1990 GHG Baseline for Building Energy Use in the Oregon University System

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OVERVIEW AND RESULTS

This memo provides an estimate of 1990 building energy use and the associated greenhouse gas (GHG) emissions for Oregon University System's seven institutions. This GHG calculation or "carbon footprint" is accompanied by a sensitivity analysis to scale the uncertainty in the calculation.

The Oregon University System, as part of its climate action planning process, seeks to put its current GHG inventory in the context of past emissions. In particular, Governor Kulongoski has issued an executive order that asks for reductions relative to 1990, the base year for consideration by the Kyoto protocol. While institutions and the system as a whole are free to pursue other more binding goals, there is a pressing need to establish this baseline to ensure compliance with the governor's stated intent. Specifically, there is a focus on building energy use, the single largest source of direct emissions and electricity-related emissions.

Establishing such a baseline is difficult. In the intervening twenty years, few institutions have maintained comprehensive records of facilities operations at this granular level. Many institutions did not, at that time, track energy use in the detail necessary to perform these calculations. Indeed, there have been data-related challenges simply in establishing data for 2004 to the present, much less for 1990.

This memo combines complete recent data, incomplete 1990 data, and a multi-year building energy survey for the Western United States, the Commercial Buildings Energy Consumption Survey (CBECS). In brief, the method assesses the value of CBECS as a proxy for current energy use by OUS institutions, then estimates 1990 use with the resulting proxy values. Energy use corrections are made for changes in building square footage. The energy use data is used to calculate GHG emissions. Corrections are made for the changes in the electricity generation mix (and modest increase in carbon intensity) of the regional grid since 1990.

As a last but crucial step, there is extensive sensitivity analysis to provide a sense of the scale of uncertainty in the estimates. The large range is driven by the lack of complete data for 1990 energy use, as well as the challenges in using CBECS to estimate energy use for specific contexts. This final section indicates potential improvements to the data that are likely to be high-leverage opportunities for narrowing the uncertainty. For more, please see the source spreadsheets that contain all original data, estimated data and calculations.

In highest-level summary, the resulting emissions were calculated as follows:

Table 1: Comparison of 2008 GHG emissions to estimated 1990 emissions baseline with uncertainty range.

2008 Building Energy Emissions	1990 Baseline Building Energy Emissions	1990 - High Estimate	1990 - Low Estimate
188,779 MT CO$_2$e*	Point Estimate: **153,187 MT CO$_2$e**	178,528 (17% above point estimate)	118,375 (23% below point estimate)

Value includes natural gas and electricity emissions (regional emissions factor) taken from Sightlines GHG inventory.

Greenhouse gas emissions from building energy use in 2008 were about 23% higher than the 1990 baseline. In other words, OUS institutions must, in aggregate reduce 2008 emissions from building energy by about 19% to get back to 1990 levels.

Over the same period, total square footage of the six institutions covered here (excluding WOU) rose 15.4%, from 16.369 million to 18.895 million gross square feet (GSF).

The estimated emissions calculated for each institution are as follows:

Table 2: Summary of 1990 GHG baseline, by OUS institution, with uncertainty range

OUS Institution	1990 estimate MT CO$_2$e	low estimate MT CO$_2$e	high estimate MT CO$_2$e
Eastern	6,014	4,484	8,830
Portland State	23,342	20,773	30,394
Southern	10,710	7,969	11,742
Western	9,523	7,098	10,440
U of O	51,597	36,867	56,556
Oregon State	49,855	39,359	58,130
OIT	2,146	1,826	2,436
Totals:	153,187	118,375	178,528

DESCRIPTION OF METHOD

This method of estimating the 1990 baseline for energy consumption and associated greenhouse gas (GHG) emissions required two primary pieces of information: the average energy intensity (energy use per square foot) of university buildings in 1990 and the emissions factor for electricity produced in the Northwest Power Pool (NWPP).

1990 Energy Consumption Baseline

Average electricity and natural gas intensity (energy consumed / square foot) statistics are available in the Energy Information Administration's *Commercial Building Energy Consumption Survey (CBECS)*[1]. The survey has been conducted in 2003, 1999, 1995, and 1992. The surveys provide average electricity and natural gas intensities by principal building use for the western census region (everything west of the Rockies from the northern to southern US borders). The principal building types included in the survey, that fit university activities include: education, food service, health care, lodging, office, public assembly and warehouse and storage.

The CBECS statistics were assigned to each university building, by primary building type (as assigned by Sightlines), to estimate electricity and natural gas consumption for 1990, using the intensities reported in the 1992 CBECS survey. Building inventories were assembled for Sightlines' work that included the construction year for all institutions. The CBECS statistics were assigned to buildings constructed prior to 1990 (so building constructed in 1989 were included but those constructed in 1990 were not) to estimate electricity and natural gas consumption.

The CBECS building type classified as "health care" was assigned to those buildings classified by Sightlines as "scientific research" buildings. The CBECS statistics do not capture the function of a university scientific research building in any of their primary building categories. McKinstry recently measured energy consumption for scientific research buildings on a number of OUS campuses; when averaged, these measured EUI values are most comparable to the CBECS statistics for the "health care" category.

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[1] The Commercial Buildings Energy Consumption Survey (CBECS) is a national sample survey that collects information on the stock of U.S. commercial buildings, their energy-related building characteristics, and their energy consumption and expenditures. Commercial buildings include all buildings in which at least half of the floor space is used for a purpose that is not residential, industrial, or agricultural, so they include building types that might not traditionally be considered "commercial," such as schools, correctional institutions, and buildings used for religious worship. The CBECS website is accessed at: http://www.eia.doe.gov/emeu/cbecs/

Table 2: Comparison of CBECS electricity and natural gas statistics for 1992 and 2003.

Principal Building Activity	1992 Electricity Energy Intensity (kWh / square foot)	2003 Electricity Energy Intensity	1992 Natural Gas Energy Intensity (cubic feet / square foot)	2003 Natural Gas Energy Intensity	1992 Energy Use Intensity (kBTU / square foot)	2003 Energy Use Intensity
Education	10.9	10.2	36.6	39.6	74.5	75.2
Food Sales	49.8	**49.8**	Not Included in Survey	Not Included in Survey	Not Applicable	Not Applicable
Food Service	45.3	31.9	189.1	**189.1**	347.4	301.7
Health Care	19.7	22.5	59.8	86.1	128.2	164.6
Lodging	28	14.7	90.4	56.6	187.7	107.9
Retail (other than mall)	10.8	14.8	38.2	18.3	75.8	69.2
Office	17.4	15	28.2	23	88.1	74.6
Public Assembly	12.7	16	41.5	32.4	85.7	87.6
Public Order and Safety	Not Included in Survey	Not Included in Survey	Not Included in Survey	Not Included in Survey	Not Included in Survey	Not Included in Survey
Religious Worship	2.5	3.6	17.2	18.1	26.1	30.7
Service	**11.4**	11.4	Not Included in Survey	Not Included in Survey	Not Applicable	Not Applicable
Warehouse and Storage	6.3	7.3	14.5	**14.5**	36.3	39.7
Other	15.6	**15.6**	Not Included in Survey	Not Included in Survey	Not Applicable	Not Applicable
Vacant	6.8	**6.8**	28.6	**28.6**	52.4	23.2
Parking Garage	6.5	**6.5**	Not Included in Survey	Not Included in Survey	Not Applicable	Not Included in Survey

Note: Bold values on the table indicate where 1992 data was <u>substituted</u> for a value that was missing from the 2003 survey. Values for some categories (in this case some principal building types) are not reported for some surveys due lack of data.

1990 Emissions Factors

Electricity - The factors needed to calculate the emissions factor for the electricity produced in the Northwest Power Pool (NWPP) subregion are provided in a Washington State - Department of Community, Trade & Economic Development (CTED) report titled *Methodology for Estimating 1990 Electricity Load-based Emissions for Washington State*[2]. The report provides the NWPP's 1990 total electricity generation and the associated emissions with that generation. The total 1990 NWPP emissions are divided by the total 1990 electricity generation to determine the 1990 emissions factor (MT CO_2 / MWh). This method results in a 1990 emissions factor of 0.3179 MT CO_2 / MWh. For comparison, the most recent eGRID value for the NWPP is 0.4093 MT CO_2 / MWh.

The 1990 emissions factors for methane (CH_4) and nitrous oxide (N_2O) are not estimated in the CTED report, so these emissions are estimated using the 2006 U.S. EPA eGRID values. It is acknowledged that these values may differ from actual 1990 values, but will still be very small compared to the CO_2 emissions factor.

Natural Gas – The emissions factors are taken from The Climate Registry's *General Reporting Protocol (version 1.1)*[3]. The emissions factors used in this analysis were published in 2008. It is used for this analysis with the assumption that the heat and carbon content of natural gas is not significantly different from 1990. The carbon dioxide (CO_2) emissions factor is a weighted U.S. average based on the heat and carbon contents of the natural gas (page 74). The methane (CH_4) and nitrous oxide (N_2O) emissions factors are for a commercial-sector boiler (page 80). The GHG emissions factor used in this analysis for natural gas is 53.36 kg CO_2e / MMBTU.

Wood and Wood Waste (12% moisture) – The University of Oregon used wood waste as fuel in 1990 which as since been replaced by natural gas. Based on interviews with the operations staff, it is assumed that 100% of the 1990 heat content as estimated by CBECS for natural gas was actually produced by wood waste. UO was not the biggest estimated user of natural gas in 1990, but the usage made up 18% of the total estimated 1990 energy consumption.

Emissions for UO were calculated using a wood waste emissions factor. This emissions factor only takes into account "tailpipe" emissions, not life-cycle emissions, and as such is almost double the GHG emissions per

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[2] The CTED report may be accessed online at: http://www.ecy.wa.gov/climatechange/TWGdocs/ene/1990WALoad-basedElectricitysectoremissions.pdf

[3] The Climate Registry, *General Reporting Protocol* may be downloaded at: http://www.theclimateregistry.org/resources/protocols/general-reporting-protocol/

MMBTU compared to natural gas. This method is being used per California Climate Action Registry's *Power Generation/Electric Utility Reporting Protocol*. As of this writing, policy consensus on the net impact on climate from the combustion of biofuels has not yet been reached. In the absence of detailed information on the sources of the wood waste, it is inappropriate to make assumptions about the forest practices that led to this energy feedstock. Accordingly, this analysis draws on default emissions factors from high-consensus protocols.

The emissions factors for wood and wood waste are taken from The Climate Registry's *General Reporting Protocol (version 1.1)*[3]. The emissions factors used in this analysis were published in 2008. It is used for this analysis with the assumption that the heat and carbon content of wood and wood waste is not significantly different from 1990. The carbon dioxide (CO_2) emissions factor is a based on the heat and carbon contents of the wood and wood waste (page 74). The methane (CH_4) and nitrous oxide (N_2O) emissions factors are for a commercial-sector technology (page 80). The GHG emissions factor used in this analysis for wood waste is 93.22 kg CO_2e / MMBTU.

Description of Calculations

The following equations represent the proposed method of estimating 1990 energy consumption for the OUS system and the associated GHG emissions. Figure 1 shows this method for in general terms for total energy consumption (electricity and natural gas). Figures 2 shows the specific equations used for electricity and natural gas respectively.

Figure 1: General formula and description of variables used to estimate 1990 emissions.

$$\text{GHGs}_{\text{total energy use}} = \frac{\text{GHGs}}{\text{unit of energy}} \times \frac{\text{unit of energy}}{\text{square footage}} \times \text{square footage}$$

Variable	Variable Description
GHGs	An estimate of greenhouse gases generated from total energy consumption during the 1990 fiscal year.
GHGs / unit of energy	This term represents the emissions factor for all energy consumed regardless of type. In practice a separate emissions factor will be used for electricity and natural gas.
Unit of energy / square footage	This term represents the CBECS statistics used to estimate 1990 energy consumption (for electricity and natural gas) for each campus. These statistics are specific to the western census region and the primary building type. For more information see the 1990 Energy Consumption Baseline section of this report.
Square footage	Existing building data provided to Sightlines by each institution will be used to determine 1990 building square footage by primary building type.

Figure 2a: Formula and description of variables to estimate electricity emissions.

$$\text{GHGs}_{\text{electricity use}} = \frac{\text{GHGs}}{\text{kWh}} \times \frac{\text{kWh}}{\text{square footage}} \times \text{square footage}$$

Variable	Variable Description
GHGs	An estimate of greenhouse gases generated from electricity during the 1990 fiscal year.
GHGs / kWh	This term represents the emissions factor for all electricity. The 1990 emissions factor for the Northwest Power Pool (NWPP) is taken from a CTED report. See the Emissions Factors section of this memo for more detail.
kWh / square footage	This term represents the CBECS statistics used to estimate 1990 electricity consumption for each campus. These statistics are specific to the western census region and the primary building type. For more information see the 1990 Energy Consumption Baseline section of this report.
Square footage	Existing building data provided to Sightlines by each institution will be used to determine 1990 building square footage by primary building type.

Figure 2b: Formula and description of variables to estimate natural gas emissions.

$$\text{GHGs}_{\text{natural gas/wood waste use}} = \frac{\text{GHGs}}{\text{cubic foot}} \times \frac{\text{cubic feet}}{\text{square feet}} \times \text{square feet}$$

Variable	Variable Description
GHGs	An estimate of greenhouse gases generated from natural gas or wood waste during the 1990 fiscal year.
GHGs / cubic foot	This term represents the emissions factor for natural gas. The 1990 emissions factor for natural gas and wood or wood waste is taken from The Climate Registry *General Reporting Protocol (version 1.1)*. These emissions factors are not specific to 1990, but the current value for both are assumed to be equal to the 1990 value. We assume the current heat and carbon content of natural gas and wood in 2009 is very similar to 1990.
cubic foot / square footage	This term represents the CBECS statistics used to estimate 1990 natural gas consumption for each campus. These statistics are specific to the western census region and the primary building type. For more information see the 1990 Energy Consumption Baseline section of this report.
square footage	Existing building data provided to Sightlines by each institution will be used to determine 1990 building square footage by primary building type.

Figure 2c: Formula for CBECS-based estimate of 1990 emissions for electricity and natural gas.

$$\text{1990 Electricity and Natural Gas Estimate}_{\text{university i}} = \frac{\text{CBECS 1990}_i}{\left(\frac{\text{CBECS 2004}}{\text{Actual 2004}}\right)_i}$$

DATA SOURCES, DATA ISSUES AND SOURCES OF UNCERTAINTY

This method has significant sources of uncertainty, but it is currently the only defensible process for estimating building energy consumption. The only truly accurate method to establish a 1990 consumption baseline is digging into facilities records and / or determining if your utilities retain records from 1990.

The first source of uncertainty is the assumption that electricity and natural gas are consumed at every building included in the Sightlines building inventories. Having a knowledgeable representative from each institution conduct a line-by-line review of the estimation spreadsheet could significantly reduce this source of uncertainty.

A second source of uncertainty is that CBECS statistics are based on averages from the Western region. This means the average energy intensity statistics are most likely skewed by mixing dramatically different climate zones. For example the heating needs of Phoenix or Los Angeles are dramatically different than those in Eugene or Corvallis, which may result in an underestimate of CBECS natural gas intensity statistics when applied to Oregon.

The third source of uncertainty is the inability of the CBECS statistics to account for on-site electricity, steam or chilled water generation. On-site generation could affect the consumption of both electricity and natural gas, depending largely on the extent of co-generation by a campus power plant.

A fourth source is that CBECS provides energy intensity values for electricity and natural gas, but no other sources of fuel. For example, it is known that the University of Oregon consumed hog fuel in 1990 at its campus power plant. With the CBECS statistics it is not possible to estimate the quantity of hog fuel consumed. This is especially significant when calculating emissions. The emissions factor and generation equipment efficiency could be significantly different, but are difficult to account for using this method.

A fifth source of uncertainty lies in the lack of good data for *any* of the institutions, for 1990 or for a nearby proxy year. The estimates for PSU and OSU are based on partial data; those datasets have limitations, but even the limitations are not entirely clear. For example, Oregon State was able to provide 1990 electricity and natural gas consumption, but is currently unable to determine if these values are based on use records or some method of estimation. There is therefore some question about what activities these values actually cover. Second, Portland State provided utilities information for FY1993 that is partial in facilities scope (only 22 buildings out of 50+ buildings in the portfolio in that year) and in time (for certain buildings, several months were missing and had to be interpolated from surrounding months).

Figure 3: Building inventory and energy consumption data availability, by OUS institution.

This section provides an attempt to scale the uncertainty associated with the estimated values for energy use and resulting GHG emissions, by institution and by fuel (electricity or natural gas).

The figures below present the estimated range of uncertainty for electricity use and natural gas use, by institution. The high and low values are based on *the widest observed diversion from the CBECS benchmark for all institutions*. In other words, the high values (for electricity and for natural gas) assume that all institutions are at the same ratio of the CBECS benchmark, the highest observed for any one institution. Similarly, the low values assume that all institutions are at the lowest ratios for any one institution. This method is probably quite cautious, as it assumes that each institution could, in 1990, fall along the spectrum experienced in 2004 (relative to CBECS) for *all institutions*. Since the institutions are likely to be more similar to themselves over time rather than to each other, this method probably overstates the likely plausible range.

Figure 4: Sensitivity analysis for electricity consumption in 1990, by OUS institution.
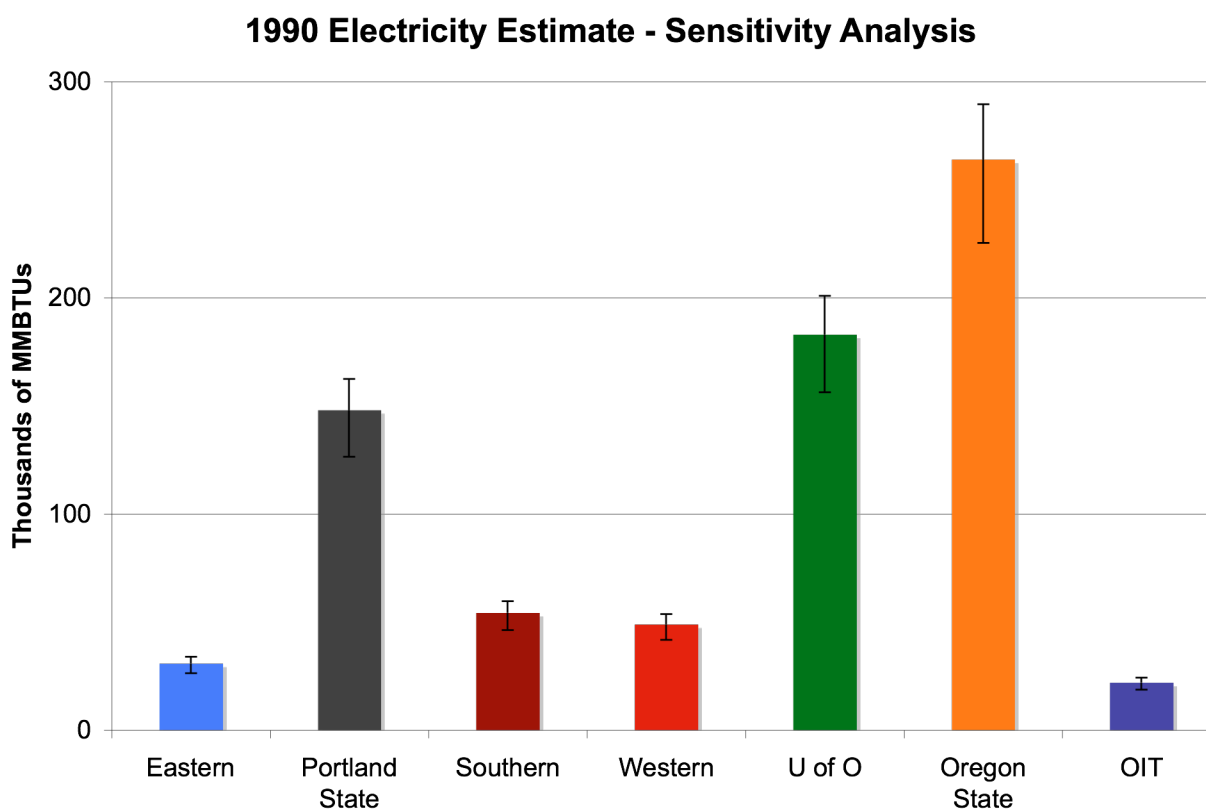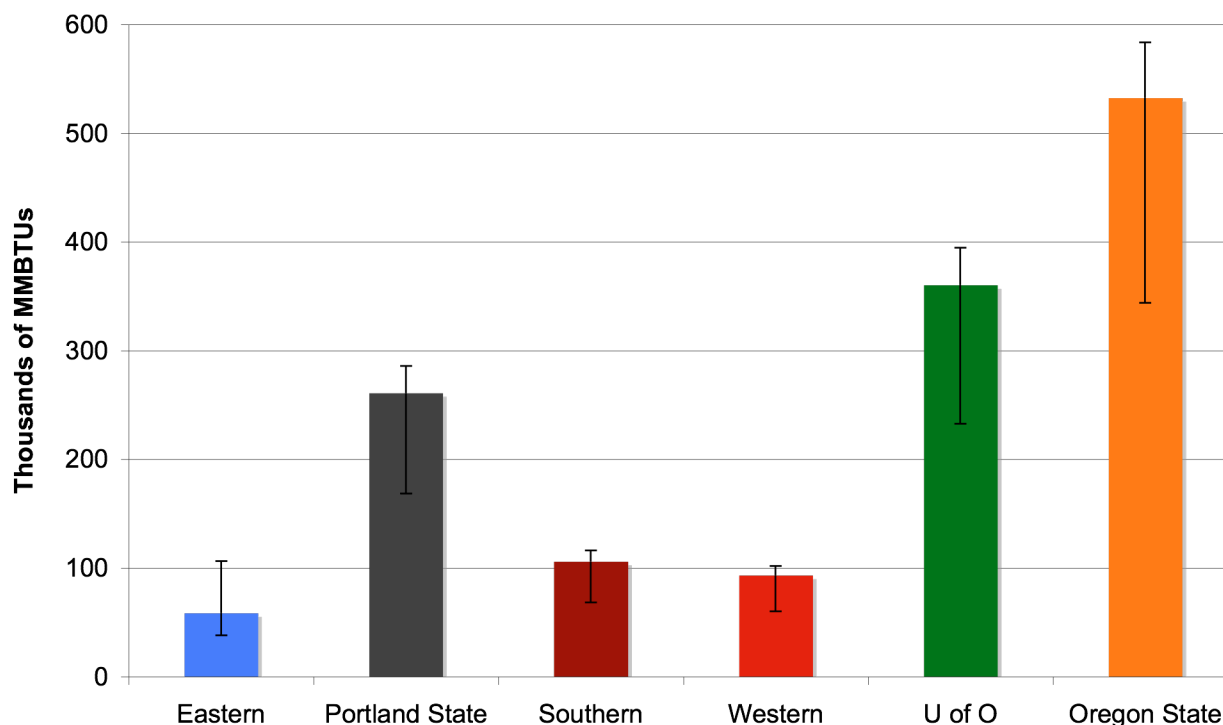

1990 Electricity Estimate - Sensitivity Analysis

Figure 5: Sensitivity analysis for natural gas consumption in 1990, by OUS institution.

1990 Natural Gas Estimate - Sensitivity Analysis

Note: OIT is excluded from the natural gas calculations because its consumption is negligible (as a result of its geothermal resource). Therefore, its consumption relative to the CBECS benchmark provides no guidance regarding to the other institutions' consumption.

There is no additional sensitivity analysis necessary in translating electricity and natural gas consumption into greenhouse gas emissions. Thus, the range of estimates of energy consumption *is*, with appropriate unit conversions (to MT CO_2e), the range of GHG calculations. Tables 3 and 4 below show the GHG conversions from the underlying data used to generate the graph above.

Table 3: 1990 estimates of GHG emissions from electricity, by OUS Institution.

OUS Institution	1990 point estimate MT CO_2e	low estimate MT CO_2e	high estimate MT CO_2e
Eastern	2,884	2,462	3,164
Portland State	13,797	11,780	15,135
Southern	5,061	4,321	5,552
Western	4,557	3,891	4,999
U of O	17,062	14,568	18,717
Oregon State	24,606	21,009	26,994
OIT	2,054	1,754	2,253
OUS Emissions:	**70,020**	**59,785**	**76,814**

Table 4: 1990 estimates of GHG emissions from natural gas (or wood waste), by OUS institution.

OUS Institution	1990 estimate MT CO_2e	low estimate MT CO_2e	high estimate MT CO_2e
Eastern	3,130	2,021	5,666
Portland State	9,545	8,993	15,259
Southern	5,650	3,648	6,190
Western	4,966	3,207	5,441
U of O	34,535	22,299	37,838
Oregon State	25,249	18,350	31,136
OIT	92	72	183
OUS Emissions:	83,167	58,590	101,713

Note: University of Oregon emissions are estimated using the wood and wood waste emissions factor and should be considered and reported as biogenic GHG emissions per California Climate Action Registry Power Generation/Electric Utility Reporting Protocol.

The sums of these ranges provide the overall range for the 1990 GHG baseline, as presented on the first page of this memo. To recap:

Table 5: Summary of 1990 GHG baseline, with uncertainty range

2008 Building Energy Emissions	1990 Baseline Building Energy Emissions	1990 - High Estimate	1990 - Low Estimate
188,779 MT CO_2e*	Point Estimate: **153,187 MT CO_2e**	178,528 (17% above point estimate)	118,375 (23% below point estimate)

*Value includes natural gas and electricity emissions (regional emissions factor) taken from Sightlines GHG inventory.

The following tables provide the electricity, natural gas and total energy use in tabular form.

Table 6: Estimates of 1990 electricity use, actual data and CBECS benchmarks.

OUS Institution	1990 / 1993			2004	
	1990 estimate Thousands of MMBTUs	constructed actual Thousands of MMBTUs	CBECS benchmark Thousands of MMBTUs	actual Thousands of MMBTUs	CBECS benchmark Thousands of MMBTUs
Eastern	31	-	39	32	33
Portland State	148	101	185	158	171
Southern	54	-	68	38	59
Western	49	-	61	33	53
U of O	183	-	229	156	262
Oregon State	264	215	330	287	309
OIT	22	-	28	24	25

Table 7: Estimates of 1990 natural gas / wood waste use, actual data and CBECS benchmarks.

OUS Institution	1990 / 1993			2004	
	1990 estimate Thousands of MMBTUs	constructed actual Thousands of MMBTUs	CBECS benchmark Thousands of MMBTUs	actual Thousands of MMBTUs	CBECS benchmark Thousands of MMBTUs
Eastern	59	-	36	63	32
Portland State	261	97	158	120	153
Southern	106	-	64	81	56
Western	93	-	56	74	51
U of O	360	-	218	493	249
Oregon State	533	414	322	564	305
OIT	2	-	27	1	23

Note: The Sightlines-reported value for PSU's FY2008 natural gas consumption was <u>substituted</u> for the 2004 consumption. This change was necessary because the 2004 value reported in the Sightlines GHG inventory is implausibly low, in addition to known accounting changes due to changes in PSU's service providers for building management and energy.

Table 8: Estimates of 1990 total building energy use, actual data and CBECS benchmarks.

OUS Institution	1990 / 1993			2004	
	1990 estimate Thousands of MMBTUs	constructed actual Thousands of MMBTUs	CBECS benchmark Thousands of MMBTUs	actual Thousands of MMBTUs	CBECS benchmark Thousands of MMBTUs
Eastern	90	-	74	95	65
Portland State	409	198	343	278	323
Southern	160	-	132	119	115
Western	142	-	118	107	104
U of O	543	-	447	649	510
Oregon State	797	629	653	852	614
OIT	24	-	54	25	48

Note: Values for the CBECS benchmarks in Table 8 are merely the sums from the previous two tables.