Note: This draft proposal represents the deliberations of a task group to an independent advisory committee, and may or may not be consistent with current GSA policy.

Expanding the Concept of Energy Use Intensity: A Proposal to GSA's Green Building Advisory Committee

Introduction

This proposal seeks to identify concepts for GSA and other Federal agencies to apply facility energy metrics that address wider energy use impacts resulting from facility decisions. The traditional Energy Use Intensity (EUI) discussion has tracked facility interior energy per square foot per year expressed in kBtu or GJ. This is a well-established metric that has been applied to over 100,000 buildings.[1]

If we leverage the value of current EUI metrics and additionally consider two more factors – 1) the user population density (occupants, which may include agency staff and visitors) of each facility and 2) the transportation energy necessary for users to access the facility -- we arrive at a more comprehensive energy picture. A new suite of metrics, building upon traditional EUI, would allow Federal agencies to consider a variety of factors as appropriate to their missions and circumstances. These wider considerations would help inform decision makers about the energy impacts and thus greenhouse gas emissions of their options when considering facility design and location. Such metrics could be used to assess both existing and new facility arrangements.

Following this logic, GSA's Green Building Advisory Committee advanced the following motion:

> Form a working group to develop guidelines for creating a new energy intensity metric that factors energy use intensity and passenger miles traveled by employees to more accurately indicate how densified facilities, centrally located workplace sites that reduce overall commuting, and expansion of telework and hoteling result in overall lower energy use per hour worked. The purpose of the new metric is to add a useful level of transparency to facility planning, design and workplace decision effectiveness to reduce overall energy use.

An EUI Task Group pursuing this motion recommends the following proposal for the full Advisory Committee's consideration:

- **Develop a new facility energy metric that correlates annual energy used per facility divided by the number of agency staff and visitors served by the facility in order to more accurately convey site specific energy efficiency.**
- **Develop a new transportation energy metric that correlates annual energy used per agency staff and visitors served by the facility in order to more accurately convey site specific energy efficiency. Express the energy used per person for facilities (Scope 1 and 2) and transportation (Scope 3) in the same units to derive a single unit to further assist strategic decision makers when seeking lower energy solutions.**

[1] ENERGY STAR: http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/understand-metrics/what-energy

Note: This draft proposal represents the deliberations of a task group to an independent advisory committee, and may or may not be consistent with current GSA policy.

Energy Use Intensity to Density Metric

> Develop a new facility energy metric that correlates annual energy used per facility divided by the number of agency staff and visitors served by the facility in order to more accurately convey site specific energy efficiency.

The energy a building consumes is a direct result of the function it serves, the design of the building, hours of operation, and the local climate. The baseline of how energy efficient a building is remains foundational to understanding overall energy efficiency. However, with the advent of efficiency initiatives that seek to reduce the size and number of facilities (e.g., Reduce the Footprint), we find that some agencies have had success with flexible workplace ideas such as teleworking, hoteling, and greater sharing of common resources. We also see that each facility design presents unique spatial opportunities that impact the user population density. Importantly, the population served correlated to the energy used varies widely from one facility to the next.

A more useful measure of how energy efficient a facility is rests in not only on considering traditional EUI metrics but on going well beyond and factoring in both staff and the public (customer) populations to arrive at a new metric that is total energy consumed by the building in one year per person served by the building. For this we can assume that a full time equivalent (FTE) of 1.0 for agency staff and the public (visitors, patients, litigants, passengers, prisoners, etc.) population represents one person. A method for addressing public access as FTE versus agency staff could also be determined. The new term could be Full Time Equivalent Occupant (FTEO). Further, the FTEO correlated to kBtu/ft2-year could be generated by an inverse occupant density of ft2/FTEO then assigning the kBtu/person-year. Significant areas of public access could be zoned separately from staff areas in such tabulations.

We can also see that different agencies and facilities have very different missions and thus their spatial requirements per person and energy used per person will vary according to the facility type. Also, the hours of operation affect the overall efficiency per person. For instance an office facility that is only open 40 hours per week also usually expends considerable energy in the other 88 hours per week the building is not used so when the energy used per person is considered the entire 168 hours of operation each week is correlated to each user. Conversely a hospital, prison, or command center may be nearly fully occupied by users the full 168 hours per week, leading to possibly higher efficiencies per person for continuously occupied facilities than facilities used only 24 percent of the time (40 hours per week worked divided by 168 hours per week operated).

A metric that correlates facility energy usage to each user is a far more useful metric than simply considering the energy used per square foot. Such a metric encourages facilities to be used more efficiently with better space planning and perhaps operated for more hours per week, such as through shift work in hoteling arrangements or additional hours of operation as appropriate, e.g., at court facilities, outpatient centers, and call centers. Complimentary uses can also be considered where conference centers and break spaces are shared between programs and perhaps used for longer hours than each separate agency operates. [2]

GSA Space Usage Facts:

- Vacancy rate: 4.3%
- Square footage: overall GSA has 378 million rentable square feet, with many small buildings but a small percentage of very large buildings account for a disproportionate % of the space: 39% of square footage is in buildings over 100k square feet.

(Source: GSA Public Buildings Service State of the Portfolio FY13 http://www.gsa.gov/portal/mediaId/202479/fileName/SOTP13_FINAL_10202014.action)

- "As part of its 'Freeze the Footprint' program GSA is reducing per-employee office space allocations in GSA-occupied space, which will significantly reduce Scope 1 and 2 GHG emissions from internal operations. By FY 2017, GSA will reduce Usable Square Feet (USF) per office based employee to 150 USF/person, down from 296 USF/person in FY 2013. By the end of FY2014, GSA will reduce USF/employee to 282 (a 4.5 percent reduction from FY 2013)."

(Source: GSA's FY14 Strategic Sustainability Performance Plan, http://www.gsa.gov/portal/mediaId/199747/fileName/GSA_FY_2014_SSPP.action)

Transportation Energy Metric

Develop a new transportation energy metric that correlates annual energy used per agency staff and visitors served by the facility in order to more accurately convey site specific energy efficiency. Express the energy used per person for facilities (Scope 1 and 2) and transportation (Scope 3) in the same units to derive a single unit to further assist strategic decision makers when seeking lower energy solutions.

Transportation is a key consumer of energy and greenhouse gas emitter in the United States. Transportation consumes 28% of all primary energy and 76% of petroleum fuels[3], and emits 27% of greenhouse gas emissions in the United States. Transportation energy thus is a key influence in the overall sustainability of office buildings. Buildings that have transportation options that include walking, bicycling and public-transportation are more sustainable than those that are exclusively or almost exclusively accessed by automobile.

[2] An important outcome of this approach may be that established facilities that represent a very significant public investment often over many decades may be comparably efficient to a new facility on a new site if the energy used per person is measured rather than the energy used per square foot. Though beyond the scope of this task, such facilities also represent considerable embodied energy (in this case the energy used to mine, harvest, process, manufacture, ship, and construct the facility) that would be entirely lost and then expended once again if a new facility were built and the old one demolished.

[3] U.S. Energy Information Administration, *Monthly Energy Review,* June 2014, table 2.1, preliminary data for 2013: http://www.eia.gov/totalenergy/data/monthly/archive/00351406.pdf

Note: This draft proposal represents the deliberations of a task group to an independent advisory committee, and may or may not be consistent with current GSA policy.

It is the recommendation of this group, therefore, that energy consumed in transportation to and from buildings be commonly used as a metric for the energy efficiency of GSA owned and leased buildings, in the same way as building operating energy is used today. The easiest and most practical way of achieving this will be to devise a metric that measures transportation energy specific to each facility. An independent consultant or an academic institution could help the GSA arrive at this metric, and/or it may be able to borrow from existing metrics or tools. Some, but not all[4], factors that could contribute to the Transportation Energy Metric for facilities could be:

1. Mode-mix, what fraction of the staff and customers access it by automobiles, transit, and by other means?
2. Trip length, what is the average length of the trip to the facility and back?
3. Utilization, what is the per-occupant (occupant: staff and customer) square footage?
4. Settlement density, what is the nature of the neighborhood, town, city and region that surrounds the building?
5. Transit options, how many train/subway stations, bus-stops, shuttles are close to the facility?
6. Bike-ped options, how many bike and pedestrian paths lead to the facility?

An illustration, but not necessarily prescriptive direction, of what a Transportation Energy Metric can look like is the "Transit Score" generated by the same people who gave us "Walk Score" – www.walkscore.com

Other, more academic and possibly more rigorous, examples exist of the evaluation of the location's environmental impact on a building. The Center for Neighborhood Technologies (www.cnt.org) have used geo-spatial analysis to do this. They have a Housing + Transportation Index that they have created (http://htaindex.cnt.org/map/) which could be adapted for the workplace for generating a Transportation Energy Index for GSA owned or rented buildings.

For more detail on methodologies employed to date in analyses and tools, please see Appendices I & II below.

Next Steps

Both metrics, EUI/FTEO and Transportation Energy, need to be developed in a way that assures they are both easy to understand and to use. A combined metric that includes both building operational energy (energy/FTEO-year) and transportation energy for each FTEO could be developed if both factors are

[4] The operational energy and embodied energy of parking lots and garages should be factored in to transportation. The first costs and operational costs of both are very significant in all climates and in colder climates these facilities present an enhanced burden of snow and ice management and corrosion and paving failures. The footprint of these facilities is immense and presents a significant loss of GHG abating forest and ground cover in all climates. Such facilities also do not last that long as they need to be significantly overhauled or even replaced sooner than the facility. A facility that is not burdened with parking such as urban locations that are served by existing transit present a far lower carbon footprint.

expressed in the same units. The two could be directly additive if the transportation energy is derived from total vehicle miles traveled data, converted to energy units, divided by FTEO. Transportation energy would be expressed as energy/FTEO-year that would be added to the building energy in the same units. We could compute these for a standard work week then multiply by 52 for the year. From data reported in the past, the transportation energy would likely be the greater of the two factors.

The metrics above should be fully transferable and scalable among federal agencies and importantly equally adaptable to private non-governmental facilities.

As the purpose of these two metrics is to provide new tools to support agency decision makers who are seeking even more value from both existing facilities and new facilities, these tools need to be attractive to decision makers above the facility planning level because they can directly support workplace planning at both a strategic level. These new metrics derive their value from the intertwined considerations of people, facility, and transportation and how comprehensive solutions can result in even better performance on many levels.

A tremendous benefit of a holistic view that uncouples simple square footage from energy is that it may help uncover unforeseen new efficiencies by agency, region, facility type, campus, and at each building through use of these metrics.

Appendix I: Measuring Commuter Transportation Energy – An Annotated Bibliography

Center for Neighborhood Technology. (March 2015). The Housing and Transportation (H+T) Affordability Index Methods. http://htaindex.cnt.org/about/HT_Index_Methods_2013.pdf

The Center for Neighborhood Technology's H+T Index is a well-known tool that measures the affordability of housing by calculating the transportation costs associated with a home's location. The model uses multidimensional regression analysis to describe relationships between transportation and household/local environment variables. The latest version of the transportation cost model estimates three components of travel behavior (dependent variables): auto ownership, auto use, and transit use. The H+T Methods also provides a list of data sources from Federal sources and other transit data sources.

Center for Neighborhood Technology. (2011). Transportation Energy Intensity (TEI) Calculator, Beta. http://tei.cnt.org/index.php

The following excerpt taken from Weigel's literature review in "Estimation of Potential Transportation and Building Energy Performance of Commercial Office Site Alternatives" (2015) provides a concise critical review of the Center for Neighborhood Technology's TEI Calculator:

"The calculator estimates a location's TEI in kBtus per day based on the address, the number of employees (stratified across ranges of earnings), and the number of days during the year that the building is in operation. The TEI calculator's estimates of commute travel origins and mode choice are based on the 2000 Census Transportation Planning Products (CTPP) Part 3 (Worker/Employee Census Tract Matrix) dataset (USGBC 2011). Mode-specific energy consumption factors and straight-line travel distance estimates for origin and destination pairs are used to calculate trip energy consumption. These approximate methods do not account for unique travel distance and speed characteristics that exist on a particular transportation network. The calculator's ability to estimate current year and future year trip patterns is significantly limited by the utilization of survey activity data. Although estimated trip origins, trip distance, and mode choice have considerable uncertainty, the TEI calculator does not explicitly account for uncertainty in the estimated travel activity or energy consumption." (Weigel, 2015)

Davis, S.C., Diegel, S.W., Boundy, R.G. (July 2014). Transportation Energy Data Book: Edition 33. Prepared for the U.S. Department of Energy by *Oak Ridge National Laboratory*. ORNL-6990. http://cta.ornl.gov/data/tedb33/Edition33_Full_Doc.pdf

The *Transportation Energy Data Book: Edition 33* is designed for use as a publically available, desk-top reference. The book "represents an assembly and display of statistics and information that characterize transportation activity, and presents data on other factors that influence transportation energy use." Chapter 2 contains information relating to energy consumption by end-use sector, source, mode, and fuel type. Chapter 8 can provide useful information and statistics such as means of transportation to work, workers by commute time, average annual vehicle-miles, vehicle trips, and trip length per household. Chapter 11 contains information related to transportation greenhouse gas emissions that can also be useful.

ENERGY STAR ® (2015). *What is Energy Use Intensity (EUI)?* US Environmental Protection Agency and US Department of Energy. http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/understand-metrics/what-energy

The ENERGY STAR website defines energy use intensity (EUI) as the total energy consumed by a building in one year (kBTU or GJ) divided by the total gross floor area of the building. The website also summarizes typical EUI values for property types (e.g., hospital, office, hotel, retail store and etc.). Some property types are more energy intensive than others, but having a low EUI general signifies good energy performance according to ENERGY STAR.

Fowler, K. et al. (2011). Re-Assessing Green Building Performance: A Post Occupancy Evaluation of 22 GSA Buildings. *Pacific Northwest National Laboratory (PNNL).* http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19369.pdf

PNNL's study examines 22 GSA buildings from seven GSA regions and compares them to industry and GSA baselines.

The Transportation section, beginning on page 67, captures occupant commute CO_2 equivalent emissions and aggregates CO_2 emissions for both transportation and the building in Table 23. Information for the transportation metric was collected using the Sustainable Places and Organizational Trends (SPOT) survey. CO_2 equivalent emissions per occupant were calculated based on population density and roundtrip commute (measured in metric tons).

General Services Administration. (2015). GSA Carbon Footprint Tool: Scope 3 Commuter Survey. https://www.carbonfootprint.gsa.gov/?Page=surveyRequest

The Scope 3 Commuter Survey can be used by federal agencies to capture Scope 3 Employee Commute information and to report emissions to DOE FEMP. The survey was first deployed for agencies in FY2010 with more than 18,000 employees participating. Commuter greenhouse gas emissions are calculated using the White House supplied Federal Greenhouse Gas Accounting and Reporting Guidance (June 2012), page C-2. The survey collects data and calculates GHG emissions as million metric tons of CO2 equivalent per commuter, which means there is potential to derive energy use (BTU) per commuter with additional assumptions and data.

Jonathan Rose Companies. (March 2011). Location Efficiency and Housing Type: Boiling it Down to BTUs. http://www2.epa.gov/sites/production/files/2014-03/documents/location_efficiency_btu.pdf

The purpose of this white paper is to analyze and portray the relationship between household energy consumption and residential development patterns. Two key points this study illustrates is that 1) a home's location relative to transportation choices has a large impact on energy consumption and 2) housing type is also a very significant determinant of energy consumption.

The authors of this paper show the methodology step-by-step and include formulas to calculate combined housing-related and transportation-related energy consumption for conventional suburban houses and transit oriented houses. Although this study focused on the energy consumption of residential homes and related transportation, the methodology could be modified to examine the relationship between office buildings and transportation energy consumption.

Moudon, A.V. & Stewart O. (June 2013). Tools for Estimating VMT Reductions from Built Environment Changes. Prepared for the Washington State Department of Transportation. http://www.reconnectingamerica.org/assets/Uploads/20130601wa-rd-806.3.pdf

This report prepared for the Washington State Department of Transportation summarizes factors associated with travel behavior and mode choice and tools to estimate travel and related outcomes.

Ramsey, K. & Bell, A. (March 2014). Smart Location Database Version 2.0 User Guide. Environmental Protection Agency (EPA). http://www2.epa.gov/sites/production/files/2014-03/documents/sld_userguide.pdf

The Smart Location Database (SLD) is a free and publically available product provided by the U.S. EPA Smart Growth Program. The SLD User Guide contains a detailed description of the data sources and methodologies used to calculate variables in the database. The purpose of the tool is to assist users in comparing the location efficiency of different locations. The SLD utilizes data from the Census 2010 block groups in conjunction with several demographic, employment and built environment variables.

The Technical Approach of this user guide provides details and equations for calculating urban design (street network density and intersection density), transit service (availability, proximity, frequency and density), and destination accessibility, among many other variables. In order to maximize usage of this tool, users should have the appropriate geodatabase software program (i.e., ArcGIS) and a working knowledge of geodatabases. In addition to the database files that can be downloaded for use, Smart Growth provides an online, interactive map viewer with limited capabilities and data sets from the full database. Reading the *Tips for Using the Smart Location Database Mapping Tool* is recommended.

Weigel, B.A. (March 2015). Estimation of Potential Transportation and Building Energy Performance of Commercial Office Site Alternatives. *Journal of Urban Planning and Development*, 141(1) 04014016.

Weigel, B.A. (2012). *Development of a Commercial Building/Site Evaluation Framework for Minimizing Energy Consumption and Greenhouse Gas Emissions of Transportation and Building Systems.* Georgia Institute of Technology. https://smartech.gatech.edu/handle/1853/44735

The objective of this research paper is to apply a calculation framework for estimating the potential transportation energy and building energy consumption of commercial office building alternatives. The calculation framework was applied to four case studies of commercial office development in Atlanta, Georgia. The author determines that transportation is a major determinant of commercial office building energy performance as a result of his research.

While it would be difficult to apply and extend the author's methodology across nationwide sites, parts of the methodology could be adapted to help formulate a transportation EUI metric. For example, the author has equations to calculate CO_2, CH_4, and N_2O emissions from fuel use (pg. 186), provides types of transportation demand management (TDM) strategies (pg. 160), and provides data on non-home based trips to/from worksites by trip purpose (Table 16, pg. 191).

Wilson, A. & Navaro, R. (Sept 2007). Driving to Green Buildings: The Transportation Energy Intensity of Buildings*.* *Environmental Building News* 16 (9). https://www2.buildinggreen.com/article/driving-green-buildings-transportation-energy-intensity-buildings

The authors of this article propose "transportation energy intensity" (TEI) as a new metric of building performance. They define the TEI of a building as the "amount of energy associated with getting people to and from that building." The authors cite calculations and data from the *Environmental Building News (EBN)*, U.S. Department of Transportation, and other experts to support their claim that transportation plays a large role in a building's operational energy. They recommend focusing on eight factors to reduce the transportation energy use of buildings: density, transit availability and access, mixed use and access to services, parking management, walkability, connectivity, bicycle accessibility, and improved efficiency of transportation options.

Note: This draft proposal represents the deliberations of a task group to an independent advisory committee, and may or may not be consistent with current GSA policy.

Appendix II: Overview of Transportation Energy/ GHG Emissions Measurement Analyses & Tools

Title	Type of Source	Purpose	Methodology	Scope	Inputs/Variables	Outputs	Primary Data Sources
Location Efficiency and Housing Type: Boiling it Down to BTUs[5]	White paper	Portray relative differences in energy consumption	Based on a formula	Residential focus on broad level	• Housing type • Type of residential development • Average miles per year per household • Average # of automobiles per house • Passenger MPG • BTUs per gallon • # of commuters per household • commute miles per person per day • BTUs per passenger mile	• Million BTU Per Year	• Energy Information Administration's 2005 Household RECS • Transportation Energy Data Book • Center for Neighborhood Technology • Nation Transit Database of Federal Transit Administration
Center for Neighborhood Technology H+T Index[6]	Index and mapping tool	Measures the affordability of housing	Multidimensional regression analysis	Residential and commercial, Location based down to the census block level, covers 917 Metropolitan and Micropolitan areas	• 13 total independent variables • Median household income • Average household size • Average commuters per household • Employment Access Index • Block density • Transit Connectivity Index • Average transit trips per week	• Results are captured in H+T mapping tool • Auto ownership • Auto use • Transit use	• 2009-2013 American Community 5-year Estimate (ACS) • U.S. Census • 2013 National Transit Database • Consumer Expenditure Survey • AllTransit

[5] Jonathan Rose Companies. (March 2011). Location Efficiency and Housing Type: Boiling it Down to BTUs. http://www2.epa.gov/sites/production/files/2014-03/documents/location_efficiency_btu.pdf

[6] Center for Neighborhood Technology. (March 2015). The Housing and Transportation (H+T) Affordability Index Methods. http://htaindex.cnt.org/about/HT_Index_Methods_2013.pdf

Title	Type of Source	Purpose	Methodology	Scope	Inputs/Variables	Outputs	Primary Data Sources
Center for Neighborhood Technology TEI Calculator[7]	TEI Calculator and mapping tool	Estimate a location's TEI in kBTUs per day	Uses mode-specific energy consumption factors and straight-line travel distance estimates	Residential and commercial, Specific to a location address	• Address location • Number of employees • Number of days during the year the building is in operation • Building characteristics	• Transportation energy intensity (kBTUs per day) • Transportation Carbon Intensity (lbs CO2 per day)	• 2000 Census Transportation Planning Products
Re-Assessing Green Building Performance: A Post Occupancy Evaluation of 22 GSA Buildings[8]	Pacific Northwest Natl Lab (PNNL) Study for GSA	Evaluate building performance	Collecting and analyzing actual performance data in comparison to industry baselines	22 sustainably designed GSA buildings	• Occupant commute data from SPOT survey • Percent of occupants who commute using mass transit • Average daily roundtrip miles traveled per occupant • Transportation CO2 equivalent per occupant (metric tons)	• Transportation MTCO2 equivalent emissions • Building MTCO2 equivalent emissions • Aggregate CO2 Emissions Performance	• Sustainable Places and Organizational Trends (SPOT) survey results
Development of a Commercial Building/Site Evaluation Framework[9]	PhD Thesis	New evaluation framework that includes building and transportation components	Use of travel surveys, regional travel and demand models, energy and emissions software	Four commercial building locations in Atlanta, Georgia	• Building site occupancy • Motorized vehicle trip reduction (VTR) • Annual motorized frequency • Trip origins • Mode choice • Annualized trip energy and GHGs • Non-home based trips (mode	• Annual building and transportation GHG emissions • Annual Energy Consumption (BTUs) • Annual GHG	• Transportation Energy Data Book • Emission dog Greenhouse Gases in US 2008 by DOE • U.S. Green Building Council • ASHRAE • ENERGY STAR

[7] Center for Neighborhood Technology. (2011). Transportation Energy Intensity (TEI) Calculator, Beta. http://tei.cnt.org/index.php

[8] Fowler, K. et al. (2011). Re-Assessing Green Building Performance: A Post Occupancy Evaluation of 22 GSA Buildings. *Pacific Northwest National Laboratory (PNNL).* http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19369.pdf

[9] Weigel, B.A. (2012). *Development of a Commercial Building/Site Evaluation Framework for Minimizing Energy Consumption and Greenhouse Gas Emissions of Transportation and Building Systems.* Georgia Institute of Technology. https://smartech.gatech.edu/handle/1853/44735

Note: This draft proposal represents the deliberations of a task group to an independent advisory committee, and may or may not be consistent with current GSA policy.

Title	Type of Source	Purpose	Methodology	Scope	Inputs/Variables	Outputs	Primary Data Sources
					and frequency)	emissions per 100 employees • Annual energy consumption per 100 employees	
GSA Carbon Footprint Tool: Scope 3 Commuter Survey[10]	Agency survey tool	Capture Scope 3 Employee Commute information and to report emissions to DOE FEMP	Surveys commuting patterns and converts to GHG emissions using established emissions factors	Commercial buildings focus on Federal agency level	• Commuter data (frequency, distance, mode of travel) • Sum mileage • Average number of commuting days within agency • Sum transportation mode emissions • Miles traveled (MT)	• GHG emissions as million metric tons of CO2 equivalent per commuter	• Federal Greenhouse Gas Accounting and Reporting Guidance Technical Support Document

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