2008 King County Community Greenhouse Gas Emissions Inventory: Supplemental Emissions Calculations

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Introduction

This report presents estimates of other sources of greenhouse gas emissions (GHGs), as well as estimates of GHGs avoided or sequestered as a result of actions in King County. This report is a companion to two greenhouse gas inventories conducted simultaneously for King County using two different methodologies:

- *The "Geographic Plus" Methodology*, which estimates the GHG emissions associated with cars and trucks, buildings, waste, agriculture, and other sources of emissions in King County.
- *The Consumption Methodology,* which estimates all emissions associated with consumption of goods and services in King County (including all citizen and government spending), no matter where the emissions occur.

The emissions sources or benefits described in this report do not fit neatly into either of these other two emissions inventories, yet they are important in describing King County's contributions to GHG emissions and in identifying potential means of supporting emissions reductions.

The other emissions sources or benefits discussed in this report include:[1]

- Municipal solid waste disposal using a "waste commitment" perspective;
- Carbon stored in disposed waste;
- Emissions benefits of recycling;
- Carbon sequestered in forests;
- Offsets retired by Seattle City Light;
- Emissions benefits of public transit.

These emissions are not considered part of either the "geographic plus" or consumption-based inventory for a variety of reasons, from seeking to avoid double-counting (e.g., for future emissions associated with waste disposal in the present) to the fact that negative emissions (whether due to recycling or offsets) are generally not considered in emissions inventories. Accordingly, these emissions sources or benefits may not simply be added to the totals displayed in either the "geographic plus" or consumption-based emissions inventories.[2] This project's summary report, *Greenhouse Gas Emissions in King County: An Updated Geographic Inventory, a Consumption-based Inventory, and an Ongoing Tracking Framework* recommends how to consider these other sources or benefits alongside other emissions sources in a comprehensive GHG measurement framework.

Municipal Solid Waste (MSW) Disposal

Two distinct methodologies can be used to estimate emissions associated with landfills and waste disposal. The "geographic plus" inventory estimates waste related emissions using a "waste in place" methodology. That approach estimates the emissions in the year 2008 as a result of all materials currently in landfills (no matter the year they were disposed) that are located within King County's geographic border. Refer to the Geographic Plus Inventory, Waste Sector section, to see the estimated fugitive landfill emissions.

The other common method, called "waste commitment", estimates emissions associated with all waste generated from within King County in 2008 (and only 2008), regardless of when or where those emissions actually occur.[3] This "waste commitment" methodology, employed in

[1] These are not the only other emissions sources or benefits that could potentially be tracked. Others may be identified in the upcoming phase of this project devoted to developing a tracking and measurement framework.
[2] Note that the consumption based inventory uses a portion of the calculation of "waste commitment" emissions to characterize emissions associated with disposal of post-consumer goods.
[3] Based on a review of WARM supporting documents (ICF. 2009. "*WARM component-specific decay rate methods*."Memorandum from ICF International to United States Environmental Protection Agency. October 30, 2009), it appears that EPA's WARM model counts methane released up to 100 years after disposal. After this period, it is assumed that no more methane is released and any remaining carbon is permanently stored.

calculations presented below, includes emissions even if they occur outside the King County geography or after 2008. For example, it includes emissions from waste, generated by Seattle residents, that is hauled by train to an Arlington, Oregon landfill. [4] Both methods include estimates of fugitive landfill emissions that result from the unintended release of landfill gas from the decomposition of organic materials at a landfill or combustion or treatment of landfill gas in flares. When organic materials are landfilled, as they decay, they produce methane and carbon dioxide. Methane is measured in the waste commitment method because the methane emissions would not occur if the materials were not landfilled. The carbon dioxide that results from the decaying materials is not counted under the waste commitment method because it is considered part of the natural carbon cycle of growth and decomposition.[5]

The waste commitment methodology estimates the total quantity of fugitive methane expected from the garbage disposed of in the inventory year, throughout its entire decay process in the landfill. The decay process takes many years, so the fugitive methane occurs only partly during the inventory year, and partly in future years. Emissions in the table below are unique in this aspect (since emissions in the "geographic plus" inventory occur solely in 2003 or 2008). Because the waste commitment emissions shown in Table 1 account for all future emissions from materials disposed in 2008, it is not appropriate to directly compare these emissions with those in the *Geographic Plus* inventory. Estimating future emissions associated with waste generated in the present may align better with the policy choices available today (e.g., waste and recycling programs and infrastructure) than would counting the actual current emissions of in-region landfills.

Other emissions are also associated with municipal solid waste (MSW) generated in King County: namely, fossil fuel combustion associated with transporting waste to landfill, processing waste at the landfill, maintaining the landfill using heavy equipment, and other general activities required to maintain the landfill. These other emissions are also estimated below, in Table 1.

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[4] Seattle's waste is disposed at the Arlington landfill, with an assumed 75% collection efficiency, lower than the at-least-90% collection efficiency at King County's Cedar Hills landfill.

[5] US EPA. 2010. "Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM): Introduction & Background". http://epa.gov/climatechange/wycd/waste/downloads/background-and-overview10-28-10.pdf; p.14

Table 1. Waste Management Emissions (Metric Tons CO_2e)

	2003	2008
Transportation to and Processing at Landfills	44,000	39,000
Fugitive Landfill Emissions Commitment	207,000	182,000
Totals	**251,000**	**222,000**

Key Drivers and Uncertainties

The key drivers of MSW disposal are personal and business consumption, which influence how much waste is generated, personal behavior (e.g., reuse, recycling), and alternative management infrastructure (e.g., recycling facilities). The key driver of landfill emissions is the presence and efficiency of a landfill gas collection system.

Several uncertainties exist in our assessment of emissions associated with MSW waste disposal. Most critically, we adjust the EPA's estimates of future fugitive methane generation at landfills by estimated collection efficiencies of fugitive landfill gas at the two dominant landfills that receive waste generated in King County, assuming that these collection efficiencies remain constant in the future. The landfill gas collection efficiencies are relatively uncertain (see source notes below and the Waste Section of the *Geographic Plus* inventory for more details), although landfill gas collection efficiencies are likely to improve over time as collection systems are improved and refined. Additionally, by using conservative collection efficiency estimates, emissions are not likely to be more than the totals estimated in this inventory. In addition to the collection efficiency, waste composition is an important variable in the amount of methane generated in landfills. We used studies conducted by King County Solid Waste Division and Seattle Public Utilities to estimate what fraction of different types of waste are generated in each year, although there is some uncertainty in these estimates.

Source Notes

MSW Disposal: Fugitive emissions from MSW were calculated by applying emission factors from version 11 of the EPA Waste Reduction Model (WARM) **(KC08-50-5_WARM_v11_exploded)** to the tons of waste disposed from King County, including Seattle, and adjusting the emission factors to account for rates of landfill gas collection efficiency at the two landfills: 90% at King County's Cedar Hills landfill and 75% at the Arlington landfill to which the City of Seattle sends its waste **(KC08-50-4_Waste_calcs)**. See the Waste Sector of the Geographic Plus Emissions Inventory for more details on the estimates of landfill gas collection efficiencies. Tons of waste disposed from King County are provided in **(KC08-50-6_KingCountyDisposal)**. Tons of waste disposed from Seattle are estimated in **(KC08-50-7_SeattleDisposal)**. Transportation and processing emissions for King County were calculated by applying fuel specific emission factors to King County's total fuel use in 2008 **(KC08-50-4_Waste_calcs)**. These estimates include emissions related to transporting and processing garbage, heavy equipment use to maintain the landfill, and related general maintenance activities. This estimate includes 151,829 gallons of 100% biodiesel equivalent, which were estimated by King County to result in roughly 57% less lifecycle emissions compared to fossil fuel diesel. Fuel use for 2003 was estimated based on the 2008 ratio of gallons of fuel per tons of waste. Transportation and processing emissions for Seattle's waste were calculated by entering the distance from Seattle to Arlington (254 miles) into WARM **(KC08-50-4_Waste_calcs).**

MSW-related Carbon Storage

The majority of MSW consists of organic matter. When organic waste is buried in a landfill, a portion decays, releasing methane and carbon dioxide, but the remaining portion remains buried in the landfill indefinitely. This remaining portion represents carbon storage, since the carbon in the waste was originally extracted from the atmosphere by means such as a food plant, garden vegetation, or a tree harvested for forest product. Table 2 lists the estimated carbon storage associated with waste disposed in landfills.

As for the fugitive methane commitment described above, the values in Table 2 are calculated for the waste disposed in the listed calendar year, but represent the storage enduring after waste decay has stabilized, many years in the future.

Table 2. Carbon Storage Associated with Landfilling of Municipal Solid Waste (Metric Tons CO_2e stored)[6]

	2003	2008
Carbon storage	-499,000	-440,000

Key Drivers and Uncertainties

As for MSW disposal, the key drivers of landfill carbon storage are personal and business consumption, individual behavior, and alternative management infrastructure. Similar uncertainties also exist in our estimates for carbon storage in landfills as for fugitive methane emissions: for example, we assume that materials that store carbon when disposed in landfills (e.g., wood) remain in the landfill, undisturbed, indefinitely, as in the EPA's WARM model.

Source Notes

MSW Sequestration: Carbon sequestration from MSW was calculated by applying emission factors from the EPA Waste Reduction Model (WARM) **(KC08-50-5_WARM_v11_exploded)** to the tons of waste disposed from King County, including Seattle **(KC08-50-4_Waste_calcs)**. Tons of waste disposed from King County were calculated based on data provided by the King County Solid Waste Division **(KC08-50-6_KingCountyDisposal)**. Tons of waste disposed from Seattle were calculated based on data provided by Seattle Public Utilities **(KC08-50-7_SeattleDisposal)**.

[6] In 2006, King County Solid Waste Division conducted its own analysis of carbon sequestration in its Cedar Hills landfill. Using waste composition data from King County's 1994 waste characterization report, the 2006 report concluded that Cedar Hills landfill sequestered 493,000 $MTCO_2$e in 2003 and 492,000 $MTCO_2$e in 2008. For more detail, please refer to Okereke,Victor. "Analysis of Carbon Sequestration in the Cedar Hills Regional Landfill." Presented at *SWANA'S 21st Annual Pacific Norhtwest Regional & Canadian Symposium*. April 5-7, 2006.

Emissions Avoided from Recycling Programs in King County

Recycling programs in King County result in emissions from their operations, but also avoid emissions associated with disposal of MSW and manufacturing of new materials and products – emissions that largely occur outside King County.

In general, the benefit of avoided materials manufacture is significantly more than the emissions associated with the recycling infrastructure. In other words, recycling programs yield a significant net GHG benefit.

Similarly, composting programs result in both carbon storage and minimal CO_2 emissions from transportation and processing. Carbon storage results from the effects of compost application on soil carbon restoration and humus formation.[7]

Estimating the avoided emissions that can result from recycling programs (or any other source of avoided emissions) can be challenging, as doing so involves assessing emissions reductions relative to what otherwise would have happened, or to "business as usual". One approach used by other communities (including the City of Seattle) has been to estimate the benefits of recycling relative to if all the material was instead disposed. However, other approaches have taken a more conservative (and arguably more realistic) approach to estimating "business as usual", instead estimating benefits relative to national average or "common practice" recycling rates.[8] Below we report results using both of these methods.

Table 3. Emissions Associated with Recycling Programs in King County (Metric Tons CO_2e)

	Relative to 100% Disposal		Relative to National Average Recycling Rates	
	2003	**2008**	**2003**	**2008**
Avoided Transportation to Landfills[9]	-25,000	-37,000	-8,000	-15,000
Avoided Landfill Emissions Commitment	-156,000	-225,000	-51,000	-79,000
Foregone Carbon Storage	532,000	823,000	123,000	209,000
Recycling Process and Avoided Manufacturing	-1,841,000	-2,442,000	-525,000	-750,000
Composting Process and Avoided Manufacturing	-49,000	-77,000	-19,000	-30,000
Totals	**-1,539,000**	**-1,959,000**	**-480,000**	**-664,000**

Note that some of the benefits of recycling (those related to energy savings at manufacturers due to using recycled materials at national average rates) are accounted for in the companion consumption-based GHG inventory. The consumption-based inventory does not fully capture

[7] Composting also emits CO_2 from the decomposition of organic source materials, but because these emissions are biogenic, they are not counted toward (anthropogenic) GHG emissions.
[8] For example, see *The Washington State Consumer Environmental Index* by Jeff Morris et al (2007) or the Climate Action Reserve's offset protocol for programs that collect and compost food waste, both of which assess benefits relative to some measure of national average or "common practice" recycling rates. In addition, the EPA WARM tool upon which our estimates are based is intended to assess the emissions benefits of a change in practices from some initial condition to an alternative practice.
[9] Net of transportation to recyclables processing facilities.

the benefits of recycling to the extent King County recycling (a) exceeds national averages; or (b) leads to forest carbon sequestration that would not otherwise have occurred (e.g., due to recycling of paper) – a carbon flux that is not included in the consumption-based inventory.

Key Drivers and Uncertainties

Similar to MSW disposal, the key drivers of recycling are personal and business consumption, individual behavior, and alternative management infrastructure. Uncertainties are large and likely greater than any other sector.

Uncertainty arises primarily due to the very nature of measuring the benefits of recycling relative to what would have otherwise happened. Characterizing this "counterfactual" requires guesswork. Even though the EPA has performed extensive analysis to attempt to characterize the benefits of recycling against "business as usual" in the various sectors of the economy that are engaged in recycling (from collection programs, to processing infrastructure to global commodities markets, to manufacturers that use recycled feedstocks), significant uncertainties still arise and limit our ability to fully assess the GHG benefits of recycling.

Uncertainties also arise from the calculation of composting emissions. For example, EPA's WARM model currently assumes that the methane (CH_4) that results from anaerobic decomposition during composting is oxidized to CO_2 before it escapes from the compost pile, though some may actually escape as CH_4. In addition, the EPA's WARM model does not quantify some potential benefits of compost: namely, the possibility that compost-amended soils may have an enhanced ability to sequester carbon beyond that carbon contained in the original compost, as well as the possibility that use of compost could displace the use of fertilizers or pesticides. These remain areas for further research.

Despite the uncertainties and the range of benefits estimated in Table 3, these results indicate that recycling and composting programs together provide a significant negative emission, meaning they offset or reduce emissions that would otherwise occur.

Source Notes

Recycling: Emissions from recycling were calculated by applying emission factors from the EPA Waste Reduction Model (WARM) **(KC08-50-5_WARM_v11_exploded)** to the tons of material recycled in King County and Seattle, both in total and also as compared with the national average recycling rate for each material **(KC08-50-8_MarginalRecycle_calcs)**. Tons of waste recycled in King County were calculated based on data provided by the King County Solid Waste Division **(KC08-50-8_MarginalRecycle_calcs)**. Tons of waste recycled in Seattle were calculated based on data provided by SPU **(KC08-50-8_MarginalRecycle_calcs)**. The national average recycling rates for each material were derived from two reports from the U.S EPA's Office of Resource Conservation and Recovery (2008 and 2003 data tables available at http://www.epa.gov/osw/nonhaz/municipal/msw99.htm).

Forest Carbon Sequestration

King County contains over 800,000 acres of forest land – land that contains large stocks of carbon.[10] Carbon is lost when land is cleared and carbon is (in most cases) gained when trees grow.

Table 4 presents estimates of the net annual flux of carbon from King County forest land: an annual gain of 440,000 metric tons CO_2e. The U.S. Forest Service does not provide sufficient data to enable separate estimates for 2003 and 2008, as in other sectors of this GHG inventory.

Table 4. Forestry Sector Emissions (Metric Tons CO_2e)

	1996-2006 (annual change)
Forestry	-440,000

As noted above, there are two components of this flux: sequestration by trees growing on lands that remain forest, and carbon loss on lands cleared of trees. Given the available data, it is not possible to clearly or definitively distinguish these two individual components. However, an approximation can be made by considering the change in acreage that the USFS considers to be forest land. In particular, USFS data indicates that, since 1996, an average of 4,400 acres of forest land were converted to other (i.e., non-forest) uses annually in King County (KC08-80-4_USFS_CCT). At an approximate average carbon density of 100 tons CO_2e per acre, that would yield roughly 440,000 tons of CO_2e of forest stocks removed annually.[11] To yield a net carbon sequestration of 440,000 tons CO_2e as reported in Table 4, then, annual sequestration on forest land that remains forest land would need to be 880,000 tons annually.[12] Interestingly, this figure is similar to a calculation for King County's prior, 2003 GHG Inventory, where it was projected that forest lands in King County could sequester 830,000 tons CO_2e annually.

Therefore, given this preliminary calculation and the finding in King County's prior, 2003 GHG Inventory, it seems reasonable to conclude that (rounded to the nearest hundred-thousand) about 800,000 to 900,000 tons of CO_2e is sequestered annually in King County forest lands, with

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[10] Our calculations are based on U.S. Forest Service (USFS) data concerning forest land. USFS defines *forest land* as "land with at least 10 percent cover (or equivalent stocking) by live trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. To qualify, the area must be at least 1.0 acre in size and 120.0 feet wide… …Treecovered areas in agricultural production settings, such as fruit orchards, or treecovered areas in urban settings, such as city parks, are not considered forest land." For further details, see http://www.fs.fed.us/rm/pubs/rmrs_gtr245.pdf.

[11] 100 tons CO_2e per acre is the value used in the calculations in the companion *Geographic Plus* inventory, based on KC-08-80-2 adjusted upward to count belowground biomass per KC-08-80-4. It is a coincidence that the net annual gain in carbon stocks of 440,000 tons CO_2e is the same (though with opposite sign) as this rough estimate of carbon stocks removed. Note that 100 tons per acre CO_2e is lower than the overall average of forests in King County of approximately 231 tons CO2e per acre based on source KC-08-80-4_USFS_CCT. We use 100 tons CO_2e per acre to be consistent with the calculations in the *Geographic Plus* inventory. This carbon density is based on a University of Washington Study of transects in King County from downtown Seattle into rural forested areas; the carbon density on these transects may more closely approximate the densities on land cleared for other uses than the overall average forest carbon stock that includes national forest land and old-growth forest.

[12] Calculated as 440,000 – (-440,000) = 880,000.

about 400,000 tons CO_2e removed, of which about 100,000 tons CO_2 is removed due to residential development (as we discuss in the *Geographic Plus* inventory).[13] The remaining carbon stocks removed from forest lands – estimated at roughly 300,000 tons CO_2e – go to unknown fates. We do not have sufficient information to characterize whether these stocks were lost due to clearing for some other land use (e.g., for road-building to support residential development, to commercial development, or to other land uses) or whether these stocks are not actually removed. For example, the removed stocks could simply have been reassigned in the US Forest Service assessment to a type of land use other than forest land, or perhaps instead due to statistical differences or changes in methodology between the US Forest Service's 1996 and 2006 estimates.[14] Additional, ongoing work by the University of Washington using satellite data may help future analysts better characterize change in carbon stocks in King County.[15]

Key Drivers and Uncertainties

As noted above, given limited data, it is not possible to fully ascertain the key drivers for loss of forest carbon stock in King County. Forest carbon stock losses due to one key driver – residential development – where estimated in the companion *Geographic Plus* inventory. Further research would be needed to understand other land conversions.

Several uncertainties exist, including the fact that USFS methodologies may not be completely consistent between the 1996 and 2006 estimates used here. In addition, these estimates include only forest carbon on lands classified by the USFS as forest land. Additional carbon is sequestered (and lost) in urban forests and suburban lands. Other data sources (e.g., satellite data) would be needed to conduct a fuller assessment of all biomass carbon stocks in King County.

Source Notes

Annual forest sector emissions were calculated based on interpolating an annual flux of forest carbon in above- and below-ground portions of live trees from average 1996 and 2006 forest carbon stocks provided for King County by the U.S. Forest Service **(KC08-80-4_USFS_CCT).**

[13] In the *Geographic Plus* inventory, we estimated that 123,000 tons CO_2 were removed in 2003 and 53,000 tons CO_2 in 2008. Given uncertainties and year-to-year variations, we say "about 100,000 tons" here.
[14] Our analysis of King County permit records indicates that, in 2003, over 3,000 acres were permitted for residential development. If most of these acres were previously forest land, then some fraction of the carbon stocks "lost" from forest land may not be lost, but instead remain on the portion of rural residential parcels that are not cleared for development.
[15] The UW's Urban Ecology Research Laboratory is using Landsat satellite data to quantify changes in carbon stocks in the Puget Sound region.

Offsets Retired by Seattle City Light

Seattle City Light generates most of its electricity from hydro and wind power, but some emissions are associated with the power City Light purchases on the market. Since 2005, City Light has invested in greenhouse gas reduction projects that offset the emissions associated with its electricity supply.

City Light emissions are presented in Table 5, below. Seattle City Light purchased offsets for the 2008 emissions. For more information on City Light's offset program, see the City of Seattle's 2008 GHG Inventory **(08-09-00)**[16] or contact Seattle City Light's Environmental Affairs Division.

Note that the reduction in Seattle City Light's electricity emissions between 2003 and 2008 was due largely to a reduction in supply from coal-fired electricity plants.

Table 5. Seattle City Light Electricity Emissions (Metric Tons CO_2e)

Offset Were Purchased for 2008 Emissions

	2003	2008
Residential	89,000	58,000
Commercial	142,000	96,000
Industrial	36,000	20,000
Total	**267,000**	**175,000**

Source Notes

Calculation steps and data sources are listed in **KC08-00-1_MasterSpreadsheet_123010 'Electricity'**.

Emissions Avoided Due to Public Transit in King County

Public transit produces GHG emissions through the vehicles and facilities used to provide service, but transit can also reduce emissions from private vehicles. Transit can lead to emissions benefits due to:

- **Mode shift:** avoided car trips through shifts from private automobiles to transit;
- **Land use:** additional avoided, or shorter, car trips due to transit's role in enabling compact communities that facilitate shorter trips, walking and cycling, and reduced car use and ownership; and
- **Congestion relief:** improved operating efficiency of private automobiles that can result from reduced idling and stop-and-go traffic.

The *Geographic Plus* inventory estimated King County Metro's annual emissions from buses (diesel) and vanpools (gasoline) at 117,000 metric tons CO_2e in 2008. King County Metro's own

[16] http://www.seattle.gov/climate/

estimates of 2008 emissions is 128,000 metric tons CO_2e and also includes emissions from trolley buses, additional rolling stock, and facilities, all sources that are included elsewhere in the *Geographic Plus* inventory and not specifically assigned to Metro.

Estimating the emissions benefits of transit are difficult because, as for recycling or GHG offsets, doing so involves assessing what otherwise would have happened had the activity (in this case, providing bus and other transit service) not otherwise occurred. Of course, knowing exactly what would have happened otherwise, or "business as usual," is impossible, but methods have been developed to estimate the impacts, typically with large uncertainties.

In particular, the American Public Transportation Association (APTA) has developed a recommended practice to estimate the avoided emissions from each of the three emissions displacement categories above.[17] Some transit agencies, such as New York City and Chicago have completed analysis of their impact using variations of the APTA method. For example, New York estimated avoided emissions by comparing land use and travel patterns for less dense areas, both national as well as adjacent areas that are not served by the Metropolitan Transportation Authority (MTA). They write:

> "Without MTA, GHG emissions could be more than 18 million tons per year… …or more than 25 percent greater than current GHG emissions. This is as conservative estimate that assumes that, without MTA, the region could have sprawled to look like the average U.S. land use. If the MTA Region became even more like low public transport, car-based cities, savings could be as high as 44 million tons per year."[18]

MTA estimated that of the three categories (mode shift, land use, congestion relieve), the land use effect provided the largest GHG benefits for New York City, greater than the mode shift and congestion benefits combined.

King County Metro Transit is currently exploring how to estimate the overall impact of King County transit service and hopes to report estimates in future inventories.

Note that the *Geographic Plus* inventory and the tracking framework recommended in the summary report *Greenhouse Gas Emissions in King County* already account for the benefits of transit, since they account for the emissions from all road travel (both private vehicles and transit), even as they are not able to attribute the specific benefits of transit relative to a "business as usual" scenario.

Sources

For further information on sources cited in this short report, please see the appendices to the *Geographic Plus* GHG inventory.

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[17] *Quantifying Greenhouse Gas Emissions from Transit*, APTA Standards Development Program, August 2009. http://www.aptastandards.com/Portals/0/SUDS/SUDSPublished/APTA_Climate_Change_Final_new.pdf

[18] http://www.mta.info/sustainability/pdf/MTA%20Carbon%20Model%20Report%20&%20Presentation.pdf