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Expanding the Concept of Energy Use Intensity (EUI):

A Proposal to GSA's Green Building Advisory Committee

By the EUI Task Group

1.0 Introduction: Why Revisit EUI?

Site Energy Use Intensity (EUI), traditionally, is a simple quotient of energy delivered to a building divided by its area (typically expressed in Btu per square foot per year (Btu/sq.ft.-yr). This definition serves the purpose of normalizing comparisons between buildings, but leaves out increasingly important factors impacting energy usage. A Source EUI, as recommended by the Energy Star program, additionally takes into account all transmission, delivery, and production losses for the energy used by a building. [1]

Two critical factors rarely considered are Occupant Density and Transportation. Two buildings with very similar Traditional EUIs, observed through the lenses of Transportation and Occupant Density, may be revealed to have very different energy use patterns.

A building with higher occupancy, say, 150 square feet (sq. ft.) per occupant, may have similar Traditional EUI as another with 300 sq. ft. per occupant due to higher plug loads. But the building with 150 sq. ft. per occupant may have a fraction of the energy use of the other building, once occupancy is factored in (i.e., energy use per person). Similarly, two buildings with similar Traditional EUIs may look very different in comparison to one another once the energy expended for travel to and from the building is accounted for. A building primarily accessed by pedestrians, bicyclists and/or public transportation will likely have much less overall energy use than another dependent exclusively on automobiles for access, even though they may have similar Traditional EUIs.

Based upon this nuanced understanding of building energy use intensity, the Green Building Advisory Committee advises the GSA to redefine building EUI for the purposes of its portfolio. A redefined EUI can guide the GSA on location choice, planning and design and tracking the energy use of its buildings. In turn, GSA practice can inform the

[1] See EPA ENERGY STAR program on source vs. site EUI: http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/understand-metrics/difference

entire universe of Federal Government buildings. Piloting a redefined EUI would be a reasonable way to roll this program out.

What follows is a proposed redefinition developed by the Green Building Advisory Committee. Though the GSA should consider developing these initial ideas further, basic findings to date suggest action can be taken now to reap the benefits of the new EUI approaches. The factors proposed in the following pages, both for Occupancy-based EUI and for Transportation-based EUI are meant to be complementary. By considering an expansion of the traditional definition of EUI to capture both facility and transportation energy usage, we will gain strategic insights as to how facility location and facility utilization can impact energy use per building occupant.

2.0 Factoring Occupant Density into EUI

2.1 Background

Buildings with lower Traditional EUIs are considered to be more energy efficient than buildings with higher Traditional EUIs, and conventional energy conservation measures usually result in a lowered EUI for the building. For this reason, Executive Order 13693[2] requires each Federal Agency to reduce the EUI of its buildings in steps to 25% by 2025. However, as explained in Section 1, there is a need for a nuanced redefinition of Traditional EUI that factors in Occupancy-based EUI and Transportation-based EUI. This section will focus on Occupancy-based EUI.

Each occupant in a building has an energy footprint. The workplace as a facility requires energy during work hours and non-work hours to operate the building systems and technology.

As an example, a 2010 study of GSA's headquarters building[3] found that workers were at their desks only one-third of the time due to business travel, vacation, sick leave and other absences. An effective hoteling strategy for such a building could potentially accommodate the same number of employees in a building half the size, with resulting reductions in lease costs, maintenance costs, etc. While such reduced space would shrink needs for heating and cooling, the increased occupancy could cause energy use per square foot to increase, given that lighting, electronics, water heating, and other

[2] Executive Order 13693, *Planning for Federal Sustainability in the Next Decade*, Retrieved from: https://sftool.gov/learn/annotation/447/executive-order-13693-planning-federal-sustainability-decade

[3] U.S. General Services Administration. (2010). *Leveraging Mobility, Managing Place: How Changing work Styles Impact Real Estate and Carbon Footprint*. http://www.gsa.gov/portal/mediaId/171183/fileName/Leveraging_Mobility_508_compliant.action

uses unrelated to heating and cooling account for over half of the energy use in commercial buildings.[4]

Moving from a Traditional EUI to Occupancy-based EUI would provide a more accurate understanding of the true energy footprint of a building. This approach can help planners better structure programs, share resources, and plan telework programs. It could also help reduce the underutilization of costly and energy intensive facilities across the nation and serve as a template for more effective real estate utilization approaches in general.

2.2 Occupancy-Based EUI: Proposed Metrics & Methodology

2.2.1 Crafting a New Occupancy-Based EUI Metric

The Traditional EUI definition based on Btu/sq.ft.-yr. should continue to be utilized as a metric based on energy per gross building area[5]. An Occupancy-based EUI can be developed based on *full time equivalent occupancy (FTEO)*. This new concept would allow more accurate estimation of energy use per actual occupant, with occupancy assumed to be the act of occupying the building space – hence not including those working outside the office during the hours in question. An occupant is defined as a physical person known or estimated to be in the building.[6]

FTEO would build on the long-established concept of an FTE. Full time equivalent (FTE) is defined by the Government Accountability Office (GAO) as the number of total hours worked divided by the maximum number of compensable hours in a full-time schedule as defined by law. The normal schedule for an FTE in a year is defined as 1645 hours [35 hours per week * (52 weeks per year – 5 weeks regulatory vacation)]. Regulatory vacation may be defined as federal holidays plus average annual leave hours earned per year. We believe the annual hours in the denominator used for calculating FTE should be constant for all facilities.

Badge in/badge out card readers could be used to calculate actual building occupancy for each hour, where such systems exist. There may be other means such as IT onsite log-in tallies, carbon-dioxide monitoring, people counting systems used in museum or

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[4] U.S. Department of Energy. (2015). Buildings Energy Databook. Table 3.1 : Commercial Sector Energy Consumption. http://buildingsdatabook.eere.energy.gov/TableView.aspx?table=3.1.5

[5] The American Society of Heating Refrigeration & Air-Conditioning Engineers (ASHRAE) Standard 105-2014 defines gross floor area as the sum of the floor areas of all the spaces within the building with no deductions for floor penetrations other than atria. It is measured from the centerline of wall separating buildings, but it excludes covered walkways, open roof-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, roof overhangs, parking garages, surface parking, and similar features.

[6] A variant on FTEO, full time equivalent remote occupancy (FTERO), may also inform the Occupancy-based EUI. Remote workers may not impose a direct energy use footprint, per se, but may do so indirectly by availing of, say, technology support that in turn has an energy footprint.

retail settings, etc. The precise means of determining occupancy may vary based upon available resources and sources of information. We recognize it can be difficult to accurately determine the annual occupant hours for various building types and the Committee remains open to occupancy calculations based upon these suggested methods or others.

The sum of the occupancy for each hour of the year divided by FTE annual hours would provide the Full Time Equivalent Occupancy for buildings predominantly occupied by employees. (Additional calculations may be needed for buildings with high transient occupancy, such as medical facilities and courthouses.)

$$FTEO = \frac{Total\ Annual\ Occupied\ Person\ Hours}{1645\ Hours}$$

To establish a baseline for verifying the accuracy of techniques for measuring or estimating the occupied hours it was recommended that GSA conduct a study to count incoming and outgoing personnel during each weekday and over a weekend during 2-3 typical (representative) weeks in 1 or more representative office buildings (e.g., 1 with just employees and 1 with high transient occupancy). This would help identify expected daily variations in occupancy schedules.

A new Occupancy-based EUI metric can then be developed, utilizing the occupant density (FTEO density) of ft2/FTEO such that Btu/ft2-yr x FTEO density (ft2/FTEO) = FTEO energy intensity (Btu/FTEO-yr).

Responding to the recommendation, the GSA, with funding from the DOE, conducted a study this year through the Pacific Northwest National Laboratory (PNNL) led by Kathleen Judd and Abinesh Selvacanabady. Two GSA buildings were studied, the GSA Headquarters in Washington, DC and the Byron Rodgers Federal Building in Denver, CO.

The results of this study indicated that as the occupant density of these facilities increased, the energy use per incremental occupant was minor compared to the base building energy consumption. This indicates that basic facility functions such as lighting, plug loads and common heating and cooling were not dramatically impacted as occupant density was increased.

However, the study did find a striking difference in traditional area-based EUIs and FTEO-based EUIs when the building occupancy increased. For instance, when the assigned occupancy increased from 2500 to 4400 in the GSA HQ Building, the Traditional EUI increased by 7% while the FTEO EUI decreased by 39%. As the federal government evaluates ways to better utilize buildings by increasing occupant density, the FTEO EUI metric and its implications become important to consider.

More work is needed to define the Occupancy-based EUI and to validate how increases in occupant density impact energy use at different types and scales of projects, i.e. courthouses, office buildings, medical facilities, and mixed use facilities. GSA facility planning guidelines can be enhanced with considerations based on Occupancy-based EUI information. Guidelines could also perhaps complement the ASHRAE Advanced Energy Design Guides (AEDG) that help stakeholders and planners envision better energy performance for many types of facilities.

3.0 Factoring Commuter Transport Energy into EUI

3.1 Background

Transportation has been shown to be a key contributor to the environmental and energy impact of buildings. Its impact can be greater than that of the embodied energy (energy that went into the materials and construction of the building) and the operational energy (energy used to maintain, warm, cool and power the building), often by orders of magnitude[7]. Locations of buildings, therefore, have a key impact on the overall energy use associated with those buildings. For that reason, an additional metric to the Traditional EUI measure is proposed here, to include and account for the impact of transportation on buildings' overall environmental impact.

Buildings that are conveniently accessed by walking, bicycling and public transportation (i.e. buildings located in downtowns and urban areas) tend to have much lower energy use, not only as it pertains to transportation but overall, than buildings that are primarily accessed by Single Occupancy Vehicles.

Transportation choices, or lack thereof, impact not only the main commute of the day, but also mid-day and workday travel, for instance to meetings, jobsites, lunch, coffee, etc. It is traditionally assumed that an employee commutes to the workplace, spends the workday at their station and commutes back at the end of the workday. From contemporary practice, though, we know this model not to be completely accurate any more. Consequently, a framework to measure Transportation Energy Use Intensity is proposed, so as to encourage the GSA to progressively move its portfolio away from automobile-oriented access toward a more diverse transportation-accessible environment.

3.2 Proposed Metrics & Methodology

[7] Source: Norman, et. al. (2006). Comparing High and Low Residential Density: Life-Cycle Analysis of Energy Use and Greenhouse Gas Emissions. *Journal of Urban Planning and Development.* Vol. 132, Issue 1

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3.2.1 Introduction

Occupant commuter transportation to and from a building plays an important but often underestimated role in the building's overall site-specific energy efficiency and sustainability. All things being equal, buildings that are more easily accessible by public transit, bicycling, or walking are more sustainable than buildings that are mostly or exclusively accessible by automobiles.

The task group proposes to develop a new transportation energy metric in the same unit as Traditional EUI – BTU/sq.ft.-yr. These metrics are intended to be comparable and incremental to the proposed Occupancy-based EUI metric. Translating energy consumption into attendant greenhouse gas emissions (also normalized per square foot) will be achieved using commonly acceptable, third-party conversion formulae and methods.

3.2.2 Potential Use of Metrics

There are two potential approaches to using the proposed transportation energy metrics. First, the metrics could be used to evaluate the commuter transportation energy of buildings in relation to each other. This method enables decision makers to compare potential workplace sites to occupy at a snapshot in time based on the location of the buildings, estimated vehicle miles traveled (VMT) by building occupants, and estimated number of building occupants or commuters. This method would require *relative* accuracy in comparing buildings.

Second, the metrics could be used to track energy and GHG emissions from commuter transportation over a period of time for a region or agency. This method would require *absolute* accuracy to reflect the impact of local management decisions. In both cases, the focus is on the direct combustion of energy and emissions from passenger vehicles commuting and does not include the production or distribution of fuel (i.e. wells-to-wheels emissions).[8]

3.2.3 Definition of Metrics and Assumptions

As mentioned, the proposed metrics are focused on the site-specific energy of a building and its corresponding commuter transportation energy and emissions for passenger vehicles. In order to calculate BTU/sq.ft.-yr., the following data requirements, conversion factors, and equations are proposed to estimate energy and GHG emissions from commuter transportation.

[8] This may be revisited in the future based on new developments and information about the carbon intensity of fuels, factoring in such considerations as the carbon intensity of fossil fuels from hydraulic fracturing and the dramatic increase in electric vehicles' market penetration.

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Vehicle miles traveled (VMT) is defined as the "number of miles traveled nationally by vehicles for a period of one year" according to the Federal Highway Administration (FHWA).[9] We will define VMT as the number of miles traveled by building occupants who commute to a specific building or region. Each building or region has commuters who travel different distances and by different modes of transportation. A representative or average VMT per occupant per day can be multiplied by the average number of commuting days in order to estimate how much travel is done to and from a building or region annually.

(a)

$$\frac{VMT}{occupant * day} \times 250\ commuting\ days = \frac{VMT}{occupant * year}$$

A representative or average VMT/occupant-year will then be multiplied by the estimated number of building occupants per GSF to determine total VMT/GSF-year.

(b)

$$\frac{VMT}{occupant * year} \times number\ of\ occupant/GSF\ = \frac{VMT}{GSF * year}$$

VMT/GSF-year will be divided by the 2016 average fuel efficiency of U.S. light duty vehicles (22.1 miles per gallon [mpg])[10], which includes passenger cars, light trucks, vans, and sport utility vehicles with a wheelbase equal to or less than 121 inches.[11] The result is an estimate of gallons per GSF per year.

(c)

$$\frac{VMT}{GSF * year} \div 22.1\ mpg\ = \frac{gallons}{GSF * year}$$

Although vehicle fuel use varies depending on the vehicle (e.g., gasoline, diesel, hybrid, electric, etc.), we will focus on the larger majority of vehicles that are single occupancy vehicles running on gasoline. Based on U.S. consumption in 2015, one gallon of

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[9] U.S. Department of Transportation, Federal Highway Administration. (Sept 2014). *Planning Glossary: V*. Retrieved from http://www.fhwa.dot.gov/Planning/glossary/glossary_listing.cfm?sort=definition&TitleStart=V

[10] U.S. Energy Information Administration, Annual Energy Outlook 2016, Table: Transportation Sector Key Indicators and Delivered Energy Consumption, from http://www.eia.gov/forecasts/aeo/data/browser/#/?id=7-AEO2016&region=0-0&cases=ref2016~ref_no_cpp&start=2014&end=2017&f=A&linechart=ref2016-d032416a.5-7-AEO2016~ref_no_cpp-d032316a.5-7-AEO2016&sourcekey=0

[11] U.S. Department of Transportation, Bureau of Transportation Statistics. (2015). *Table 4-23: Average Fuel Efficiency of U.S. Light Duty Vehicles*. Retrieved from http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_23.html

gasoline is equivalent to 120,405 British thermal units (Btu) or 120.405 kBtu.[12] Therefore:

(d)

$$\frac{gallons}{GSF * year} \, x \, \frac{120{,}405 \; Btu}{gallon} = \frac{Btu}{GSF * year}$$

In sum, T-EUI may be calculated as follows:

(e)

$$BTU \; per \; person \; per \; day = \frac{VMT}{22.1 \; mpg} x \; 120{,}405 \; Btu$$

3.2.4 Assessment of VMT Tool Estimates

We have identified two primary tools available to GSA that can provide VMT data. The first tool is the GSA Public Buildings Service (PBS) Urban Development/Good Neighbor Program's Smart Location Calculator (SLC), which recently became publicly available at https://www.slc.gsa.gov/slc/#. The tool provides a Smart Location Index (SLI), VMT estimate, and emissions estimate based on a provided address location.

The tool is census block based and only requires limited information such as employee count and male/female breakdown of the workforce. It calculates average commuter distances in urban and semi-urban areas based on CBSAs (core-based statistical areas). Currently, the tool provides estimated percentages of people who travel by single occupancy vehicles, carpools, walking/biking, and public transit.

The second tool is GSA's Carbon Footprint Tool (CFT), which offers the Scope 3 Commuter Survey for use by federal agencies to capture Scope 3 Employee Commute information and to report emissions to DOE FEMP.[13] The survey collects commuter information such as estimated VMT, type of transportation, carpool/vanpool, and number of commute days. Commuter greenhouse gas emissions are calculated using the White House-supplied Federal Greenhouse Gas Accounting and Reporting Guidance (June 2012).[14] The survey collects data and calculates GHG emissions as million metric tons of CO_2 equivalent per commuter.

[12] U.S. Energy Information Administration. (Last updated: August 9, 2016). *Energy Units and Calculators Explained*. Retrieved from http://www.eia.gov/energyexplained/?page=about_energy_units

[13] U.S. General Services Administration. (2015). *GSA Carbon Footprint Tool: Scope 3 Commuter Survey*. Retrieved from https://www.carbonfootprint.gsa.gov/?Page=surveyRequest

[14] White House Council on Environmental Quality. (June 2012). *Federal Greenhouse Gas Accounting and Reporting Guidance Technical Support Document*. Retrieved from https://www.whitehouse.gov/sites/default/files/federal_greenhouse_gas_accounting_and_reporting_guidance_technical_support_document.pdf

Noblis, a contractor to GSA, conducted an analysis to assess the pros and cons of these two tools, examining several addresses for comparison. Table 1 in Appendix I shows a comparison of VMT estimates for locations in the DC Metropolitan area. While the Carbon Footprint Tool measures actual employee trip VMT (based on survey data), the Smart Location Calculator uses the characteristics of VMT data from all workplaces in the vicinity.

As a result, the CFT numbers are heavily driven by characteristics of surveyed individuals while the SLC numbers are driven by characteristics of place. In order to compare one potential site to another, the SLC numbers may be more relevant. If trying to influence trip management programs within a specific workplace, the CFT numbers would be more relevant. In short, both tools have pros and cons depending on what one is trying to measure and the types of decisions one is trying to inform. Table 2 in Appendix I summarizes pros and cons of each tool.

The SLC provided the advantage for purposes of this Task Group proposal of being simple and convenient to use and not requiring significant data-gathering, while allowing for meaningful comparisons of the relative location efficiency of selected addresses within the same metropolitan area. As a result, the Task Group worked successfully with the GSA PBS Urban Development/Good Neighbor Program to incorporate the proposed Transportation EUI (T-EUI) metric into the SLC tool.

T-EUI is now calculated and featured along with other metrics when one selects the "Show Statistics" button that appears on the left side of the SLC screen after the user inputs any building address. The SLC User Guide, available at the bottom of the screen, is being updated to explain and provide background on this new metric.

The Task Group appreciates GSA's collaboration in revising this tool to incorporate the proposed T-EUI metric and encourages greater promotion and dissemination of the SLC to encourage its use.

4.0 A Redefined EUI – Game Changing

Traditional EUI, then, is proposed to be enhanced with new complementary versions of the EUI: an Occupancy-based EUI factor and a Transportation-based EUI factor. These three EUI factors can then be used to compare buildings, make location choices, measure the success of energy conservation measures, help shrink the building footprint, etc.

The energy impact of improved planning around facility occupant density and transportation simply cannot be understated. Long difficult energy intensive commutes degrade commuter personal time and readiness, consume a massive share of our national energy budget, and contribute greatly to the climate change impacts already well under way. Facilities not efficiently utilizing their space end up using more energy per occupant than those that are appropriately and thoughtfully densified, meaning that we can serve the same number of occupants with smaller facility footprints while harvesting the energy savings per person served.

Appendix I

Table 1 – Comparison of Carbon Footprint Tool (CFT) and Smart Location Calculator (SLC) VMT Estimates* **

Site Name	Site Address	CFT VMT	SLC VMT*	Percent Difference
National Museum of Natural History	1000 Constitution Ave NW, Washington DC 20560	22.5	17	-24.4%
Capital Gallery	600 Maryland Ave SW, Washington DC 20560	24	17	-29.2%
William Jefferson Clinton Building	1200 Pennsylvania Ave NW, Washington DC 20004	15.4	17	10.4%
Environmental Science Center	701 Mapes Road, Fort Meade, MD 20755	24.6	22	-10.6%
One Potomac Yard	One & Two Potomac Yard, Arlington, VA 22202	21.5	20	-7.0%
Stafford Place	4201 Wilson Boulevard, Arlington, VA 22230	27.1	18	-33.6%
	Average Consistency:			**-15.7%**

*Assumes a 50/50 male and female split for all buildings.

**For DC metropolitan area. Additional comparisons are available for locations in New York City, Kansas City (MO), and Atlanta (GA).

Table 2 – Pros and Cons of VMT Tool Estimates

	Pros	Cons

Carbon Footprint Tool (CFT)	• Available to all Federal agencies to capture Scope 3 Emissions
	• More detailed commuter survey information is available
	  ○ Multiple modes of transportation
	  ○ Carpool/vanpool information
	• Potential to create additional
		• CFT facility-level data not readily available to GSA and requires time and effort to obtain specific data
		• Need permission to use or publish agency-specific data
		• Quality and usefulness of data depends on whether agencies use the tool and how many users complete the survey

	analyses • Reflects Federal workforce behaviors rather than general populace behaviors	• Some agencies set up survey to report VMT/GHG in aggregate rather than at building level
Smart Location Calculator (SLC)	• VMT and GHG estimates readily available with provided location information • Requires only high level information about building occupants • Interactive results and display for users • VMT estimates appear comparable to CFT's survey results	• Model based on assumption of national average travel behavior for areas outside the National Household Travel Survey • GHG emissions only account for CO_2 emissions at this time • Results are based on general populace behaviors rather than Federal workforce behaviors

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Appendix II

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