Survey Data vs. Energy Audits: Comparing Two Forms of Data Collection in the Commercial Buildings Energy Consumption Survey

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ABSTRACT

The Commercial Buildings Energy Consumption Survey (CBECS) is a complex sample survey, first conducted in 1979, that produces the only national-level data on the characteristics and energy use in commercial buildings in the United States. As part of the 2012 CBECS, a subset of the buildings was asked to participate in a follow-up energy audit or energy assessment (EA) to test the reliability of CBECS data collection through the survey questionnaire. This paper discusses the impetus for the energy assessments and compares the two methods of data collection. CBECS questionnaire and energy assessment data are compared in three main areas: square footage, principal building activity (PBA), and fuels used. The advantages and disadvantages of each method are discussed while exploring the reasons for data discrepancies in each area. In conclusion, the reasons for relying on a questionnaire for commercial building data collection are discussed and potential ways to improve the energy assessment process are listed.

Background

The Commercial Buildings Energy Consumption Survey (CBECS) is a complex sample survey that produces the only national-level data on the characteristics and energy use in commercial buildings in the United States. The survey was first conducted in 1979 and was then conducted triennially between 1983 and 1995. Starting in 1995, it has been conducted quadrennially, with the exception of 2011 when EIA budget cuts caused a delay in data collection, postponing the tenth CBECS until 2012. The sample size for the CBECS has historically ranged from 5,000 to 7,000 buildings. The target 2012 CBECS sample size was increased to improve precision and support broader uses of the data; the final responding sample for the 2012 CBECS was 6,720 buildings with a response rate of more than 70%.

The CBECS data are used for many purposes, such as: benchmarking, building design, policy planning, building code development, market research, forecasting energy consumption, and as a critical input to the Environmental Protection Agency's ENERGY STAR models. The data are also made available to the public through tables, reports, and public use data files containing building-level records (with identifiers stripped) to allow users to conduct their own analyses.

CBECS data are collected in two-parts, a buildings survey and a follow-up Energy Suppliers Survey (ESS). In the first part, detailed information about the building is collected from building owners and managers by professional interviewers using a computerized survey instrument. These data include building size, age, structural characteristics, operating hours, ownership, energy sources and uses, and types of energy-related equipment used. Energy consumption and expenditures data for a one-year reference period are collected from building respondents whenever possible. When building respondents cannot provide sufficient usage data,

CBECS contacts energy suppliers for the building to obtain these data. In 2012 most of the ESS data were collected via the web, in contrast to mail collection in earlier studies.

In 2012, the National Research Council published a report on how to improve the Energy Information Administration (EIA)'s consumption surveys, which included the CBECS. The report recommended that EIA test the feasibility of using energy auditors for data collection, in tandem with, or instead of, trained survey interviewers. The panel posited that the data obtained in this experiment, even if small in scale, might help EIA to assess CBECS data quality, as well as to evaluate post data collection editing procedures, and the regression model that determines whether a building needs to be sent to post-interview energy supplier follow-up.

Our goals for this project were both data driven and procedural. First, we wanted to explore differences, both quantitative and qualitative, between data collected by trained interviewers with a computerized survey instrument and data collected by an energy professional with a standardized paper checklist. EIA identified a number of areas where a comparison of the CBECS data and data collected by an energy professional is appropriate. By observing how energy professionals quantify building characteristics and systems, EIA may be able to improve survey questions and concepts in the next CBECS cycle. This paper compares the survey interview with the energy audit for three key variables: square footage, primary building activity (PBA), and fuels used. The second issue addresses the potential gain in data quality relative to the costs of time, money, and respondent burden. Finally, we asked whether the addition of an energy audit is desirable or feasible for future rounds of CBECS data collection.

Data Collection Process

EIA set a target of completing 200 Energy Assessments (EAs) based on budget and time. Table 1 compares the CBECS interview process with the EA process. The assessments were designed to be consistent with an American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Level 1 audit. EIA referred to them as "assessments" to alleviation potential concern from respondents about a federal agency conducting an "audit" on their building. To cover a variety of climates and building types, EIA selected Primary Sampling Units (PSUs) that covered all five national climate zones, and included at least two PSUs per zone. EIA also set minimum target levels for certain primary building activities (as reported by respondents during the CBECS survey) including office, warehouse, food sales, education, food service, hospital, lodging, and non-mall retail buildings in order to make sure these building types were included. These building activities were selected based on their diverse energy intensities, among other substantive criteria of interest to the research team.

Table 1. CBECS and EA data collection comparison.

Data collection characteristic	CBECS Interview	Energy Assessment
Mode	In-person or telephone interview	Onsite
Data collector	Survey interviewer	Building auditor
Tool	Survey questionnaire	Paper checklist
Method	Respondent interview	Auditor observation with assistance from respondent

Thirteen energy assessors were trained by the EIA contractor to complete building assessments. Their experience performing building audits ranged from one to sixteen years, with a mean of seven years' experience. To maintain independence during data collection, assessors were only given the building name, address, respondent name, and contact information. They did not have access to any other information collected during the CBECS interview. Additionally the assessors were told to not make any recommendations for improving the energy efficiency of the buildings.

During CBECS interviewer training, interviewers are trained extensively on building boundaries, and differences between the definitions of buildings, establishments, and leased vs. owned areas of buildings. Energy assessors were intentionally provided with very little training on the CBECS interview since EIA wanted to attempt to create an unbiased comparison between the two methods.

In order to aid with analysis of the EA data, EIA worked with our contractor, an engineering services consultant who had significant experience with energy audits, to develop a standardized paper checklist for use by assessors. A paper checklist was selected over a computer instrument due to resource constraints. The checklist was designed to cover both small buildings with simple equipment layouts and very large buildings with complex building systems.

After completing the CBECS interview, all building respondents in the selected PSUs were asked if they would like to participate in a follow-up energy assessment project. Only respondents that said yes were added to the list of potential EA buildings. Because the sample was voluntary with no post-collection data adjustments, the results from the EA data are not statistically representative of the entire sample of CBECS buildings or at any other geography.

After EA data collection was completed, the EIA research team mapped the data from the EA checklists to the CBECS variables. The comparison was made results, using only information provided by the assessor, in the form of notes or attachments of additional documents (such as utility bills, equipment lists, floorplans, or images). The use of the internet or CBECS data was prohibited to maintain the independence of the data. If an editor was uncertain how to code an EA variable into CBECS categories, the analysis group adjudicated the appropriate response.

Data

The traditional 2012 CBECS data collection took place between April 2013 and November 2013. Approximately 250 trained survey interviewers completed a total of 6,720 on-site CBECS computer assisted personal interviews. During 2012 CBECS data collection, 1,022 building respondents were asked to participate in the follow-up EA project based on geographic location. One-half of the CBECS building respondents (554) agreed to the follow-up assessment. From these buildings the EIA team selected 475 for the assessment sample. Buildings excluded from the EA list included those with out-of scope activities (such as vacant buildings) or buildings too distant from the rest of the sample.

Energy assessments were completed in 203 eligible buildings between August 2013 and February 2014.[1] Assessors completed from two to 40 energy assessments each, for an average of

[1] 206 buildings actually completed assessments, but 1 building was determined to be residential, and therefore out of scope for CBECS, and two others were determined to be incorrect building assessments.

15 per assessor. Assessors were successful in obtaining most of the building information needed during their time onsite.

Building assessments averaged 3.2 hours per site. Assessors spent about one hour, making an average of 3.12 contacts, to schedule an appointment for each building.

Results

Square Footage

Building square footage is a main determinant for overall building energy consumption. Square footage is the denominator for intensity, used during benchmarking. Square footage is also a key driver for the National Energy Modeling System (NEMS) which is used for many of EIA's energy forecasts. NEMS uses both total floor space and also considers floor to ceiling height in order to capture three dimensional conditioned space.

The majority of buildings matched on square footage category. In the CBECS questionnaire, respondents are asked to provide an exact square footage, including finished and unfinished areas, basements, hallways, lobbies, stairways, elevator shafts, and indoor parking areas. If the respondent is unable to provide an exact square footage, they are asked to place the building into a category of approximate square footage. Analysts at EIA later used the square footage category to impute an exact square footage for the building based on other respondents. For the EAs, the checklist included the same definition and question wording but square footage categories were not available.

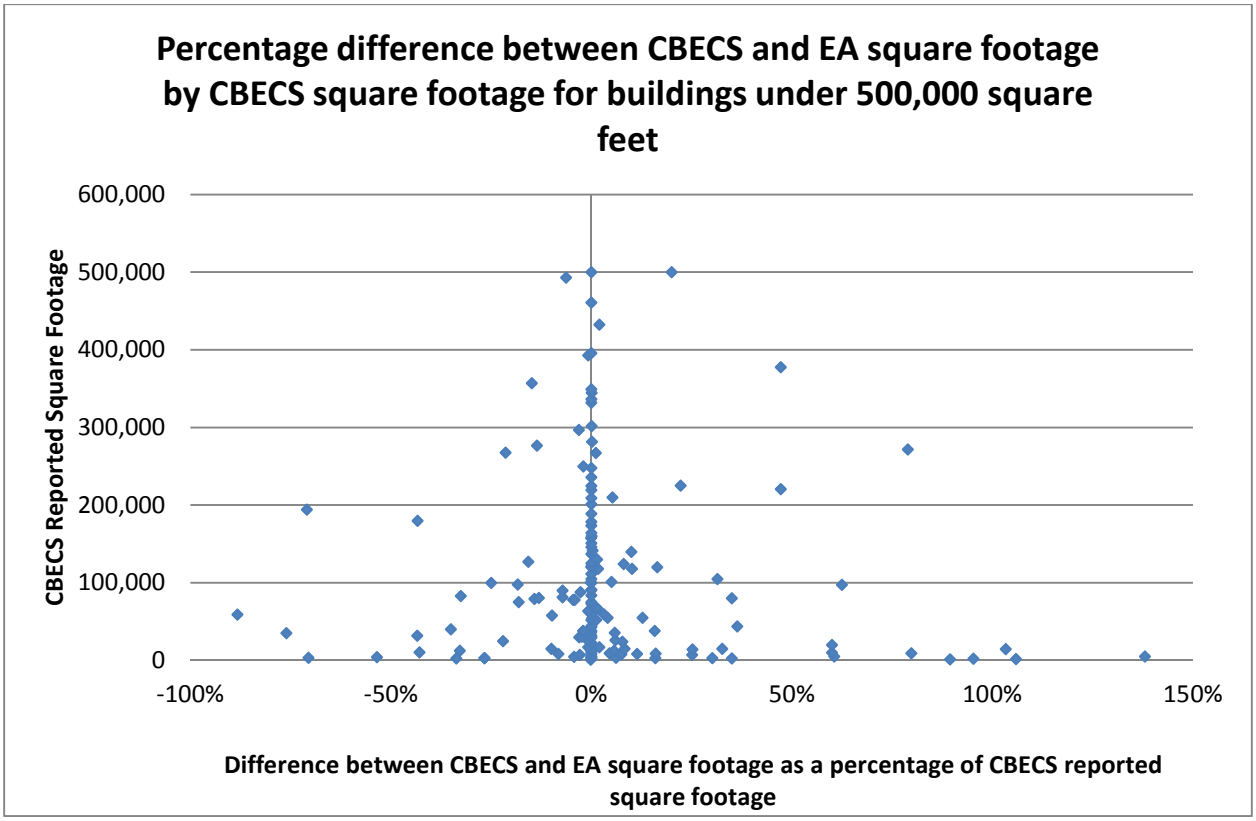
One weakness of the CBECS estimate of square footage is that it depends on respondent reports. Respondents may recall a square footage estimate they heard earlier from real estate listings or tax records, which may not include unconditioned areas of the building. In addition, square footage estimates are subject to rounding errors.

EIA anticipated that assessor reports of square footage would be more accurate due to their use of floor plans, blueprints, or other provided materials. However, since part of the initial assessment process was an interview with a representative of the building, many assessments used the same respondent to gather general building characteristics as the CBECS interview instead of relying on blueprints, public records, or measurements. 177 of the 203 buildings included in the EAs had a response for exact square footage in both the CBECS interview and EA. Of those buildings, 52 were exact matches. 37 of the buildings where the square footage was an exact match had the same respondent for both the CBECS interview and the EA, and in 30 of those cases the assessor obtained the square footage information by asking the respondent only, not using any documents or through their own observations.

Since not all buildings are able to give an exact square footage in the CBECS interview, many provide a square footage category from a list of eight possible response categories. In order to include those buildings in the EA analysis, we coded all EA reported square footage into the eight CBECS categories. 85% of buildings matched when placed into categories, with an additional 12% falling within one category difference. Of those buildings that had agreement at the categorical square footage level, 66% had the same respondent for both the CBECS interview and the EA, and most of the EA data came from the assessor asking the respondent for the square footage (52%).

Buildings with negative differences in square footage indicate that the CBECS interview had a larger square footage number than the EA. A positive difference indicates that the EA

square footage was larger than the CBECS data. Since the absolute difference in square footage can be deceiving, due to differing building size, we compared the percentage difference by square footage for only buildings with less than 500,000 square feet in Figure 1.



Note: In order to better show the differences, outliers have been removed. This figure only shows buildings with less than 500,000 square feet and also excludes one outlier with a 244% difference between CBECS and EA square footage.

Figure 1. Percent difference in square footage between the interview and the assessment without outliers (n=156)

While the majority of buildings have relatively low discrepancies in square footage, smaller buildings, those with fewer than 500,000 square feet, had a harder time estimating building square footage based on the percent difference. After looking at these results, we performed a qualitative outlier analysis, using Google Earth, CBECS interview data and comments, and Computer Audio Recorded Interviewing (CARI) information obtained during the CBECS interview to try to determine whether the CBECS interview data or EA data seemed correct. We looked at the buildings in the top 5% of discrepancies by square footage, where the percentage difference was between 43% and 244% of the total CBECS building square footage.

For the 16 buildings included in the analysis, six were inconclusive, meaning we could not determine whether the CBECS respondent or the assessor incorrectly reported the square footage. Six CBECS responses were deemed incorrect, but two of the six cases were corrected during the regular editing process. For the CBECS cases, the CARI recordings revealed that in some cases the respondent was really unsure of the exact square footage and probably should

have selected a category instead, included parking areas that should have been excluded, or the interviewer failed to read the question text as worded, which led to confusion about what should be included in the square footage estimate.

For the final four cases, it was determined that the assessor incorrectly estimated the square footage. For the assessor errors, there seemed to be two sources of error. The assessor either used google earth to estimate the square footage them self, and reported the footprint of the building without taking into account multiple floors, or the assessor incorrectly omitted sections of the building they did not think should be included, such as residential spaces above a commercial building, or tenant areas where they were unable to gain access.

Principal Building Activity

Building activity is a key variable collected in the CBECS. Data users who rely on CBECS for benchmarking information usually use building activity as the first criterion for comparison; similarly, EPA creates models for the ENERGY STAR buildings program separately for each building activity.

The data collection approach for building activity differed between the CBECS questionnaire and the EA. CBECS interviewers presented respondents with a Show Card listing 18 building activities and asked if one of the activities takes up 75% or more of the floor space in the building. If the answer was yes, they recorded which one and a follow-up question asked for a more detailed subcategory (the list of choices is dependent on the general building activity). Using the chosen subcategory, the survey instrument mapped the correct general activity as defined by CBECS. For example, a respondent may have said their main activity was Education, and then chosen library as the subcategory, which by CBECS definition is Public Assembly. The activity would be changed to Public Assembly. If one activity did not take up 75% of the building, CBECS collected the top three, the corresponding percentages, and then the subcategory for the majority percent (or using a hierarchy based on energy intensity if there are equal maximum percentages).

In the EA, the checklist provided spaces to record the top five space types and gave the assessor 19 types to choose from, a list which mostly matched the CBECS general building activities. Below the space types, the assessor recorded the corresponding percent of area served by each activity, and below that, the CBECS space subcategory, a list which was found as an addendum on the last page of the checklist. These subcategories closely matched the CBECS subcategories.

An incorrectly assigned PBA has less impact on the EA data than on the CBECS data. The CBECS has question branching that is dependent on the PBA, so if the PBA is not captured correctly multiple relevant questions could be skipped. Because the EA checklist was on paper, no questions were missed due to incorrect PBAs.

As with square footage, one of the weaknesses in the way that the CBECS collects PBA is that it relies on the respondent to classify their building activity. EIA has tried to remove any bias of self-reporting by using Show Cards listing many activity subcategories (some purposely duplicated within main categories) and then mapping into the appropriate main CBECS activity. There could be an advantage to using assessors for this task in that they could be thoroughly trained on which types of buildings belong in each category by CBECS definition, however this was not an emphasis in the training of the 2012 CBECS assessors.

In order to compare the quality of the PBA, after we had mapped all the EAs to a CBECS PBA, we compared the unedited CBECS PBA to the EA PBA. Cases where the PBA matched would be considered to have high quality PBA assignments and demonstrate that either method could work well. For the cases that did not match, EIA conducted research to find the "correct" PBA in order to evaluate whether one method seemed advantageous over the other.

Whereas the assignment of PBA is done electronically by the survey instrument in the CBECS, the assignment of PBA for the EAs required a bit of manual work, for various reasons, such as: the assessors did not always provide percentages for the activities; the assessors didn't always provide subcategories, which are necessary for some activities to assign the final CBECS activity (e.g. inpatient health care vs. outpatient health care); and sometimes the subcategories did not match up with the general categories, so a judgment call had to be made as to which one the assessor actually meant. In some cases it was necessary to go back to the paper checklist and other information collected by the assessors (e.g., floorplans) and look through all available information to assign the PBA. We were able to assign a PBA to all the EA cases with the information found within the case folders.

In 78% of the cases (159/203), the PBAs matched. The building activity which had the highest match rate (considering only EA types with more than 5 cases in the sample) was non-refrigerated warehouses, followed by lodging and then inpatient health care buildings. Seemingly the hardest to classify were outpatient health care, retail, and office. Many of these building types are hard for interviewers or even respondents to distinguish. For example, the difference between an outpatient health care building and an office building is not obvious for a doctor's office. Small educational facilities can also appear to be offices as well.

Table 2. Comparison of EA PBA to CBECS PBA

EA PBA	Total EA cases	CBECS and EA matches	Not matched		
			CBECS correct	EA correct	Unable to determine
Non-refrigerated warehouse	7	7			
Lodging	10	9			1
Inpatient health care	14	12		2	
Public assembly	27	22	4	1	
Education	40	32	6	1	1
Service	10	8	1		1
Food service	9	7		1	1
Office	48	37	6	4	1
Retail (other than mall)	10	7		3	
Outpatient health care	12	6	4	2	
Nursing	3	3			
Religious worship	2	2			
Food sales	1	1			
Laboratory	1	1			
Refrigerated warehouse	1	1			
Public order and safety	5	1	1	2	1
Vacant	3	0	1	2	

Total for all buildings	**203**	**156**	**23**	**18**	**6**

While we would have expected the match rates to be higher when an interview was part of the EA, since that mode would have most closely resembled the CBECS, there did not seem to be any major differences in match rates when looking at the source of the EA data (interview, observation, and/or documents). Similarly, the match rate did not seem affected by whether the same respondent answered the interview and the EA, or by the number of activities reported.

A closer look at all 44 of the cases where the PBAs did not match showed that there was not an obvious advantage to either the CBECS interviews or the EAs in assigning the "correct" PBA. The CBECS questionnaire was determined to be correct in 89% of the cases and the EA was determined to be correct in 87% of the cases. We looked at each case individually to try to determine what the PBA should be according to CBECS definition. Resources used for this investigation included the CBECS interview, the EA case folder information, and web searches. In most cases, we were able to determine which was correct; there were six cases in which the *edited* CBECS PBA (but not the original) matched the EA PBA, an indication that in those cases, the EA accurately collected the PBA more readily than the CBECS interview. There were three cases for which either of the activities could be right; for example, the building seemed to contain both activities and it wasn't clear from any of the available resources which was the majority activity. There were also two cases where we were not able to determine the correct activity or neither the CBECS nor the EA activity seemed to be correct (in one, the CBECS edited activity seemed correct but did not match the EA activity).

Of the 39 cases where it was clear that either the CBECS or the EA PBAs were correct, it was almost evenly split – the EA was correct in 20 cases and CBECS was correct in 19 cases. One factor that led to incorrect EA assignment of PBA was the allowance of five activities, where CBECS limits to the top three. This led to finer segmentation in the EAs which in some cases redefined the activity. An important message to take away is that, for the most part, even in the cases that don't match exactly, the activities aren't that different from each other – for example, we don't see offices being called lodging, or education being called retail. For the mismatches that may seem a little odd, there is usually a good explanation. For example, there are two cases where the EA activity is office when the correct CBECS activity is inpatient health care; in both of these cases it seems very likely that the office portion is really more like medical offices or outpatient health care, but the subcategory was either not provided or was not provided correctly.

Fuels Used

The questions determining which fuels are used in the building and for what end-uses are key to accurate CBECS data collection for two main reasons. First, not collecting data from a fuel used means that the supplier is never contacted and so there are no data collected for consumption and expenditures and second, failure to capture a fuel used means an end-use model is never calculated for that fuel type. Additionally, not allocating an end-use to the correct fuel results in that end-use being allocated to another fuel, creating problems in that end-use model as well.

Both the CBECS questionnaire and the energy assessments allow for the determination of whether eight different fuel categories are used in the building or not. The method by which the fuels used are collected is more straight-forward in the CBECS interview. The first question in

this section of the CBECS survey asks broad questions for which of nine fuels were used for any purpose in 2012. Subsequent sections on specific equipment types and end-uses ask for the fuel for each use and so any original oversights should be detected later as well.

By contrast, the energy assessor collects utility information for the top five utility accounts as part of the energy assessment. Later sections on specific equipment types and end-uses also ask for the fuel for each use but there is no section that just asks the assessor to list all fuels used in the building so if a specific end-use is never discussed, the fuel may be missed. Despite these differences, both the questionnaire and the assessment form should have enough different places to collect each fuel that all fuel data should be captured. Therefore, it is expected that the data will be very similar for fuels used.

Table 3 below shows the reported number of buildings using each fuel type from the CBECS and the energy assessment data collection.

Table 3. Comparison of Fuels Used from CBECS Questionnaires and Energy Assessments

Fuel	CBECS Questionnaire	Energy Assessment	Match
Electricity	203	196	195
Natural Gas	141	135	126
Fuel Oil, Diesel, or Kerosene	74	32	29
Bottled Gas (LPG or Propane)	10	8	4
District Steam	25	15	15
District Hot Water	9	1	1
District Chilled Water	17	7	7
Solar	5	11	3

The energy assessments collected fewer cases using each fuel, with the exception of solar. The results are fairly close for electricity and natural gas but many more cases are missed for the less common fuels. For electricity and natural gas, the CBECS questionnaires seem to be accurate in all cases. The missing cases from the EAs were cases where the assessor did not report a utility for a fuel and then did not report a specific end-use for either natural gas or electricity. However, these cases all reported lighting or other clear uses of electricity and natural gas so it is clear that the EA missed these fuels.

Fuel oil reporting had the lowest match rate with the assessments only collecting 40% of all cases where the survey respondent reporting using the fuel. Of the 45 mismatched cases where the interview had fuel oil and the assessment did not, 44 of those cases had the interview reporting fuel oil used for generation. All 44 of those cases were back-up generators which were directly asked about in the CBECS questionnaire but were not explicitly listed on the EA paper checklist. The assessors should have captured the backup equipment but did not. The last fuel oil discrepancy was a piece of secondary heating equipment that was captured in the CBECS interview, but missed in the energy assessment.

District steam, hot water, and chilled water were also all missed in the energy assessments. For most of these cases, the energy assessor seemed to just leave the fuel blank. Determining the fuel when it comes from outside the building is more difficult to determine since the assessors may not have access to the source of the steam or water. Only one of the nine

cases where the questionnaire respondent reported district water was captured by the energy assessment.

For solar energy, it is unclear if the CBECS questionnaire or the EA is correct. All six of the extra solar cases captured by the EA are schools in the same district where it was reported that solar energy was used for backup generation. This was added in the post-data collection editing process so it is unclear if that is referring to the specific schools or to a centralized district office.

In conclusion, the CBECS questionnaire fared much better in capturing all fuels used by each building. Some of the shortcomings of the EA could be corrected by including a more general section for fuels used, but most of the cases were situations where the assessor simply missed the equipment.

Discussion

After reviewing the selected results from the CBECS and EA checklist, we could not determine if one of the two data collection methods resulted in more accurate data for key building characteristics. For square footage and principal building activity, the CBECS data and EA data are very consistent. However, this data is also acquired mainly from speaking to a respondent, in which case a priming effect may come into play. Priming occurs when the same respondent has already answered similar questions (in this case during the CBECS interview) which may affect recall during subsequent interviews with the same questions (in this case during the EAs). 65% of the EAs where conducted with the same respondent that completed the CBECS interview.

Other data, such as fuels used, are more difficult to capture, especially when larger buildings are involved although the CBECS questionnaire captured several fuels that were not captured by the EA. In cases where discrepancies were discovered and could be resolved, the CBECS interview fared as well and even slightly better than the energy assessment. Part of this may be due to shortcomings with the assessment checklist but the expected advantage of energy assessments was not found.

When factoring in the time and expense of creating an assessment tool, hiring energy assessors, and making a separate visit to the site for the assessment, it is likely that the CBECS interview is a much more cost-effective option. The energy assessments conducted as part of the 2012 CBECS seem to validate the CBECS interview data, even for potentially more complex data such as fuels used where confusing one fuel for another would be more likely.

If it is determined that an energy assessment is still an advantageous alternative to the CBECS interview, another round of assessments could be conducted with the following recommended changes to the energy assessment process:

- In order to streamline, standardize, and expedite data capture, we believe it would be advantageous to test an electronic EA checklist versus a paper checklist. A large amount of the EIA team's time was spent keying data, resolving discrepancies or errors on the checklist data, and editing the data to make it comparable to the CBECS data. If an electronic EA checklist was developed, this would eliminate the time spent keying the checklist, eliminate errors due to poor penmanship, and potentially standardize some of the data collection across assessors. The checklist would have to include space for some notes, since energy systems are not standardized across all buildings, and EIA does not want to eliminate the assessors' ability to capture unique data, if applicable.

- Assessors need more training on the CBECS definition of a building and other terms specific to CBECS. The assessors seemed to struggle with these definitions, often noting that they were not allowed into tenant areas, and eliminating any information about these areas from the EA data collection. In retrospect, intentionally providing energy assessors with very little training on the CBECS interview in an attempt to create an unbiased comparison between the two methods made it very difficult to compare the two methods.
- Cognitive research and pre-testing need to be conducted on the equipment sections of the CBECS interview, specifically on heating and cooling equipment, in order to make sure that the names and descriptions of equipment are consistent with and inclusive of the respondent's definitions of equipment as well as standard EIA and industry definitions of equipment. The assessors were given a list of possible equipment for the heating and cooling sections, which we thought was exhaustive during the development of the checklist; however we still encountered a number of write-ins and notes.

In conclusion, EIA determined that the energy assessment portion of the 2012 CBECS was a valuable test of the CBECS process. EIA learned that the CBECS questionnaire is doing a very reasonable job of collecting the information that would be collected in a much more thorough energy assessment or audit and at a fraction of the time and expense.

References

"Effective Tracking of Building Energy Use: Improving the Commercial Buildings and Residential Energy Consumption Surveys", National Research Council, The National Academies Press, 2012.