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Impact of More Precise Construction Data on Estimated Savings from Energy Standard Adoption for Commercial Buildings

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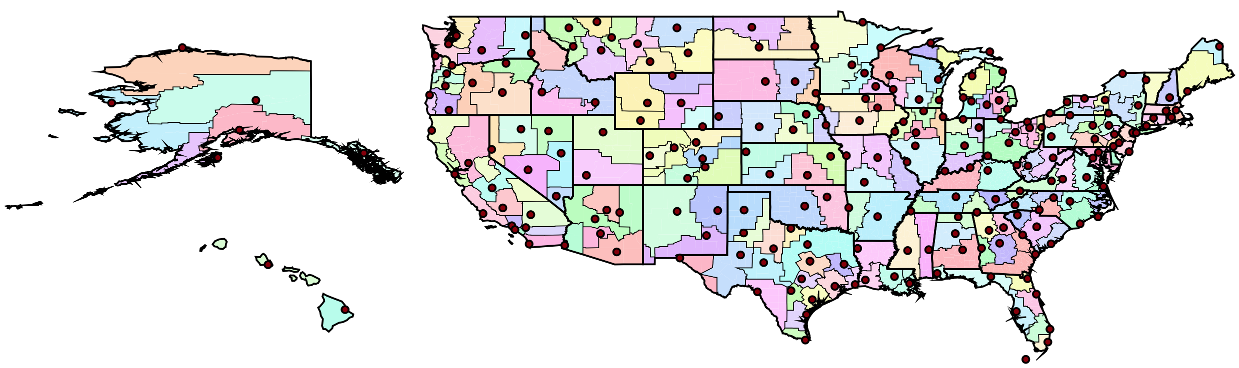

National Institute of Standards and Technology
U.S. Department of Commerce

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Impact of More Precise Construction Data on Estimated Savings from Energy Standard Adoption for Commercial Buildings

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Abstract

The Applied Economics Office (AEO) of the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST) has developed the Building Industry Reporting and Design for Sustainability (BIRDS) database, which estimates the sustainability (energy, economic, and environmental) performance for eleven commercial building prototypes designed to different energy efficiency levels. Analysis of the BIRDS database estimates both the average percentage change in energy consumption and the aggregate changes in energy consumption for one year's worth of new construction for each U.S. state. Due to the limited publically-available new construction data, the estimates are calculated by giving equal weighting to all the cities in a state that are included in the BIRDS database. However, such an approach leads to underweighting the importance of cities with more new construction and overweighting cities with less new construction.

The purpose of this study is to explore the impact of implementing a non-equal weighting approach on state-level energy consumption impacts of adopting a more restrictive state energy code. New construction floor area completion data for 2012 was obtained for each county in the United States to assist in increasing the accuracy of these impact estimates.

Keywords

commercial buildings; whole building energy simulation; energy efficiency; new construction data; geospatial mapping

Preface

This study was conducted by the Applied Economics Office (AEO) in the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST). The study is designed to compare the sensitivity of estimated savings from energy standard adoption to the precision of the construction data. The intended audience includes researchers in the building sector concerned with energy performance in buildings.

Disclaimers

The policy of the National Institute of Standards and Technology is to use metric units in all of its published materials. Because this report is intended for the U.S. construction industry that uses U.S. customary units, it is more practical and less confusing to include U.S. customary units in addition to metric units. Measurement values in this report are therefore stated in metric units first, followed by the corresponding values in U.S. customary units within parentheses.

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Author Information

Joshua D. Kneifel
Economist
National Institute of Standards and Technology
100 Bureau Drive, Mailstop 8603
Gaithersburg, MD 20899-8603
Tel.: 301-975-6857
Email: joshua.kneifel@nist.gov

David Butry
Economist
National Institute of Standards and Technology
100 Bureau Drive, Mailstop 8603
Gaithersburg, MD 20899-8603
Tel.: 301-975-6136
Email: david.butry@nist.gov

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List of Acronyms

Acronym	Definition
AEO	Applied Economics Office
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BIRDS	Building Industry Reporting and Design for Sustainability
CBECS	Commercial Buildings Energy Consumption Survey
EL	Engineering Laboratory
NIST	National Institute of Standards and Technology

1 Introduction

Energy efficiency requirements in current energy codes for commercial buildings vary across states, and many states have not yet adopted the latest editions of *American Society of Heating, Refrigerating and Air-Conditioning Engineers* (*ASHRAE) Standard 90.1*, which is the industry consensus standard to establish the minimum energy-efficient requirements of commercial and non-low-rise residential buildings. Some states do not have a code requirement for energy efficiency, leaving it up to the locality or jurisdiction to set its own requirement. There may be significant energy savings to be realized by states if they were to adopt more recent editions of the commercial building energy standards.

The Applied Economics Office (AEO) of the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST) has developed the Building Industry Reporting and Design for Sustainability (BIRDS) database, which estimates the sustainability (energy, economic, and environmental) performance for eleven commercial building prototypes designed to different energy efficiency levels.[1] The analysis in Kneifel (2013a, 2013b, 2013c, 2013d, 2013e) uses the BIRDS database to estimate both the average percentage change in energy consumption and the aggregate changes in energy consumption for one year's worth of construction for each U.S. state. Due to the limited publically-available new construction data, the estimates are calculated by giving equal weighting to all the cities in a state that are included in the BIRDS database. However, such an approach leads to underweighting the importance of cities with more new construction and overweighting cities with less new construction.

The purpose of this study is to explore the impact of implementing a non-equal weighting approach on state-level energy consumption impacts of adopting a more restrictive state energy code. New construction floor area completion data from 1970 to 2012 was obtained from McGraw-Hill Dodge Construction database (2013) for each county in the United States to assist in increasing the accuracy of these impact estimates. Each county is associated with one of the 228 cities in the BIRDS database, creating a "cluster" of counties that use the average performance of each building type for the associated city to estimate the impacts of adopting a more stringent state energy code.

[1] For details on the design of the BIRDS database, see Kneifel (2011) and Kneifel (2012).

2 City Average Approach

The calculations used in previous analyses of the BIRDS database were twofold: (1) average percentage change in annual energy consumption in a state and by building in a state and (2) aggregate change in annual energy consumption in a state. They were calculated using a city average approach, detailed below.

The ***average percentage change in annual energy consumption in a state*** is estimated using what will we have defined as the city average approach (CAA) as:

$$(1)\ E_{PCT,j}^{CAA} = \frac{\sum_{i \epsilon B}^{I_p} \frac{\sum_{k}^{K_j} E_{PCT,ijk}}{K_j}}{I_p}$$

where $E_{Pct,j}$ = weighted-average percentage change in energy consumption for state *j*,
$E_{Pct,jik}$ = percentage change in energy consumption for city *k* for building type *i* for state *j*,
I_p = number of prototype building types,
B = set of prototype building types, and
K_j = number of cities in state *j*.

The percentage change in annual energy consumption in a state ($E_{PCT,j}^{CAA}$) is calculated in two steps. First, calculate the average percentage change across all cities *K* in a state for building type *i* ($E_{PCT,ij} = \frac{\sum_{k}^{K_j} E_{PCT,ijk}}{K_j}$). Second, calculate the average of those average changes for all building prototypes in the state ($\frac{\sum_{i \epsilon B}^{I_p} E_{PCT,ij}}{I_p}$). The approach results in equal weighting across cities and building types.

This is mathematically equivalent to the following, which is the calculation implemented to calculate the results and allows for direct comparisons across approaches:

$$(2)\ E_{PCT,j}^{CAA} = W_{1,j}^{CAA} * \sum_{i \epsilon B}^{I_p} \sum_{k}^{K_j} E_{PCT,ijk}, \text{ and}$$

$$(3)\ W_{1,j}^{CAA} = \frac{1}{K_j I_p}$$

The approach leads to equal weighting for each city and building type.

The ***average percentage change in annual energy consumption in a state by building type*** is estimated using the city average approach as:

$$(4)\ E_{PCT,ij}^{CAA} = W_{2,j}^{CAA} * \sum_{k}^{K_j} E_{PCT,ijk}, \text{ and}$$

$$(5)\ W_{2,j}^{CAA} = \frac{1}{K_j}.$$

Again, an equal weighting structure results.

The ***aggregate change in annual energy consumption in a state*** is estimated using the city average approach as:

$$(6)\ E_{CFA,j}^{CAA} = \frac{\sum_{i\epsilon B}^{I_p} CFA_{ij} * \frac{\sum_{k}^{K_j} E_{CFA,ijk}}{K_j}}{\frac{\sum_{i\epsilon B}^{I_p} CFA_{ij}}{\sum_{i}^{I} CFA_{ij}}},$$

where $E_{CFA,j}$ = total change in energy consumption for state j,
CFA_{ij} = newly constructed floor area for building type i for state j in 2012,
$E_{CFA,ijk}$ = change in energy consumption per unit of floor area for city k for building type i for state j,
I = number of (all) building types, and
I_p = number of prototype building types.

The aggregate change in annual energy consumption in a state ($E_{CFA,j}^{CAA}$) is calculated in three steps. First, calculate the average change per unit of floor area across all cities K in a state for building type i ($E_{CFA,ij} = \frac{\sum_{k}^{K_j} E_{CFA,ijk}}{K_j}$). Second, calculate the aggregate change for building type i ($E_{CFA,ij}^{CAA}$) in the state by multiplying the change per unit of floor area ($E_{CFA,ij}$) by the amount of new floor area for building type i in the state (CFA_{ij}). Third, sum the aggregate changes for all prototype building types I_p ($\sum_{i\epsilon B}^{I_p} E_{CFA,ij}^{CAA}$) and divide by the fraction of statewide newly constructed floor area represented by the prototype buildings ($\frac{\sum_{i\epsilon B}^{I_p} CFA_{ij}}{\sum_{i}^{I} CFA_{ij}}$). This final adjustment is to account for the new floor area not accounted for by the prototype buildings in the database. [2]

This is mathematically equivalent to the following:

$$(7)\ E_{CFA,j}^{CAA} = \sum_{i\epsilon B}^{I_p} W_{3,ij}^{CAA} \sum_{k}^{K_j} E_{CFA,ijk},$$

$$(8)\ W_{3,ij}^{CAA} = \frac{CFA_{ij}}{K_j \frac{\sum_{i\epsilon B}^{I_p} CFA_{ij}}{\sum_{i}^{I} CFA_{ij}}},$$

[2] A key assumption is that the impacts for the building prototypes included in the BIRDS database are representative of all new construction in a state.

The ***aggregate change in annual energy consumption in a state by building type*** is estimated using the city average approach as:

$$(9)\ E_{CFA,ij}^{CAA} = W_{4,ij}^{CAA} \sum_{k}^{K_j} E_{CFA,ijk},$$

$$(10)\ W_{4,j}^{CAA} = \frac{CFA_{ij}}{K_j}.$$

As is shown in Formula (6), the aggregate approach, implemented in previous analyses of the BIRDS database, estimates energy consumption savings that result from adoption of more stringent state energy codes. This approach uses new construction data aggregated at the state level. Jarnagin and Bandyopadhyay (2010) use the Commercial Buildings Energy Consumption Survey (CBECS) and McGraw-Hill Dodge Construction data on new commercial building construction by building type within a state. The Commercial Buildings Energy Consumption Survey (CBECS) is a sample survey that collects information on the existing stock of U.S. commercial buildings. The sample includes 5215 buildings across the U.S. in 14 building type categories, as shown in Table A-1. These categories include: education, food sales, food service, health care, lodging, mercantile, office, public assembly, public order and safety, religious worship, service, warehouse and storage, other, and vacant. The survey data do not report the age or specific location of the building to protect the confidentiality of the respondents. The McGraw-Hill dataset includes data for all new commercial buildings and additions, with over 254 000 records and 761.8 million m^2 (8.2 billion ft^2) of new construction, for 2003 through 2007. The data are more detailed than the CBECS data, and includes year of construction and location.

Jarnagin and Bandyopadhyay (2010) map the more detailed McGraw-Hill dataset to the CBECS categories and subcategories shown in Table 2-1. The prototype commercial buildings analyzed in this study, shown in **bold**, represent 46.4 % of nationwide new commercial building stock square footage for 2003 through 2007. However, for this study a prototype building is assumed to represent its entire CBECS category (e.g. secondary school also represents primary school), which implies the prototypes together represent 56.8 % of the new commercial building stock for 2003 through 2007.

Table 2-1 New Commercial Building Construction (U.S., 2003 through 2007)

Building	Detail	Conditioned Floor Area 1000 m^2 (1000 ft^2)	Percentage in Category	Percentage of Total
Office	**Large**	**20 451 (220 134)**	**22.2 %**	**2.6 %**
Office	**Medium**	**37 170 (400 091)**	**40.4 %**	**4.8 %**
Office	**Small**	**34 468 (371 009)**	**37.4 %**	**4.5 %**
Retail		**93 762 (1 009 246)**		**12.2 %**
Strip Mall		34 847 (375 093)		4.5 %
School	Primary	30 697 (330 418)		4.0 %
School	**Secondary**	**63 686 (685 508)**		**8.3 %**
Hospital		21 194 (228 131)		2.8 %
Other Health Care		26 865 (289 171)		3.5 %
Restaurant	**Sit Down**	**4055 (43 650)**		**0.5 %**
Restaurant	Fast Food	3605 (38 809)		0.5 %
Hotel	**Large**	**30 432 (327 562)**		**0.4 %**
Hotel/Motel	Small	10 576 (113 837)		1.4 %
Warehouse		102 746 (1 105 951)		13.4 %
Apartment	**High-rise**	**55 114 (593 241)**	**55.1 %**	**7.2 %**
Apartment	**Mid-rise**	**44 997 (484 343)**	**44.9 %**	**5.9 %**
No Prototype		153 270 (1 649 785)		20.0 %
Total (2003-2007)		767 934 (8 265 977)		100.0 %

The types and floor area of buildings being constructed vary across states. Table A-2, Table A-3, and Table A-4 in the Appendix report new building construction for 2003 through 2007 by building type and state, in total square meters, total square feet, and percentage terms, respectively. Previous studies used these data to aggregate the total savings for the new construction in the CBECS categories represented by the eleven prototype buildings. Nine of the eleven prototype commercial buildings analyzed in this study are covered by data reported in Table 2-1. No data for dormitories are reported, and therefore, statewide impacts of the two types of dormitoriescannot be estimated..

Nationwide average annual construction from 2003 to 2007 is 153.6 million m^2 (1.7 billion ft^2), with significant variation across states from as low as 200 000 m^2 (2.2 million ft^2) to as high as 16.5 million m^2 (177.6 million ft^2), as shown in Figure 2-1.

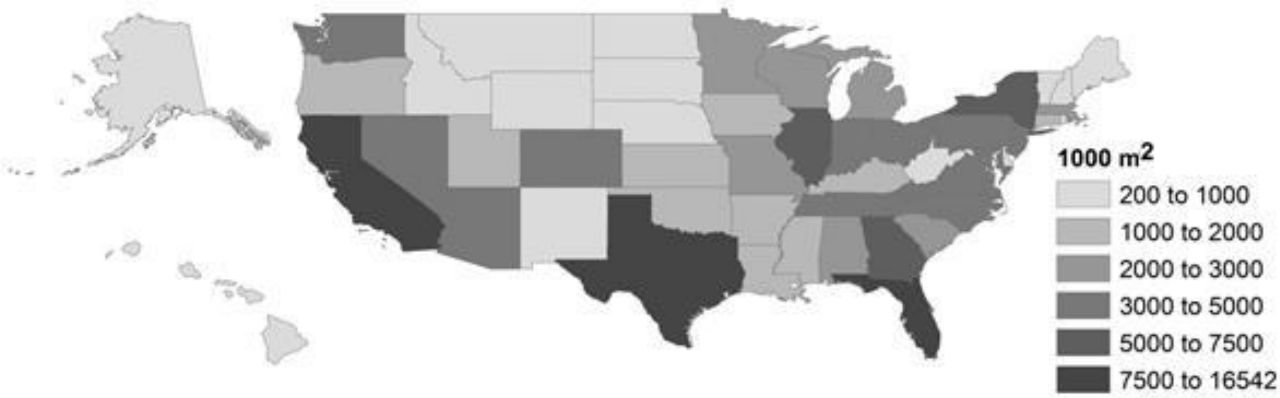

Figure 2-1 New Floor Area by State (1000 m^2)

This study considers the change in energy consumption from adoption of the Low Energy Case (LEC) design (based on ASHRAE 189.1-2009) relative to each state's energy code as of December 2011. The results are shown in Table A-5 in the Appendix in descending order of energy consumption savings. These results are also shown on the map of U.S. states in Figure 2-2, which shows that the change in energy consumption varies from 37 GWh to 3791 GWh. By comparing Figure 2-1 to Figure 2-2, it can be seen that the states with the greatest amount of new floor area (Florida, California, Georgia, Illinois, New York, and Texas) realize the greatest amount of energy consumption savings from adopting the LEC design.

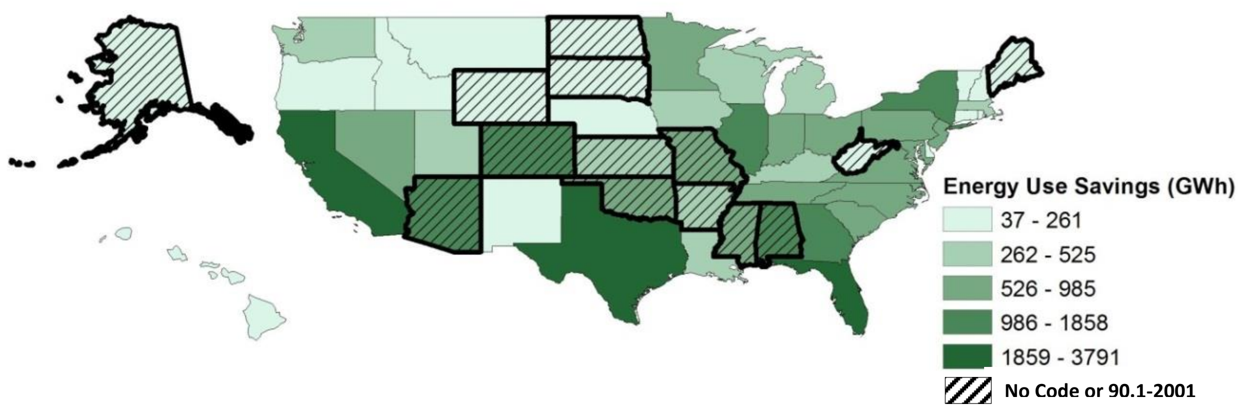

Figure 2-2 Total 10-Year Energy Use Savings by State (GWh)

This analysis approach has its limitations. Each city is weighted equally even though variation in new construction across cities could be significant, leading to overweighting cities with little to no new construction and underweighting cities with greater new construction. Additionally, the publically available construction data covers a time period (2003 to 2007) that is not representative of historical or current construction volume. The timeframe spans the five years of significant expansion immediately before the beginning of the severe economic recession. As a result, the annual construction volume for 2003 to 2007 is significantly higher than the amount of new floor area that has been constructed in more recent years.

3 City Cluster Weighting Approach

In order to address the limitations of the previous approach, a more detailed new-construction database was obtained from McGraw-Hill Dodge Construction, which includes the amount of new floor area for each county in the United States for 1 for the 2012 calendar year.[3] The BIRDS database results are for 228 cities across the United States, and in order to associate these city data with the county construction data it is necessary to determine which city results should be used for each county.

The approach implemented in this study to map the city-level and county-level data is referred to as "clustering," where "clusters" of counties are mapped to a particular city. In this study, a county is matched to the closest city in its state based on distance to the city from the centroid (geometric center of a two-dimensional region) of the county within the same climate zone. If there is not a city located in the same climate zone within the state, then the closet city located within the same state is selected. Of the 3140 counties, 2911 counties are matched to a city within the same climate zone while 229 are matched to a city not within the same climate zone. Figure 3-1 shows the 228 cities in the BIRDS database and their associated county clusters.

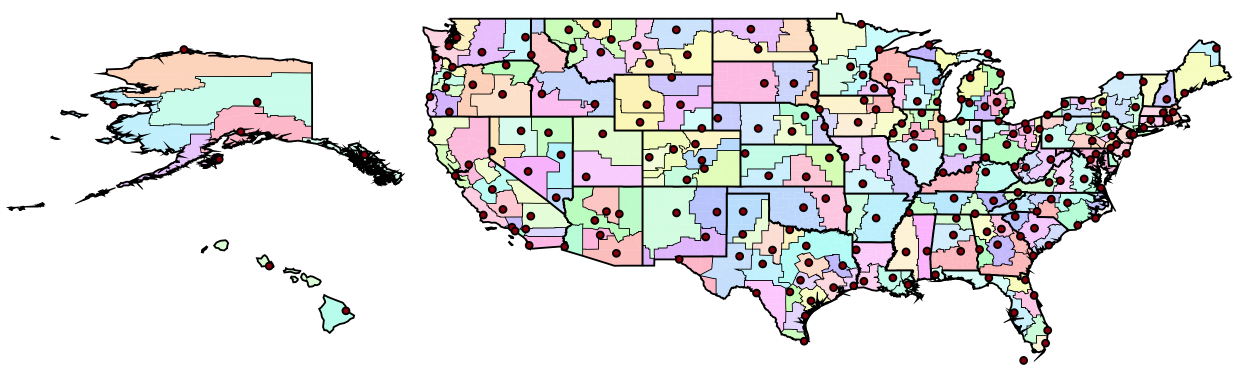

Figure 3-1 Cities and Associated (Colored) County Clusters

Three county-cluster-based weights are used to produce (1) the weighted-average percentage change in energy consumption by state, (2) the weighted-average percentage change in energy consumption by state/building type combination, (3) the aggregate change in energy consumption by state, and (4) the aggregate change in energy consumption by state/building type combination.

The ***average percentage change in annual energy consumption in a state*** is estimated using the city county cluster approach (CWA) as:

(11) $E_{PCT,j}^{CWA} = \sum_{i\epsilon B}^{I_p} \sum_{k}^{K_j} W_{1,ijk}^{CWA} * E_{PCT,ijk},$

[3] McGraw-Hill Dodge Construction (2013)

$$(12)\ W_{1,ijk}^{CWA} = \frac{CFA_{ijk}}{\sum_i^I \sum_k^{K_j} CFA_{ijk}}.$$

The weight ($W_{1,ijk}^{CWA}$) is the proportion of newly constructed floor area for building type *i* in city-county-cluster *k* with respect to total newly constructed floor area within state *j* in 2012. The sum of the percentage changes for building type *i* in city-county-cluster *k* ($E_{PCT,ijk}$) multiplied by its weight over all city-county-clusters and building prototypes is the average percentage change for the state ($E_{PCT,j}^{CWA}$).

The ***average percentage change in annual energy consumption in a state by building type*** is estimated using the city-county-cluster approach as:

$$(13) E_{PCT,ik}^{CWA} = \sum_k^K W_{2,ijk}^{CWA} * E_{PCT,ijk},$$

$$(14)\ W_{2,ijk}^{CWA} = \frac{CFA_{ijk}}{\sum_k^{K_j} CFA_{ijk}}.$$

The weight ($W_{2,ijk}^{CWA}$) is the proportion of newly constructed floor area for building type *i* in city county-cluster *k* with respect to total newly constructed floor area within state *j* for building type *i* in 2012.

The ***aggregate change in annual energy consumption in a state*** is estimated using the city-county-cluster approach as:

$$(15)\ E_{CFA,j}^{CWA} = \sum_{i\epsilon B}^{I_p} \sum_k^{K_j} W_{3,ijk}^{CWA} * E_{CFA,ijk},$$

$$(16) W_{3,ijk}^{CWA} = \frac{CFA_{ijk} \sum_{i\epsilon B}^{I_p} \sum_k^{K_j} CFA_{ijk}}{\sum_i^I \sum_k^{K_j} CFA_{ijk}}.$$

The weight ($W_{3,ijk}^{CWA}$) is the amount of newly constructed floor area by state, cluster, and building type combination normalized by the proportion of newly constructed floor area in the prototypical building types with respect to total newly constructed floor area within state *j* in 2012.

The change per unit of floor area for building type *i* in city-county-cluster *k* ($E_{CFA,ijk}$) multiplied by its weight, and then summed over all city-county-clusters and building prototypes is the average percentage change for the state ($E_{CFA,j}^{CWA}$).

The ***aggregate change in annual energy consumption in a state by building type*** is estimated using the city-county-cluster approach as:

$$(17)\ E_{CFA,ij}^{CWA} = \sum_{k}^{K_j} W_{4,ijk}^{CWA} * E_{CFA,ijk},$$

$$(18) W_{4,j}^{CWA} = CFA_{ijk}.$$

The weight is the amount of newly constructed floor area by state, cluster, and building type combination.

The crosswalk between the building types in the BIRDS database and the McGraw-Hill Dodge Construction project type is shown in Table 3-1.

Table 3-1 Crosswalk between BIRDS buildings and McGraw-Hill Dodge Construction project type and story class combinations

BIRDS	**McGraw-Hill Dodge Construction**	
Building	Project Type	Story Class
A04	Apartments with 5 or more units	Mid-Rise
A06	Apartments with 5 or more units	High-Rise
D04	Lodging	Mid-Rise
D06	Lodging	Mid-Rise
H15	Lodging	High-Rise
HS2	Education	Low-Rise
HS2	Education	Mid-Rise
HS2	Education	High-Rise
O03	Office	Low-Rise
O08	Office	Mid-Rise
O16	Office	High-Rise
RET	Stores	Low-Rise
RET	Stores	Mid-Rise
RET	Stores	High-Rise

Figure 3-2 shows the new floor area constructed in 2012 by both state and county cluster. Depending on the state, the importance of appropriately weighting each city cluster may have a significant impact on the results. For example, major city clusters in Texas (Dallas/Fort Worth, Austin, and Houston) are realizing new construction of over 3.7 m^2 (40.0 million ft^2) while northern Texas clusters have construction of less than 372 000 m^2 (4.0 million ft^2). As a result, the previous approach would lead to under/overweighting by a factor of ten, muting any differences in energy savings across cities.

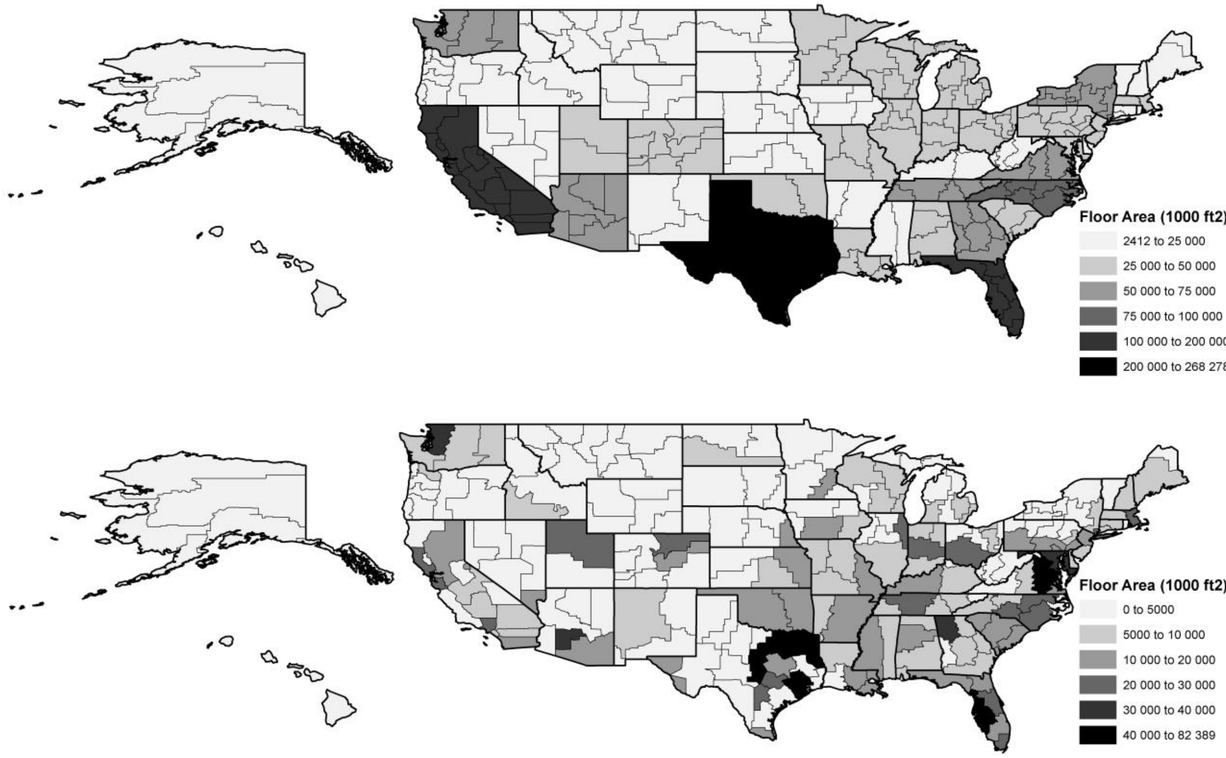

Figure 3-2 New Floor Area by State and County Cluster

This clustering approach leads to more accurate estimates than the previous approach by controlling for both the variation in building performance across a state due to weather as well as the amount of new construction for each building type for each location considered in this study. Additionally, the more recent new construction data (2012) is more representative of current and near-future construction volume because the data is post-recession and less than two years old.

4 Energy Consumption Savings Comparison

In this chapter, the impact of a nationwide adoption of the LEC design as a state's energy code is estimated using the two approaches defined in Section 2 and Section 3 for new construction in 2012. Results are first analyzed in detail for a single state (New York) to show how differences in the amount of new construction across city clusters will impact the magnitude of the energy consumption savings realized by adopting the LEC design as a state's energy code. These results are then calculated and compared for all states in the nation. Finally, the aggregate results are analyzed at the Census region and national level.

4.1 Detailed Impacts for New York State

The amount of new floor area constructed in New York in 2012 was 5.0 million m^2 (53.4 million ft^2). The city average approach calculates the average change in energy consumption per unit of floor area for all cities for each building type, and associates statewide newly constructed floor area to each building type. The city cluster approach uses the same amount of new construction, but each city cluster is weighted based on its associated amount of construction for each building type. Figure 4-1 shows that New York City is the only city cluster that had more than 1.9 million m^2 (20.0 million ft^2) of new construction, Albany is the only cluster with 465 000 m^2 to 929 000 m^2 (5.0 million ft^2 to 10.0 million ft^2), and the other five cities have less than 465 000 m^2 (5.0 million ft^2). As a result, New York is an ideal state with which to test the impact of using the more precise city weighting approach.

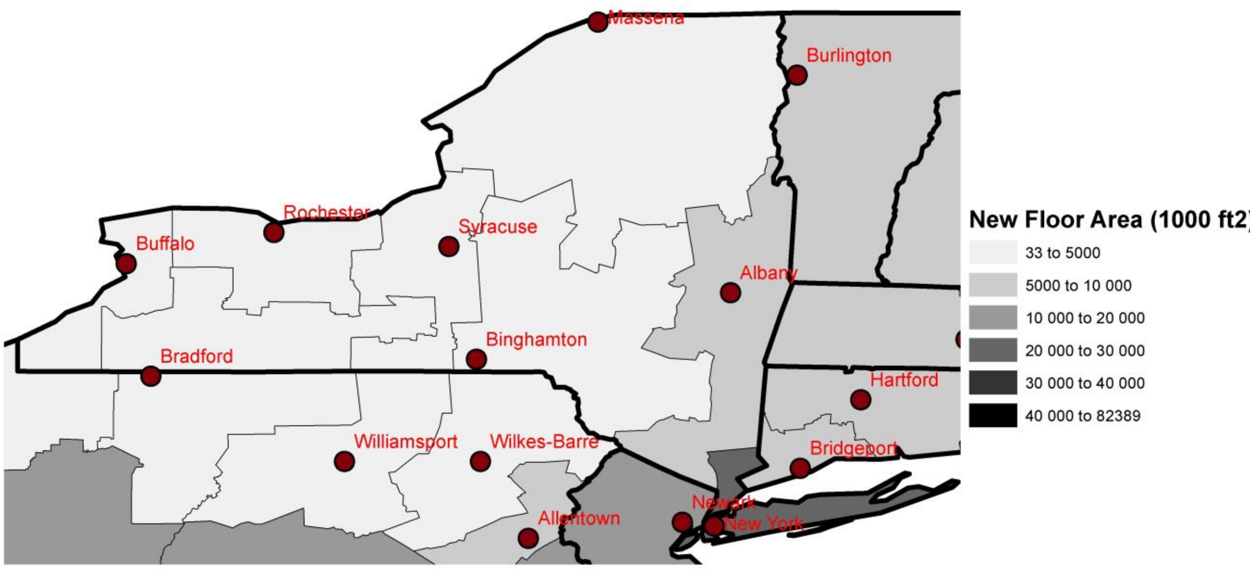

Figure 4-1 New Floor Area by City Cluster for New York

Table 4-1 shows the percentage change in energy consumption and aggregate change in energy consumption for New York State for each weighting approach. The city cluster weighting approach leads to a 1.7 percentage point decrease (11.8 % versus 13.5 %) in the average annual percentage reduction in energy consumption relative to the city average approach. The impact varies across building types due to different types of buildings being constructed in different locations of the state. The greatest difference occurs for the 16-story office building (6.6 %) and 15-story hotel (4.9 %).

Table 4-1 Change in Energy Consumption by Weighting Approach and Building Type - New York

Building Type	Change in Energy Use (%)		Change in Energy Use (GWh)	
	City Average	City Cluster	City Average	City Cluster
A04	-9.2	-10.3	-28 428	-28 335
A06	-9.6	-11.1	-28 569	-26 529
D05[1]	-10.1	-10.4	-10 873	-10 645
H15	-11.2	-16.1	-12 364	-15 669
HS2	-6.2	-8.7	-9227	-10 312
O03	-16.9	-16.8	-5083	-5127
O08	-17.0	-16.5	-2091	-2301
O16	-13.9	-20.5	-9746	-13 103
RET	-12.4	-11.1	-16 832	-15 699
Total	**-11.8**	**-13.5**	**-123 213**	**-127 720**

[1]BIRDS buildings D04 and D06 map to the same McGraw-Hill project type and story class combination. A new 'building' type was created, D05, which is the average of D04 and D06.

The aggregate change in energy consumption is shown to vary across the two weighting approaches. Based on the City Average Approach approach, the estimated yearly energy consumption savings for the prototypical buildings in New York over a 10-year study period is 123 213 GWh. Based on the city cluster approach, the estimated energy consumption savings is 128 000 GWh.

4.2 Aggregate Impacts

The total change in energy consumption by state based on the amount of construction in 2012, for each of the weighting approaches, is presented in Table 4-2. Averaged over all states, the city average weighting approach results in smaller savings, per state, than does the cluster weighting approach (average of 360 GWh). However, the effects are not consistent. For 19 states, the savings are smaller using the city average approach, with Arizona experiencing the largest total difference. For 26 states, the savings are larger using the cluster approach, with Florida showing the largest total difference. For five states, the city average and clustering approach produce identical results because there is only one city for each of those states, in which case there are not multiple cities for which to weight. The difference in nationwide aggregate savings is 17 985 GWh, or 0.3 % of total nationwide aggregate savings.

Table 4-2 Change in State Energy Consumption (GWh) by Weighting Approach

STATE	CITY AVG	CLUSTER	PCT DIFF
ALABAMA	-172 679	-172 154	-0.3%
ALASKA	-20 224	-24 752	22.4%
ARIZONA	-227 327	-213 284	-6.2%
ARKANSAS	-100 822	-100 857	0.0%
CALIFORNIA	-321 313	-325 799	1.4%
COLORADO	-218 658	-227 666	4.1%
CONNECTICUT	-30 820	-30 926	0.3%
DELAWARE	-16 686	-16 686	0.0%
FLORIDA	-300 706	-314 072	4.4%
GEORGIA	-172 637	-169 557	-1.8%
HAWAII	-18 839	-19 842	5.3%
IDAHO	-21 766	-21 135	-2.9%
ILLINOIS	-133 006	-126 683	-4.8%
INDIANA	-119 282	-119 375	0.1%
IOWA	-60 532	-58 014	-4.2%
KANSAS	-116 306	-120 004	3.2%
KENTUCKY	-49 077	-49 512	0.9%
LOUISIANA	-69 830	-70 731	1.3%
MAINE	-35 146	-31 486	-10.4%
MARYLAND	-102 881	-102 881	0.0%
MASSACHUSETTS	-93 607	-95 153	1.7%
MICHIGAN	-58 388	-54 930	-5.9%
MINNESOTA	-150 063	-141 749	-5.5%
MISSISSIPPI	-135 049	-135 985	0.7%
MISSOURI	-171 388	-169 205	-1.3%
MONTANA	-12 522	-14 246	13.8%
NEBRASKA	-28 594	-30 415	6.4%
NEVADA	-27 572	-28 041	1.7%
NEW HAMPSHIRE	-16 738	-16 738	0.0%
NEW JERSEY	-76 482	-77 550	1.4%
NEW MEXICO	-17 417	-17 191	-1.3%
NEW YORK	-203 376	-210 815	3.7%
NORTH CAROLINA	-161 947	-161 884	0.0%
NORTH DAKOTA	-86 962	-86 732	-0.3%
OHIO	-120 417	-121 847	1.2%
OKLAHOMA	-154 549	-153 724	-0.5%
OREGON	-27 474	-29 457	7.2%
PENNSYLVANIA	-136 972	-141 259	3.1%
RHODE ISLAND	-4991	-4991	0.0%
SOUTH CAROLINA	-100 796	-102 879	2.1%
SOUTH DAKOTA	-37 712	-37 759	0.1%
TENNESSEE	-160 339	-162 684	1.5%
TEXAS	-644 137	-644 976	0.1%
UTAH	-72 754	-76 154	4.7%
VERMONT	-10 934	-10 934	0.0%
VIRGINIA	-153 217	-152 597	-0.4%
WASHINGTON	-82 713	-82 012	-0.8%
WEST VIRGINIA	-39 578	-37 785	-4.5%
WISCONSIN	-88 896	-87 158	-2.0%
WYOMING	-26 371	-26 211	-0.6%

Figure 4-2 shows that the state-level results for the city cluster approach are relatively similar to the results using the city average approach. The energy consumption changes by 2.5 % or less for 31 states (62 %) and 5.0 % or less for 41 states (82 %). Using the city cluster approach leads to energy consumption changes greater than 10 % for only three states (Alaska, Montana, and Maine). All three states have relatively small amounts of new construction, which can cause small changes in magnitude to be large percentages.

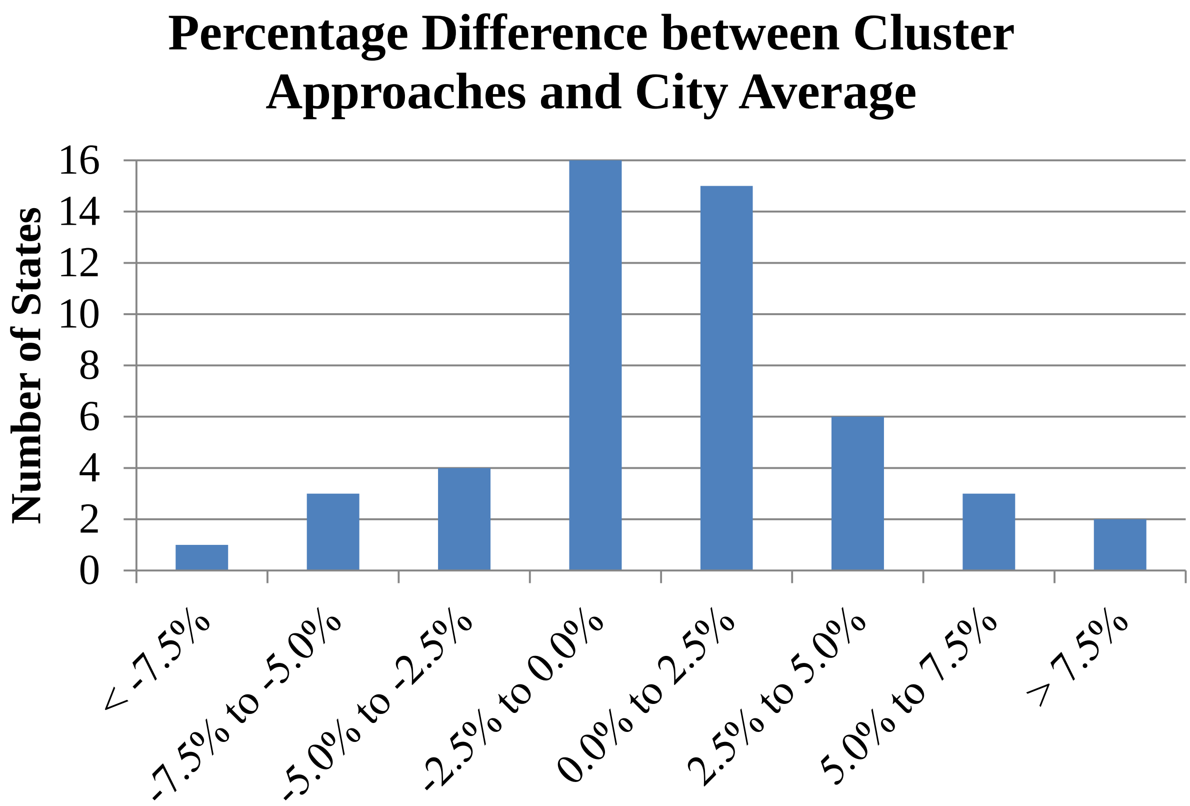

Figure 4-2 Difference between Energy Savings using the City Cluster Approach relative to City Average Approach

5 Discussion, Limitations, and Future Research

This study explores the importance of increased precision in the construction data used to estimate the state-level impacts of more stringent energy efficiency requirements in newly constructed commercial buildings based on the BIRDS database. Newly constructed floor area data for 2012 was obtained for each county in the United States to assist in increasing the accuracy of these impact estimates relative to state-level construction data. Each county is associated with one of the 228 cities in the BIRDS database, creating a “cluster” of counties that use the average performance for each building type for the associated city to estimate the impacts of adopting a more stringent state energy code.

5.1 Analysis

A number of key results have been identified from the analysis in this study. For many states, the amount of new construction by city cluster varies significantly. For example, new construction is over three times greater in the New York City cluster than most of the other city clusters in the State of New York. As a result, there is potential that more detailed construction data could lead to significant impacts on the estimated energy savings. The state average percentage reduction in energy use from adopting the Low Energy Case (LEC) as New York’s state energy code for a given building type can be significantly different depending on the weighting approach used in the analysis, ranging from 0.3 percentage points to 6.6 percentage points, with an average of 1.7 percentage points (11.8 % using the city average approach versus 13.5 % using the city cluster weighting approach). Similarly, using the city cluster weighting approach, the aggregate energy savings for a given building type varies by 0.3 % to 34.4 % relative to the simple average approach with the total aggregate savings for all building types in the state varying by 3.7 %. At the building level, aggregate results can vary significantly while at the state level, it appears that the results are relatively similar. More precise construction data can increase the accuracy of the results, but the relative magnitude of the results is similar.

The city cluster weighting approach leads to 19 states realizing smaller savings and 26 states realizing larger savings relative to the city average approach. Five states realize identical results because there is only one city for each of those states in the BIRDS database, in which case there are not multiple cities for which to weight. Since states are split between realizing smaller and larger estimated savings, the difference in nationwide aggregate savings is small at 0.3 % of the total nationwide aggregate savings.

The state-level results for the city cluster approach are relatively similar to the results using the city average approach. The energy consumption changes by 2.5 % or less for 31 states (62 %) and 5.0 % or less for 41 states (82 %). Using the city cluster approach leads to greater than 10 % for only three states (Alaska, Montana, and Maine). All three states have relatively small amounts of new construction, which can cause small changes in magnitude to be large changes in percentage terms.

5.2 Limitations and Future Research

This study attempts to improve upon the analysis approach from previous research using the BIRDS database. Based on the results, it appears that the accuracy of the energy savings estimates are impacted by the weighting approach used in the analysis. The city cluster approach described in this study alleviates some of the inherent issues/problems created in using the equal weighting approach. However, there are still aspects of this approach that can be improved upon to increase the accuracy of the results.

First, the current cluster approach restricted clustering across state borders even though the closest city may be in a bordering state. An example of this can be seen in Figure 5-1, where the counties within Kentucky and the surrounding states are mapped to a city that is often much further away than a city in another state. As a result, the climatic and economic conditions for those counties may not be matched to the optimal (i.e., most representative) city in the database.

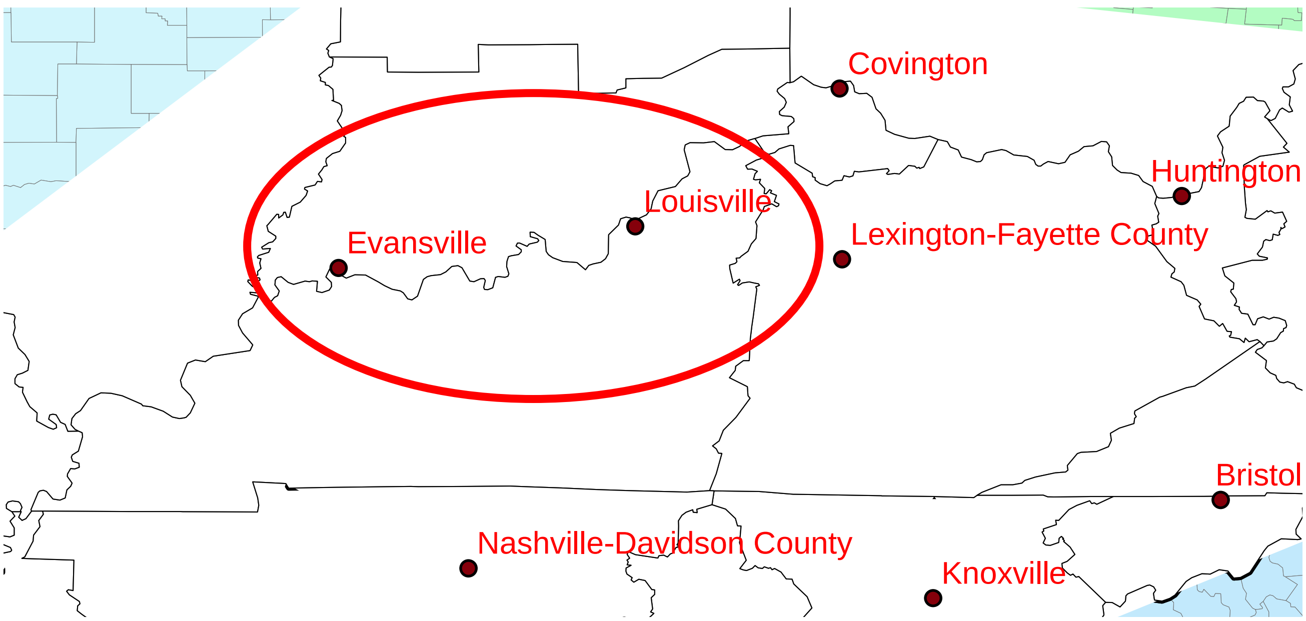

Figure 5-1 City Clusters - Kentucky and Surrounding States

The reason for the state border restriction was because the results from the BIRDS database used for this study are based on comparison of the LEC design to each state's energy code as of December 2011, which may vary across states. Future work should use the results in the BIRDS database to match each county with the closest city regardless of state, but use the results for the standard edition that meets the county's state energy code. For example, the counties on the northern border of western Kentucky will be matched to the energy performance of buildings located in Evansville, Indiana instead of Louisville, Kentucky while using the building designs that meet Kentucky's state energy code.

Second, the results are estimated using the current eleven building types in the BIRDS database and the new construction data associated with those building types. The results are then extrapolated to the entire new building stock. Future research should incorporate additional building types into the BIRDS database to increase the fraction of building stock directly accounted for in BIRDS, which will increase the accuracy of the estimated impacts.

Third, the analysis in this study updates the impact estimates for energy consumption savings. The same city cluster weighting approach should be applied to the other sustainability metrics included in the BIRDS database: energy costs, life-cycle costs, and the twelve environmental impact categories.

Finally, future research should test the sensitivity of the sustainability performance results to other underlying assumptions in the analysis approach for which city and/or county level data may be available. For example, electricity prices can vary significantly across cities in a state. Doing so should further increase the accuracy of the results.

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A Building Type, New Construction, and Energy Savings

Table A-1 CBECS Categories and Subcategories

Category	Subcategory
Education	elementary or middle school high school college or university preschool or daycare adult education career or vocational training religious education
Food Sales	grocery store or food market gas station with a convenience store; convenience store
Food Service	fast food restaurant or cafeteria
Health Care Inpatient	hospital inpatient rehabilitation
Health Care Outpatient	medical office (see previous column) clinic or other outpatient health care outpatient rehabilitation veterinarian
Lodging	motel or inn hotel dormitory, fraternity, or sorority retirement home nursing home, assisted living, etc. convent or monastery shelter, orphanage, halfway house

Category	Subcategory
Public Assembly	social or meeting recreation entertainment or culture library funeral home student activities center armory exhibition hall broadcasting studio transportation terminal
Public Order and Safety	police station fire station jail, reformatory, or penitentiary courthouse or probation office
Religious Worship	None
Service	vehicle service or vehicle repair shop vehicle storage/ maintenance (car barn) repair shop dry cleaner or laundromat post office or postal center car wash gas station photo processing shop beauty parlor or barber shop tanning salon copy center or printing shop kennel

Mercantile Non-Mall	retail store beer, wine, or liquor store rental center dealership or showroom for vehicles or boats studio/gallery
Mercantile Malls	enclosed mall strip shopping center
Office	administrative or professional office government office mixed-use office bank or other financial institution medical office (see previous column) sales office contractor's office non-profit or social services research and development city hall or city center religious office call center

Warehouse and Storage	refrigerated warehouse non-refrigerated warehouse distribution or shipping center
Other	airplane hangar crematorium laboratory telephone switching agricultural with some retail space manufacturing or industrial with some retail space data center or server farm
Vacant	None

Table A-2 New Commercial Building Construction Volume for 2003 through 2007 by State and Building Type (S-I)

State	Building Construction Volume (1,000 m^2)									
	Apartment	Healthcare	Hotel	Office	Public Assembly	Restaurant	Retail	School	Warehouse	No Prototype	Total
AK	19	130	126	226	111	13	208	231	126	259	1448
AL	801	705	853	1504	639	169	2485	1534	842	1740	11 272
AR	118	465	483	647	335	77	1359	1295	335	815	5928
AZ	1043	1505	1047	4030	1180	271	4891	2294	3721	3808	23 790
CA	9761	3310	3129	9219	3092	534	10 623	7085	13 364	12 345	72 462
CO	2033	1387	997	2158	708	199	2896	1654	1541	2889	16 461
CT	611	403	489	618	510	65	1245	1194	817	1271	7223
DC	1174	71	111	1462	112	4	104	191	34	830	4092
DE	70	155	124	224	119	16	237	290	160	323	1719
FL	21 397	3399	2979	9031	3124	678	11 904	7760	9692	12 748	82 712
GA	3696	1551	1510	3630	1212	331	5893	5580	7449	5350	36 202
HI	1280	91	92	171	59	9	273	92	132	485	2682
IA	143	639	427	999	657	74	1350	1262	621	1062	7234
ID	233	372	221	716	230	46	699	636	360	496	4008
IL	7303	1765	1304	2930	1714	232	5660	3083	6473	4179	34 643
IN	360	1728	856	1746	1323	255	3302	2558	3771	2415	18 313
KS	98	533	353	877	295	97	1122	826	513	670	5384
KY	268	757	643	1167	760	138	1667	1270	2001	1106	9778
LA	169	650	807	1175	593	135	1736	842	1011	1379	8498
MA	2959	728	884	1103	632	121	1772	1356	854	2484	12895
MD	3341	813	826	2802	580	109	1549	1527	1989	3388	16 924
ME	64	209	166	224	134	34	566	313	281	494	2485
MI	446	1797	713	1696	1359	200	3245	2058	864	2442	14 820
MN	1437	1018	473	1633	527	102	2135	1175	803	2342	11 645
MO	875	940	881	1226	780	158	2513	1626	819	1972	11 791
MS	150	336	479	631	411	55	1166	743	1593	692	6255
MT	45	122	118	149	94	18	253	174	76	142	1190
NC	1607	1362	1178	3368	1119	230	4472	3418	1910	3520	22 185
ND	7	118	91	138	113	14	331	174	57	100	1145
NE	147	453	303	631	331	54	1149	514	340	676	4599
NH	141	227	226	276	154	51	648	411	191	438	2763
NJ	2807	796	943	1235	774	112	2494	2627	3008	2587	17 382
NM	89	247	418	617	350	62	765	752	292	491	4083
NV	2867	528	2963	1626	1195	157	2382	960	1669	3231	17 579
NY	11 622	1639	1959	3330	1075	210	3633	2247	1286	3354	30 354
OH	635	2452	925	2674	1266	372	5132	4452	3382	3243	24 533
OK	115	794	512	763	878	141	1364	1179	932	1271	7950
OR	1253	918	360	922	383	68	1382	651	1142	1648	8727
PA	1503	1908	1406	2424	1354	219	3762	3660	3512	3556	23 305
RI	238	60	192	251	81	26	278	197	114	236	1674
SC	1981	746	563	1539	539	168	2600	2222	1101	2132	13 590
SD	13	119	86	257	126	13	341	268	88	205	1515
TN	987	1036	683	2296	733	199	3581	1809	2698	2337	16 360
TX	5548	4508	3571	8328	3325	849	13 121	12 693	10 609	9676	72 230
UT	622	569	314	1365	475	76	1424	1269	1274	1201	8590
VA	3502	1011	1361	3693	1096	200	3014	2387	1826	4406	22 495
VT	161	99	96	113	71	6	63	136	88	165	998
WA	3397	1085	871	2435	833	107	2504	1841	1880	3598	18 551
WI	906	1519	583	1556	746	137	2489	1129	882	1981	11 928
WV	65	215	148	193	117	39	668	484	179	288	2397
WY	4	72	166	66	127	9	158	254	67	228	1151
Total	100 111	48 059	41 007	92 089	38 550	7661	128 609	94 383	98 773	118 693	767 935

Table A-3 New Commercial Building Construction Volume for 2003 through 2007 by State and Building Type (I-P)

State	Building Construction Volume (1,000 ft^2)										
	Apartment	Healthcare	Hotel	Office	Public Assembly	Restaurant	Retail	School	Warehouse	No Prototype	Total
AK	201	1401	1357	2428	1190	137	2240	2484	1356	2787	15 581
AL	8619	7587	9184	16 191	6876	1821	26 748	16 514	9060	18 729	121 329
AR	1272	5000	5198	6962	3611	829	14 624	13 936	3609	8768	63 810
AZ	11 223	16 195	11 272	43 383	12 701	2918	52 646	24 692	40 052	40 986	256 068
CA	105 071	35 633	33 678	99 228	33 281	5747	114 344	76 262	143 853	132 882	779 978
CO	21 885	14 926	10 735	23 225	7618	2142	31 177	17 804	16 582	31 094	177 186
CT	6582	4333	5261	6651	5485	698	13 403	12 856	8798	13 679	77 746
DC	12 636	769	1199	15 734	1202	38	1122	2051	363	8934	44 047
DE	755	1672	1330	2410	1282	173	2551	3126	1722	3480	18 501
FL	230 315	36 591	32 071	97 212	33 622	7299	128 133	83 524	104 327	137 213	890 306
GA	39 780	16 699	16 254	39 076	13 043	3563	63 430	60 062	80 180	57 586	389 672
HI	13 773	979	989	1838	630	95	2939	985	1417	5220	28 865
IA	1542	6875	4598	10 749	7069	796	14 534	13 586	6688	11 426	77 863
ID	2506	4001	2375	7703	2478	493	7526	6847	3876	5343	43 147
IL	78 609	18 998	14 037	31 542	18 451	2497	60 928	33 180	69 674	44 977	372 893
IN	3875	18 600	9210	18 791	14 242	2747	35 539	27 535	40 591	25 992	197 123
KS	1057	5734	3795	9442	3178	1039	12 076	8892	5521	7216	57 950
KY	2888	8150	6922	12 558	8185	1489	17 941	13 672	21 538	11 906	105 248
LA	1823	7001	8689	12 647	6386	1454	18 681	9061	10 886	14 841	91 469
MA	31 854	7832	9516	11 868	6808	1306	19 079	14 599	9197	26 742	138 802
MD	35 967	8750	8888	30 163	6242	1173	16 672	16 432	21 414	36 463	182 163
ME	687	2245	1791	2411	1441	368	6088	3374	3021	5320	26 745
MI	4800	19 346	7671	18 251	14 629	2153	34 934	22 151	9305	26 283	159 523
MN	15 465	10 954	5093	17 575	5673	1098	22 985	12 643	8643	25 212	125 342
MO	9420	10 121	9483	13 197	8395	1705	27 054	17 497	8818	21 226	126 915
MS	1613	3618	5153	6789	4423	587	12 551	7999	17 146	7447	67 326
MT	481	1313	1265	1602	1007	195	2723	1871	821	1533	12 810
NC	17 294	14 663	12 678	36 249	12 044	2481	48 139	36 794	20 559	37 891	238 792
ND	76	1265	982	1490	1221	155	3567	1871	617	1077	12 320
NE	1586	4880	3263	6790	3562	577	12 369	5533	3660	7279	49 498
NH	1523	2440	2437	2974	1653	548	6970	4421	2059	4717	29 741
NJ	30 209	8563	10 145	13 295	8335	1210	26 842	28 280	32 383	27 841	187 103
NM	957	2655	4499	6636	3770	670	8235	8097	3142	5290	43 950
NV	30 856	5684	31 894	17 504	12 863	1691	25 644	10 337	17 969	34 776	189 218
NY	125 095	17 639	21 083	35 842	11 572	2259	39 107	24 186	13 845	36 104	326 732
OH	6832	26 393	9959	28 780	13 630	4004	55 245	47 919	36 400	34 909	264 071
OK	1242	8547	5511	8216	9450	1523	14 686	12 691	10 032	13 680	85 577
OR	13 492	9885	3878	9927	4118	728	14 881	7004	12 291	17 738	93 941
PA	16 177	20 535	15 135	26 096	14 577	2361	40 489	39 397	37 805	38 280	250 852
RI	2559	649	2069	2707	877	278	2990	2125	1228	2540	18 021
SC	21 321	8033	6056	16 562	5801	1810	27 984	23 920	11 848	22 949	146 284
SD	142	1285	922	2767	1354	138	3668	2884	950	2202	16 312
TN	10 621	11 152	7347	24 718	7891	2145	38 548	19 476	29 045	25 152	176 095
TX	59 723	48 519	38 437	89 641	35 794	9142	141 238	136 629	114 193	104 156	777 473
UT	6695	6123	3384	14 698	5110	822	15 331	13 657	13 716	12 926	92 462
VA	37 694	10 887	14 646	39 749	11 794	2149	32 438	25 691	19 659	47 422	242 129
VT	1736	1063	1030	1214	765	68	674	1463	946	1777	10 737
WA	36 566	11 683	9378	26 209	8964	1147	26 954	19 817	20 236	38 731	199 685
WI	9754	16 350	6273	16 751	8030	1474	26 793	12 148	9497	21 325	128 395
WV	697	2314	1592	2081	1259	421	7191	5215	1930	3098	25 797
WY	42	774	1787	713	1370	97	1696	2737	718	2453	12 387
Total	1 077 585	517 302	441 399	991 233	414 953	82 459	1 384 339	1 015 925	1 063 186	1 277 597	8 265 977

Table A-4 New Commercial Building Construction Share by State and Building Type

	Percentage of Building Construction Volume											
State	Apartment	Healthcare	Hotel	Office	Public Assembly	Restaurant	Retail	School	Warehouse	No Prototype	Total	Rep. by Study
AK	1.3 %	9.0 %	8.7 %	15.6 %	7.6 %	0.9 %	14.4 %	15.9 %	8.7 %	17.9 %	100.0 %	56.8 %
AL	7.1 %	6.3 %	7.6 %	13.3 %	5.7 %	1.5 %	22.0 %	13.6 %	7.5 %	15.4 %	100.0 %	65.2 %
AR	2.0 %	7.8 %	8.1 %	10.9 %	5.7 %	1.3 %	22.9 %	21.8 %	5.7 %	13.7 %	100.0 %	67.1 %
AZ	4.4 %	6.3 %	4.4 %	16.9 %	5.0 %	1.1 %	20.6 %	9.6 %	15.6 %	16.0 %	100.0 %	57.1 %
CA	13.5 %	4.6 %	4.3 %	12.7 %	4.3 %	0.7 %	14.7 %	9.8 %	18.4 %	17.0 %	100.0 %	55.7 %
CO	12.4 %	8.4 %	6.1 %	13.1 %	4.3 %	1.2 %	17.6 %	10.0 %	9.4 %	17.5 %	100.0 %	60.4 %
CT	8.5 %	5.6 %	6.8 %	8.6 %	7.1 %	0.9 %	17.2 %	16.5 %	11.3 %	17.6 %	100.0 %	58.5 %
DC	28.7 %	1.7 %	2.7 %	35.7 %	2.7 %	0.1 %	2.5 %	4.7 %	0.8 %	20.3 %	100.0 %	74.4 %
DE	4.1 %	9.0 %	7.2 %	13.0 %	6.9 %	0.9 %	13.8 %	16.9 %	9.3 %	18.8 %	100.0 %	55.9 %
FL	25.9 %	4.1 %	3.6 %	10.9 %	3.8 %	0.8 %	14.4 %	9.4 %	11.7 %	15.4 %	100.0 %	65.0 %
GA	10.2 %	4.3 %	4.2 %	10.0 %	3.3 %	0.9 %	16.3 %	15.4 %	20.6 %	14.8 %	100.0 %	57.0 %
HI	47.7 %	3.4 %	3.4 %	6.4 %	2.2 %	0.3 %	10.2 %	3.4 %	4.9 %	18.1 %	100.0 %	71.4 %
IA	2.0 %	8.8 %	5.9 %	13.8 %	9.1 %	1.0 %	18.7 %	17.4 %	8.6 %	14.7 %	100.0 %	58.8 %
ID	5.8 %	9.3 %	5.5 %	17.9 %	5.7 %	1.1 %	17.4 %	15.9 %	9.0 %	12.4 %	100.0 %	63.6 %
IL	21.1 %	5.1 %	3.8 %	8.5 %	4.9 %	0.7 %	16.3 %	8.9 %	18.7 %	12.1 %	100.0 %	59.2 %
IN	2.0 %	9.4 %	4.7 %	9.5 %	7.2 %	1.4 %	18.0 %	14.0 %	20.6 %	13.2 %	100.0 %	49.6 %
KS	1.8 %	9.9 %	6.5 %	16.3 %	5.5 %	1.8 %	20.8 %	15.3 %	9.5 %	12.5 %	100.0 %	62.6 %
KY	2.7 %	7.7 %	6.6 %	11.9 %	7.8 %	1.4 %	17.0 %	13.0 %	20.5 %	11.3 %	100.0 %	52.7 %
LA	2.0 %	7.7 %	9.5 %	13.8 %	7.0 %	1.6 %	20.4 %	9.9 %	11.9 %	16.2 %	100.0 %	57.2 %
MA	22.9 %	5.6 %	6.9 %	8.6 %	4.9 %	0.9 %	13.7 %	10.5 %	6.6 %	19.3 %	100.0 %	63.6 %
MD	19.7 %	4.8 %	4.9 %	16.6 %	3.4 %	0.6 %	9.2 %	9.0 %	11.8 %	20.0 %	100.0 %	60.0 %
ME	2.6 %	8.4 %	6.7 %	9.0 %	5.4 %	1.4 %	22.8 %	12.6 %	11.3 %	19.9 %	100.0 %	55.0 %
MI	3.0 %	12.1 %	4.8 %	11.4 %	9.2 %	1.3 %	21.9 %	13.9 %	5.8 %	16.5 %	100.0 %	56.4 %
MN	12.3 %	8.7 %	4.1 %	14.0 %	4.5 %	0.9 %	18.3 %	10.1 %	6.9 %	20.1 %	100.0 %	59.7 %
MO	7.4 %	8.0 %	7.5 %	10.4 %	6.6 %	1.3 %	21.3 %	13.8 %	6.9 %	16.7 %	100.0 %	61.7 %
MS	2.4 %	5.4 %	7.7 %	10.1 %	6.6 %	0.9 %	18.6 %	11.9 %	25.5 %	11.1 %	100.0 %	51.5 %
MT	3.8 %	10.2 %	9.9 %	12.5 %	7.9 %	1.5 %	21.3 %	14.6 %	6.4 %	12.0 %	100.0 %	63.5 %
NC	7.2 %	6.1 %	5.3 %	15.2 %	5.0 %	1.0 %	20.2 %	15.4 %	8.6 %	15.9 %	100.0 %	64.3 %
ND	0.6 %	10.3 %	8.0 %	12.1 %	9.9 %	1.3 %	29.0 %	15.2 %	5.0 %	8.7 %	100.0 %	66.1 %
NE	3.2 %	9.9 %	6.6 %	13.7 %	7.2 %	1.2 %	25.0 %	11.2 %	7.4 %	14.7 %	100.0 %	60.8 %
NH	5.1 %	8.2 %	8.2 %	10.0 %	5.6 %	1.8 %	23.4 %	14.9 %	6.9 %	15.9 %	100.0 %	63.5 %
NJ	16.1 %	4.6 %	5.4 %	7.1 %	4.5 %	0.6 %	14.3 %	15.1 %	17.3 %	14.9 %	100.0 %	58.8 %
NM	2.2 %	6.0 %	10.2 %	15.1 %	8.6 %	1.5 %	18.7 %	18.4 %	7.1 %	12.0 %	100.0 %	66.2 %
NV	16.3 %	3.0 %	16.9 %	9.3 %	6.8 %	0.9 %	13.6 %	5.5 %	9.5 %	18.4 %	100.0 %	62.3 %
NY	38.3 %	5.4 %	6.5 %	11.0 %	3.5 %	0.7 %	12.0 %	7.4 %	4.2 %	11.1 %	100.0 %	75.8 %
OH	2.6 %	10.0 %	3.8 %	10.9 %	5.2 %	1.5 %	20.9 %	18.1 %	13.8 %	13.2 %	100.0 %	57.8 %
OK	1.5 %	10.0 %	6.4 %	9.6 %	11.0 %	1.8 %	17.2 %	14.8 %	11.7 %	16.0 %	100.0 %	51.3 %
OR	14.4 %	10.5 %	4.1 %	10.6 %	4.4 %	0.8 %	15.8 %	7.5 %	13.1 %	18.9 %	100.0 %	53.1 %
PA	6.4 %	8.2 %	6.0 %	10.4 %	5.8 %	0.9 %	16.1 %	15.7 %	15.1 %	15.3 %	100.0 %	55.7 %
RI	14.2 %	3.6 %	11.5 %	15.0 %	4.9 %	1.5 %	16.6 %	11.8 %	6.8 %	14.1 %	100.0 %	70.6 %
SC	14.6 %	5.5 %	4.1 %	11.3 %	4.0 %	1.2 %	19.1 %	16.4 %	8.1 %	15.7 %	100.0 %	66.8 %
SD	0.9 %	7.9 %	5.7 %	17.0 %	8.3 %	0.8 %	22.5 %	17.7 %	5.8 %	13.5 %	100.0 %	64.5 %
TN	6.0 %	6.3 %	4.2 %	14.0 %	4.5 %	1.2 %	21.9 %	11.1 %	16.5 %	14.3 %	100.0 %	58.4 %
TX	7.7 %	6.2 %	4.9 %	11.5 %	4.6 %	1.2 %	18.2 %	17.6 %	14.7 %	13.4 %	100.0 %	61.1 %
UT	7.2 %	6.6 %	3.7 %	15.9 %	5.5 %	0.9 %	16.6 %	14.8 %	14.8 %	14.0 %	100.0 %	59.0 %
VA	15.6 %	4.5 %	6.0 %	16.4 %	4.9 %	0.9 %	13.4 %	10.6 %	8.1 %	19.6 %	100.0 %	62.9 %
VT	16.2 %	9.9 %	9.6 %	11.3 %	7.1 %	0.6 %	6.3 %	13.6 %	8.8 %	16.6 %	100.0 %	57.6 %
WA	18.3 %	5.9 %	4.7 %	13.1 %	4.5 %	0.6 %	13.5 %	9.9 %	10.1 %	19.4 %	100.0 %	60.1 %
WI	7.6 %	12.7 %	4.9 %	13.0 %	6.3 %	1.1 %	20.9 %	9.5 %	7.4 %	16.6 %	100.0 %	57.0 %
WV	2.7 %	9.0 %	6.2 %	8.1 %	4.9 %	1.6 %	27.9 %	20.2 %	7.5 %	12.0 %	100.0 %	66.7 %
WY	0.3 %	6.2 %	14.4 %	5.8 %	11.1 %	0.8 %	13.7 %	22.1 %	5.8 %	19.8 %	100.0 %	57.1 %
Total	13.0 %	6.3 %	5.3 %	12.0 %	5.0 %	1.0 %	16.7 %	12.3 %	12.9 %	15.5 %	100.0 %	60.4 %

Table A-5 Energy Consumption Savings by State

State	Code	Average Annual New Floor Area 1000 m^2 (1000 ft^2)	Energy Use (GWh)
FL	2007	16 542 (178 061)	3790.5
TX	2007	14 446 (155 495)	2831.6
CA	2007	14 492 (155 996)	2543.2
AZ	1999	4758 (51 214)	1857.5
GA	2007	7240 (77 934)	1348.0
IL	2007	6929 (74 579)	1212.7
CO	2001	3292 (35 437)	1112.9
AL	1999	2254 (24 266)	1050.6
NY	2007	6071 (65 346)	1037.6
MO	None	2358 (25 383)	984.7
VA	2007	4499 (48 426)	871.3
NC	2007	4437 (47 758)	827.9
OH	2007	4907 (52 814)	826.8
MN	2004	2329 (25 068)	816.7
TN	2004	3272 (35 219)	807.8
PA	2007	4661 (50 170)	764.9
NV	2004	3516 (37 844)	709.0
MS	1999	1251 (13 465)	689.6
IN	2007	3663 (39 425)	656.9
MD	2007	3385 (36 433)	622.2
OK	1999	1590 (17 115)	598.1
SC	2004	2718 (29 257)	594.5
NJ	2007	3476 (37 421)	581.6
WA	2007	3710 (39 937)	525.0
MI	2007	2964 (31 905)	511.9

State	Code	Average Annual New Floor Area 1000 m^2 (1000 ft^2)	Energy Use (GWh)
WI	2007	2386 (25 679)	491.0
KS	None	1077 (11 590)	438.6
AR	2001	1186 (12 762)	426.1
MA	2007	2579 (27 760)	403.8
KY	2007	1956 (21 050)	378.0
LA	2007	1700 (18 294)	324.6
UT	2007	1718 (18 492)	286.6
IA	2007	1447 (15 573)	283.7
OR	2007	1745 (18 788)	261.4
CT	2007	1445 (15 549)	232.0
ME	None	497 (5349)	216.6
WV	2001	479 (5159)	177.2
NE	2007	920 (9900)	170.8
NM	2007	817 (8790)	153.7
ID	2007	802 (8629)	139.9
HI	2004	536 (5773)	138.4
SD	None	303 (3262)	122.3
NH	2007	553 (5948)	108.0
ND	None	229 (2464)	104.5
AK	1999	290 (3116)	99.4
WY	1999	230 (2477)	76.6
DE	2007	344 (3700)	60.1
RI	2007	335 (3604)	55.3
MT	2007	238 (2562)	52.5
VT	2007	200 (2147)	37.3