalent footprint suggested by purchasing electric power from conventional sources is estimated at 413 tons per year. By purchasing from green sources, this added off-site emission effect could be avoided.

**Carbon Footprint Calculator**  
(Illustrative Example - Streetcar Green Energy Effect)

Green Energy		
	Calculations	Comments
<b>A. Streetcar Energy Use</b>		
Weekday Streetcar VMT	1,389	<i>Portland Streetcar Loop Project EA, September 2007</i>
Annual Energy Consumption (kWh)	988,620	<i>Portland Streetcar Loop Project EA, September 2007</i>
Carbon Footprint (per kWh)	0.000418	<a href="http://www.begreennow.com/calculator">www.begreennow.com/calculator</a>
Streetcar Footprint (metric tons/year)	413	Calculator is from Green Mountain Energy, partner w/PGE 2002
<b>B. Added Savings w/Green Energy</b>		
Suburban Annual Carbon Footprint	82,978	Base level carbon footprint suburban development
Urban Savings over Suburban Base	(49,444)	From prior calculations
Added Green Energy Savings	(413)	Resulting from streetcar green energy purchase
Adjusted Urban Carbon Footprint	33,121	
<b>C. Percentage Savings</b>		
Urban Savings over Suburban Base	59.6%	
Added Green Energy Savings	0.5%	
Combined Footprint Reduction	60.1%	

Note: Carbon footprint modeling calculations are for illustrative purposes only  
Estimates are preliminary and subject to revision  
Source: E. D. Hovee & Company, LLC  
Date: 4-Feb-08

When viewed in the context of other carbon footprint reductions achievable with reduced VMT and more efficient development, the purchase of green energy for streetcar appears to be a relatively small fraction of the total savings achievable. In effect, the added savings associated with green energy procurement is estimated at 0.5% compared to the suburban alternative.

While green energy purchase for streetcar operation, by itself, does not yield a major added carbon footprint savings, this initiative may be viewed as more important for its symbolic value – as an icon for Portland’s commitment to a more sustainable city and region.

## NEXT STEPS

Results of this first phase research assessment demonstrates that the methodologies and data exist to estimate *carbon footprints* associated with the transportation and development components of residential and employment based activity – in high density urban versus lower density suburban contexts. In effect, carbon footprint savings can be illustrated for development-

oriented transit on a district- or corridor-wide planning basis as well as for individual building or development projects.

Subsequent phase refinements suggested from this initial analysis include:

1. Continued review and refinement of this initial transportation and development *modeling methodology, data and assumptions* by local/regional planning and transportation agencies – together with outside reviewers offering added carbon footprint/offset experience and expertise.
2. Refinement of *with and without streetcar* development potentials – with particular focus on refined employment scenarios as are currently being prepared for the Lloyd District as part of the proposed planned eastside streetcar loop extension.
3. Determination of how to further strengthen and implement the *with streetcar advantage* predicated on a higher level of green design and resulting environmental performance – as a sustainable urban advantage over comparable suburban development standards – as is outlined with this modeling process.<sup>33</sup>
4. Resulting second phase carbon modeling refinements and Portland *streetcar benefits modeling finalization* – including prospective utilization with the Portland Streetcar System Plan (PSSP) process underway and nationally as with a proposed nationwide Streetcar Circulator Initiative.

E. D. Hovee & Company, LLC appreciates the opportunity to conduct carbon benefits modeling – as integral to assessing Portland Streetcar impacts from both economic and environmental perspectives. As with the earlier initial draft memorandum of September 2007, questions and suggestions regarding any aspect of this updated first phase modeling research and application are welcome.

## APPENDIX A. CONSULTANT BACKGROUND

E. D. Hovee & Company, LLC has served public, non-profit and private development clients both in and outside the Pacific Northwest since 1984. The firm has considerable experience in evaluating the nexus between transit and economic development.

Within the Portland metro area, E. D. Hovee & Company has conducted numerous transit-economic development assessments including:

- Central Eastside URA development projections with and without streetcar for the Portland Development Commission (2007).
- Portland Streetcar development impact analysis for Portland Streetcar Inc. (2005) – quantifying the impacts of streetcar investment for development in the Downtown, Pearl, University and South Waterfront districts of Portland’s westside.
- Analysis of projected economic development benefits associated with extension of service to the eastside with the proposed Portland Streetcar Loop.
- Evaluation of effects on business and property values of Portland Transit Mall refurbishment and light rail extension – including both long-term valuation and shorter term construction impact assessments (2004-2005).

Both in and outside Portland’s Central City, E. D. Hovee & Company, LLC has been involved in a wide range of transit and economic development assessments including light rail impact and station area planning (east, north, west and south MAX/LRT corridors), associated smaller city development (at Gresham and Hillsboro LRT termini). Central City development assessments have been conducted in the Pearl, Old Town, Downtown core, West End, University, South Waterfront, Lloyd and Central Eastside Districts over the last 20+ years.

Outside the Portland metro area, E. D. Hovee & Company, LLC has experience with urban redevelopment throughout the U.S. on behalf of cities, private firms and non-profit organizations such as the National Main Street Center and National Trust for Historic Preservation. The firm has conducted transit-economic development assignments in communities as diverse as West Orange (NJ), Santa Cruz (CA), SeaTac (WA), and Ketchikan (AK).

In recent years, the firm has become increasingly involved with green development and sustainability spanning both rural and urban settings. For the non-profit Oregon Forest Resources Institute, E. D. Hovee has evaluated opportunities for a reconfigured statewide forest cluster – embracing rapidly emerging opportunities for green design, alternative forest health/management regimes, biomass utilization and nanotechnology for sustainability and renewed market leadership.

Currently, the firm is engaged in planning and economic development assessment for prospective long-term extension of streetcar service city-wide – as part of the Portland Streetcar System Plan.

## APPENDIX B. PROJECT CONTACTS & REFERENCE LISTING

**Project Contacts & Reviewers.** In preparing this carbon footprint methodology, E. D. Hovee & Company, LLC has made an initial set of research contacts followed by review of a first draft (September 28, 2007) carbon benefits modeling report. Individuals contacted have included:

### *Research Contacts:*

- Clark Brockman, SERA Architects
- Christina Deffebach, Metro
- Eric Hesse, Tri-Met
- James Irish, Sound Transit
- Kyung-Hwa Kim, Metro
- Patrick Sweeney, City of Portland Department of Transportation
- Mark Turpel, Metro

### *Carbon Footprint Methodology Reviewers:*

- Michael Armstrong, City of Portland Office of Sustainable Development
- Scott Bernstein, Center for Neighborhood Technologies
- Clark Brockman, SERA Architects
- Sean Cryan, Mithun Architects
- Sean Penrith, Earth Advantage

Information provided by the initial research contacts proved instrumental, especially regarding pertinent local planning initiatives and suggestions regarding project resource materials. While the project approach methodology used with this analysis did not change appreciably as a result of first draft review, comments provided are incorporated with this updated draft document.

**References Reviewed.** What follows are references reviewed in conjunction with this assessment first phase assessment for carbon footprint benefits modeling:

Architecture 2030 ([www.architecture2030.org](http://www.architecture2030.org)), The 2030 Challenge (powerpoint), 2006-2007.

BuildCarbonNeutral.org ([www.buildcarbonneutral.org](http://www.buildcarbonneutral.org)), *Construction Carbon Calculator*, 2007.

Cascadia Region Green Building Council, *The Living Building Challenge User's Guide*, Draft Version 1.2, April 2007.\*

City of Portland, Office of Sustainable Development and Portland Development Commission, *Economic Development Opportunities for Portland's Green Building Industry*, October 2007.\*

Climate Care ([www.climatecare.org](http://www.climatecare.org)), Car Calculator, 2007.

The Climate Trust, ([www.carboncounter.org](http://www.carboncounter.org)), individual and business carbon calculators, 2006.\*

Clean Air-Cool Planet, *A Consumer's Guide to Carbon Offset Providers*, 2006.\*

E. D. Hovee & Company, LLC, *Portland Streetcar Development Impacts*, prepared for Portland Streetcar Inc., November 2005.

E. D. Hovee & Company, LLC, *Central Eastside Development Scenarios DRAFT*, prepared for Portland Development Commission, May 22, 2007.

Metro, *System Development Charges*, prepared by Galardi Consulting in association with Dr. Arthur C. Nelson, Parametrix, and Beery, Elsner, and Hammond, LLP, July 2007.\*

Portland Streetcar Loop Project FY 2008 Evaluation and Rating Process, *TEMPLATE 14 – Economic Development Effects*.\*

*Portland Streetcar Loop Project Environmental Assessment*, prepared by FTA, U.S. Department of Transportation in Cooperation with the City of Portland, Metro, Tri-Met, Draft, September 2007.\*

SAIC Energy Solutions Operation (Todd Davis, Monica Hale), *Public Transportation's Contribution to U.S. Greenhouse Gas Reduction*, September 2007.

Shiels Oblatz Johnsen, *Streetcar Circulator Initiative: A Proposal for the Federal Government to Partner with Cities*, August 16, 2007.\*

U.S. Green Building Council, *Pilot Version: LEED for Neighborhood Development Rating System*, updated June 2007.

World Resources Institute, *Hot Climate, Cool Commerce: A Service Sector Guide to Greenhouse Gas Management*, May 2006.

\* Note: Sources indicated with an asterisk (\*) have been prepared by Portland based firms or organizations.

# APPENDIX C . ILLUSTRATIVE MODEL WORKSHEETS

## Carbon Footprint Calculator - Residential Development Module

	High Density Environment	Suburban Environment	Comments
<b>A. Transportation Footprint</b>			
Annual Miles per Household	6,748	15,004	
Tons of CO <sub>2</sub> per Household	1.50	6.29	Climate Trust data assuming average 24 mpg
Annual Per Household Savings	4.78		
Number of Households	3,432	3,432	Added potential w/Eastside streetcar
Annual Tons of CO <sub>2</sub>	5,163	21,582	
Annual High Density Savings	16,419		
<b>B. Residential Unit Footprint</b>			
<i>Embodied Carbon w/ Construction</i>			
Average Unit Size (Sq Ft)	1,200	2,400	Illustrative example for discussion purposes
Life of Structure (Years)	60.0	40.0	Longer life for urban steel/concrete structure
Tons of CO <sub>2</sub> per Household	62.35	95.17	Based on concrete for urban, wood for suburban (dropping to 49 tons/year w/ urban wood frame)
Lifetime Per Household Savings	32.82		
Annualized Tons of CO <sub>2</sub> per Household	1.04	2.38	Based on assumed lifetime of structure
Annualized Household Savings	1.34		
Number of Households	3,432	3,432	Added potential w/Eastside streetcar
Tons of CO <sub>2</sub> with Development	213,985	326,612	Embodied over life of project
Lifetime High Density Savings	112,627		
Annualized Tons of CO <sub>2</sub> per Household	3,566	8,165	Annualized for data comparability
Annualized High Density Savings	4,599		
<i>Operational Carbon</i>			
Tons of CO <sub>2</sub> per Household	3.39	8.47	Climate Trust data @ average apartment size (urban) versus single family (suburban) density
Annual Per Household Savings	5.08		
Number of Households	3,432	3,432	
Annual Tons of CO <sub>2</sub>	11,634	29,069	
Annual High Density Savings	17,435		
<b>C. Combined Footprint</b>			
Annual Tons of CO <sub>2</sub> per Household	5.9	17.1	Residential-driven; work place benefits excluded
Annualized Per Household Savings	11.2		
Number of Households	3,432	3,432	
Annual Tons of CO <sub>2</sub>	20,364	58,817	
Annualized High Density Savings	38,452		
% High Density Savings	65%		

Source: E. D. Hovee & Company, LLC  
Date: 4-Feb-08

## Carbon Footprint Calculator - Employment Module

	High Density Environment	Suburban Environment	Comments
<b>A. Transportation Footprint</b>			
Annual Miles per Employee	6,748	15,004	Similar job footprint as for households per Metro
Tons of CO <sub>2</sub> per Employee	1.50	6.29	Climate Trust data assuming average 24 mpg
Annual Per Job Savings	4.78		
Added Eastside Jobs Forecast	10,806	10,806	Per Metro TAZ forecast, adjusted to 2005-25
% of Jobs Allocated to Streetcar	30%	30%	Based on CEURA analysis, with slight bump-up for Lloyd District; subject to further revision
% of Jobs w/Eastside Residence	20%	20%	Eliminates double counting from residential side
Jobs Allocated to Streetcar	2,593	2,593	The streetcar difference -- hypothetical example
Annual Tons of CO <sub>2</sub>	3,902	16,309	
Annual High Density Savings	12,407		
<b>B. Job Development Footprint</b>			
Assumed Employment Density	400	400	For industrial / commercial development Blend of office, retail, service-industrial per gsf
<b>Embodied Carbon w/ Construction</b>			
Average Building Size (Sq Ft)	100,000	100,000	Per development scenarios for PDC / CEURA
On-Site Employment (per building)	250	250	
Life of Structure (Years)	60.0	40.0	Longer life for urban steel/concrete structure
Tons of CO <sub>2</sub> per Building	6,620	4,680	Mithun assumes new construction, concrete building @ 7 floors urban vs. 2 floors suburban
Tons of CO <sub>2</sub> per Job	26.48	18.72	
Lifetime Per Job Savings	(7.76)		
Annualized Tons of CO <sub>2</sub> per Job	0.441	0.312	Assumes 40 year average life of structure
Number of Jobs	2,593	2,593	Added potential w/Eastside streetcar
Tons of CO <sub>2</sub> with Development	68,674	48,549	Embodied over life of project
Lifetime Eastside Savings	(20,125)		
Annualized Tons of CO <sub>2</sub> per Job	1,145	1,214	Annualized for data comparability
Annual High Density Savings	69		
<b>Operational Carbon</b>			
Tons of CO <sub>2</sub> per 100,000 SF Building	783	640	From Climate Trust calculator, assumes three buildings with suburban example
Tons of CO <sub>2</sub> per Job	3.1	2.6	
Annual Per Job Savings	(0.6)		
Number of Jobs	2,593	2,593	
Annual Tons of CO <sub>2</sub>	8,124	6,639	
Annual High Density Savings	(1,485)		
<b>C. Combined Footprint</b>			
Annual Tons of CO <sub>2</sub> per Job	5.1	9.2	Jobs module; housing benefit is separate
Annualized Per Job Savings	4.1		
Number of Jobs	2,593	2,593	
Annual Tons of CO <sub>2</sub>	13,170	24,162	
Annual High Density Savings	10,992		
% High Density Savings	45%		

Source: E. D. Hovee & Company, LLC  
Date: 4-Feb-08

## Carbon Footprint Parameters

	High Density Environment	Suburban Environment	Comments
<b>A. Transportation Footprint</b>			
Per Household Miles per Year	6,748	15,004	Per Portland VMT data
Carbon Footprint (Tons/Year)	1.50	6.29	per www.carboncounter.org (Climate Trust - PDX)
Tons/1,000 miles	0.22	0.42	Based on mid-size car average of 24 mpg
Tons/Capita	1.12	2.50	From base calculator
<b>B. Residential Unit Footprint</b>			
Households	3,432	3,432	
Population / Household	1.34	2.52	Based on ESRI 2007 Actuals
Population	4,599	8,649	
<b>Embodied Carbon w/ Construction</b>			
Average Unit Size (Sq Ft)	900	2,400	
Units per Acre	120	12	
Land Area (Sq Ft)	43,560	43,560	
Total Living Sq Ft per Acre	108,000	28,800	Assumes average of six above grade levels
Living SqFt to Gross Building Area	85%	100%	
Gross Building Area	127,059	28,800	Does not include parking in structure
Parking Garage Ratio (per DU)	1.00	2.00	
Garage Parking Sq Ft	350	720	For high density, one below grade level
Total Gross Building Area	169,059	37,440	Use rounded 210,000 sf for high density
Landscaped Area	20,000	22,440	Assume two above levels + bsmt garage
Embodied Carbon Footprint (Tons)	7,482	1,142	per www.BuildCarbonNeutral.org (Mithun)
- Concrete	7,482		Note: data may be conservative for single family
- Steel			
- Mixed			
- Wood		1,142	
Embodied Carbon / Unit (Tons)	62.35	95.17	
<b>Annual Residential Footprint</b>			
<i>(Tons per Year)</i>			
Per Unit (Typical Size)	3.39	8.47	per www.carboncounter.org (Climate Trust - PDX)
Per Unit (Large Size)	5.08	10.16	
<b>C. Employment Footprint</b>			
Building Size (GSF)	100,000	100,000	Urban one building, suburban @ three
Building Size (with parking structure)	150,000	100,000	
Number of Floors (excluding parking)	7	2	
Building Footprint	14,286	50,000	For average floor, extends larger for first two floors
Parking Area	50,000	122,500	1/5 of parking for urban @ grade, 2 below grade flrs
Levels of Parking	2	1	Below grade w/ high density, @ grade for suburban
Spaces per 1,000 GSF	1.4	3.5	
Parking Spaces	143	350	
Area per Parking Space (Sq Ft)	350	350	
Sum of Parking + Footprint	18,000	172,500	Includes up to 10,000 sf parking @ grade level
Landscaped Area	2,000	30,440	15% of suburban site
Total Site Area	20,000	202,940	

Source: E. D. Hovee & Company, LLC  
Date: 4-Feb-08

## END NOTES

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<sup>1</sup> Information for this *first phase* of benefits modeling has been obtained from sources generally deemed to be reliable. However, E. D. Hovee & Company, LLC does not guarantee the accuracy of information obtained from third-party sources. Information is subject to change without notice.

Observations and findings contained in this report are those of the author. They should not be construed as representing the opinion of any other party prior to express approval, whether in whole or part.

<sup>2</sup> While desired, all components of this life cycle definition are not always readily measurable, as for the embodied energy associated with transportation infrastructure. Throughout the duration of this report, carbon footprint is expressed in terms of metric tons of CO<sub>2</sub> equivalents.

<sup>3</sup> There is not yet clear consensus on whether and to what degree “carbon neutral” should include carbon offsets, essentially paying others to remove or sequester CO<sub>2</sub> at off-site locations. This preliminary research assessment takes no specific position on this question.

<sup>4</sup> Greenhouse gases (GHGs) covered by the Kyoto Protocol are carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons and perfluorocarbons.

<sup>5</sup> Multnomah County estimates of carbon emissions are as of 2006, from the City of Portland Office of Sustainable Development. They are very similar to 2004 numbers in an OSD report of June 2005, available at <http://www.portlandonline.com/osd/index.cfm?c=41901&>.

<sup>6</sup> The remaining 25% of the nation’s carbon footprint is accounted for by industry. Data is from U.S. Energy Information Administration Statistics, as cited by Architecture 2030 ([www.architecture2030.org](http://www.architecture2030.org)), The 2030 Challenge (powerpoint), 2006-2007.

Separate analysis published in 2007 by the Urban Land Institute titled *Growing Cooler: The Evidence on Urban Development and Climate Change* includes the finding that “people who move into compact, ‘green neighborhoods’ are making as big a contribution to fighting global warming as those who buy the most efficient hybrid vehicles, but remain in car-dependent areas.”

<sup>7</sup> Per capita carbon footprint data is as cited by Clean Air-Cool Planet, *A Consumer’s Guide to Carbon Offset Providers*, 2006. While not directly addressed as part of this report, it is noted that the price of carbon offsets currently ranges from \$5 - \$25 per ton, averaging about \$10. Quality of offsets can vary widely depending on the retail provider.

<sup>8</sup> The size of the global offset market is estimated at \$30.4 billion as of 2006, according to the Canadian organization Point Carbon – as cited by *The Economist*, “Trading thin air,” June 2, 2007.

<sup>9</sup> One test of an emissions baseline involves the concept of *additionality* – the assurance that a carbon offset would not have happened otherwise. Consistent standards for determination of additionality have not yet been established. Also important is the avoidance of *double counting* – ensuring that each offset or project benefit is only counted once.

<sup>10</sup> See E. D. Hovee & Company, LLC, *Portland Streetcar Development Impacts*, prepared for Portland Streetcar Inc., November 2005.

<sup>11</sup> This estimate of added eastside residential development potentially attributable to streetcar is from E. D. Hovee & Company, LLC, *Portland Streetcar Development Impacts*, prepared for Portland Streetcar, Inc., November 2005.

<sup>12</sup> Discussion with Metro staff indicate some level of ambivalence with applying results from the 1994 *Travel Survey* to both household and employment-related trips. One Metro staff person indicates that land use based tables can apply to trip generators of any type – household or employment. However, another suggests using that a separate Metro data run from an attraction side might generate more reliable data (or verification) for work-based trips associated with commercial or industrial development. Some concern with resulting reliability of VMT estimates is also expressed.

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This is a topic for further discussion with possible second phase refinements to carbon benefits modeling. For this initial model, similar results are assumed for home and work based trips – with both types of trips generated from eastside *good transit/mixed use* locations.

- <sup>13</sup> The E. D. Hovee prepared *Portland Streetcar Development Impacts Report* of November 2005 indicates that a comparison of baseline Metro employment with added streetcar jobs-related development was not readily possible for two primary reasons: a) the Metro TAZ projection did not account for the substantial (45%) portion of the study area's taxlot area within developed industrial sanctuary lots (limiting future redevelopment opportunity), and b) the Metro allocation methodology was based upon allocation a control total rather than derived exclusively from an assessment of developable land capacity.
- <sup>14</sup> This employment-related development potential is documented by E. D. Hovee & Company, LLC, *Central Eastside Development Scenarios DRAFT*, prepared for Portland Development Commission, May 22, 2007.
- <sup>15</sup> Other carbon calculators provide estimates based on more detailed variables such as vehicle type (e.g., car, SUV, truck), engine size, or even make and model of vehicle. In review of a preliminary draft, some concern is expressed with utilization of carbon calculators due to wide variations within or between regions of the U.S. Suggested is a neighborhood (or sub-metro) methodology that involves running a location efficiency model to produce VMT per household coupled with travel demand survey and/or smog check/inspection maintenance at a geographically disaggregated level, then using measured mpg and CO<sub>2</sub> emission factors from a source such as the Mobile 6 model. Further checking against transit level of service and connectivity is also recommended to better validate research results. Based on email correspondence from Scott Bernstein, Center for Neighborhood Technology to Gloria Ohland, Reconnecting America, January 5, 2008. A more refined research work program is suggested as an appropriate follow-on to this preliminary analysis – whether on a Portland-specific or national case study basis.
- <sup>16</sup> Construction carbon is often accounted for as of the day of building occupancy. Amortization (or annualization) of embodied carbon offers a means to simplify the analytical process of comparing construction and operational carbon. While consistent with the way that developers consider project costing and valuation, this approach is inconsistent with the issues of carbon release when viewed on a building-by-building (rather than district-wide or systematic) basis. The reality is a considerable portion (about 18% of the total building carbon footprint) is released in the first 1-2 years of construction. Based on email correspondence with Sean Cryan, Mithun Architects, September 21 and December 3, 2007. Accounting for construction and operational carbon in a unified accounting framework is a topic that warrants continued discussion beyond this initial research project, especially as may applied systemically to a range of urban and suburban environments within a metropolitan region.
- <sup>17</sup> Source is the U.S. Green Building Council, *Pilot Version: LEED for Neighborhood Development Rating System*, updated June 2007.
- <sup>18</sup> As examples, one of three site design prerequisites is that “projects may only be built on previously developed sites, either greyfield or brownfield.” An energy prerequisite stipulates that “100 percent of the building's energy needs be supplied by on-site renewable energy on a net annual basis.” A materials prerequisite is that “the project must account for the embodied carbon footprint of its construction through a one-time carbon offset tied to the building's square footage and general construction type.” Source is Cascadia Region Green Building Council, *The Living Building Challenge User's Guide*, Draft Version 1.2, April 2007.
- <sup>19</sup> One methodological limitation of the *Architecture 2030* approach is a focus on operational aspects of building (i.e. reduction of fossil fuel used by buildings) with less emphasis on construction (or embodied) carbon.
- <sup>20</sup> The *Consumer's Guide to Retail Carbon Offset Providers* prepared by Clean Air-Cool Planet suggests that: “Ancillary environmental and other benefits are desirable, but shouldn't substitute for technical quality...”
- <sup>21</sup> Much of this discussion of indirect effects is adapted from World Resources Institute, *Hot Climate, Cool Commerce: A Service Sector Guide to Greenhouse Gas Management*, May 2006.
- <sup>22</sup> This definition of green power is also provided by World Resources Institute, *Hot Climate, Cool Commerce*.

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- <sup>23</sup> Carbon issues with hydropower include construction-related (as in concrete and earth moving) and operations effect (with decay in biomass on land flooded to create the dam that can no longer as readily absorb CO<sub>2</sub>).
- <sup>24</sup> The City of Portland Office of Sustainable Development encourages entities to take responsibility for emissions associated with electric use. With its participation in the Chicago Climate Exchange, the City has opted to include emissions from electricity since these constitute the majority of the City's readily measurable CO<sub>2</sub> emissions.
- <sup>25</sup> Metro expects to estimate air pollution outputs using the Mobile 6 vehicle emission modeling, run from the regional VMT model.
- <sup>26</sup> Metro travel tables by transit and land use type may be suitable for application both to household and employment-related trips. Per email correspondence of Mark Turpel, Metro, September 21, 2007.
- <sup>27</sup> In the Seattle area, Sound transit has estimated CO<sub>2</sub> effects for LRT projects during construction by translating the project's energy consumption into a CO<sub>2</sub> equivalent. For operations, the change in regional VMT between the no build and build conditions multiplied by an emissions factor is used to estimate carbon footprint. Sound Transit has not attempt to estimated potential land use changes as they are not viewed as a direct part of its light rail project. Per email from James Irish, Sound Transit, December 6, 2007.
- <sup>28</sup> Carbon accounting and comparison of streetcar induced development to the suburban alternative is not covered, for example, with the draft *Portland Streetcar Loop Environmental Assessment*, August 2007. For the Portland metro area, further modeling of construction carbon effects for streetcar construction versus comparable suburban road development is could be considered in conjunction with Metro regional transportation modeling and the *Portland Streetcar System Plan (PSSP)* process now underway.
- <sup>29</sup> In addition to lack of detailed analysis of the Lloyd District, methodological issues associated with detailed eastside employment projections that could be attributable to streetcar include: a) less empirical experience with job than residential development on the westside, b) lack of detailed land capacity analysis associated with Metro TAZ-level employment projections, and c) potential non-comparability of Central Eastside development patterns and potentials with those of the Lloyd District (due to presence of industrial sanctuary and older building stock in the Central Eastside).

However, it can reasonably be expected that the overall eastside rate of streetcar development dependence would be greater for the whole eastside than Central Eastside due to likelihood of a greater mix of new construction with a lower proportion of building renovation with fewer restrictions and greater appeal of higher density employment uses. In effect, the hypothetical example provided with this memorandum should be viewed as a conservative representation of streetcar-induced job development for the Lloyd District and the entire eastside. *As noted in this report, the Lloyd District employment projection is subject to further refinement.*

- <sup>30</sup> For illustrative purposes, this *revised draft* analysis applies 2007 estimates of 1.34 persons per residential household in the Central City versus 2.52 region-wide. Also assumed is average suburban single family household size of 2,400 square feet, comparable to Clark County construction experience averaging 2,380 square feet for new single family construction in 2006 (excluding the downtown Vancouver area). Average single family single family unit size for all of Washington County (suburban and urban) was 2,150 square feet. An average assumed figure of 900 square feet per unit is applied to urban high density development.
- <sup>31</sup> The Construction Carbon Calculator created by Seattle's Mithun Architects ([www.buildcarbonneutral.org](http://www.buildcarbonneutral.org)) for an urban mid-rise building indicates hypothetical embodied carbon savings of 30% for steel, 42% for wood and 37% for mixed construction compared to concrete construction.

The potential embodied carbon disadvantages of urban scale mid-high rise buildings is indicative of some growing concern over the compatibility of high density construction with a green agenda. For example, an August 2007 article in *Urban Land* titled "Climate of Change" suggests that in Europe: "Some analysts are predicting the EU's new Energy Performance of Buildings Directive (EPBD) will spell the death of the 'glass tower' altogether." In addition to concerns of curtain-wall glazing and energy-intensive materials, critics also are raising questions about solar gain, shading, wind and heat island effects caused by high-rise buildings.

These tradeoffs can be expected to gain greater prominence as more U.S. architecture turns to green design. Offsetting these potential disadvantages may require substantially increased carbon-friendly performance in other areas of urban building design and development.

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- <sup>32</sup> Transit system effects are identified by the draft *Portland Streetcar Loop Environmental Assessment*. Future streetcar improvements beyond the eastside loop extension as envisioned by the Portland Streetcar System Plan (PSSP) could involve displacement of bus by streetcar transit. In this event, an added corresponding carbon benefit might be realized as streetcars/LRT transit in Portland runs in the range of 1,100-1,400 BTU of energy per passenger mile with buses in the range of 3,500-4,500 BTU per passenger hour. Estimates are as provided by Scott Bernstein, Center for Neighborhood Technology.
- <sup>33</sup> It has been suggested that urban development associated with high levels of public investment could be expected to perform at a higher level of green design than comparable suburban development. Portland examples include public sector building and PDC-assisted private building mandates for LEED-certified development.