# Cracking the Code: An Approach to Estimating Savings from Energy Codes

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## ABSTRACT

Utility energy efficiency programs face an uphill battle to meet accelerating savings targets measured against escalating baselines defined by increasingly stringent codes and standards (C&S). By consistently raising the bar against which traditional energy efficiency program savings are measured, improved codes can inadvertently cannibalize utility program savings claims. To accommodate this situation, some regulatory commissions recognize utility savings claims from C&S upgrades themselves, provided such claims are supported by utility activities and also evaluated, measured, and verified. Evaluating savings from C&S upgrades is a complex undertaking that requires determination of multiple factors: market baselines, unit energy savings, code compliance rates, the normal rate of code adoption absent utility influence, net savings discounts, and allocation of market-wide savings to specific utility service territories. In Arizona, recent upgrades to residential and commercial construction codes presented the author with a unique opportunity to develop a novel approach for estimating potential savings from code upgrades occurring in various jurisdictions throughout the state. Using the methodology presented herein, utilities can develop measurable and realistic goals for both their C&S programs and their traditional energy efficiency programs' influence on C&S adoption. The methodology will minimize the uncertainty associated with quantifying energy code impacts before considering attribution of savings to discrete utility efforts. Furthermore, use of the methodology can provide justification for utilities to engage in code development efforts.

## Introduction

Certain regulatory commissions throughout the United States recognize utility savings claims from C&S upgrades, provided such claims are supported by utility activities and also evaluated, measured, and verified. For example, as stated in section R14-2-2404 part E of the Arizona Electric Energy Efficiency Standards (Docket No. RE-00000C-09-0427)[1],

> *"An affected utility may count toward meeting the standard up to one third of the energy savings, resulting from energy efficiency building codes, that are quantified and reported through a measurement and evaluation study undertaken by the affected utility."*

The logic behind regulatory approval of C&S savings claims is, since the utility efficiency programs influence the market for energy efficient products and services, the programs can help ready the market for more stringent codes and standards to be adopted, and can improve existing code compliance rates. Some utilities also participate as a constituent in the C&S development or compliance enhancement process, and claim savings from their direct influence on policymakers at the state, regional, or national level. Like measurement of spillover, market transformation, and net to gross ratios, measurement and verification of C&S savings is a challenge that involves tracking market activity, developing attribution logic, and making assumptions about the normal rate of efficiency adoption absent utility program influence.

Navigant used the California industry standard C&S program evaluation protocol evaluation (see **Figure 1**), which as a template for the codes program. The remainder of this paper explains the process

[1] Note the one-third adjustment factor is an Arizona-specific policy choice and does not apply to all C&S evaluations.

outlined in **Figure 1** within the specific context of measuring savings from Arizona residential and commercial new construction codes.

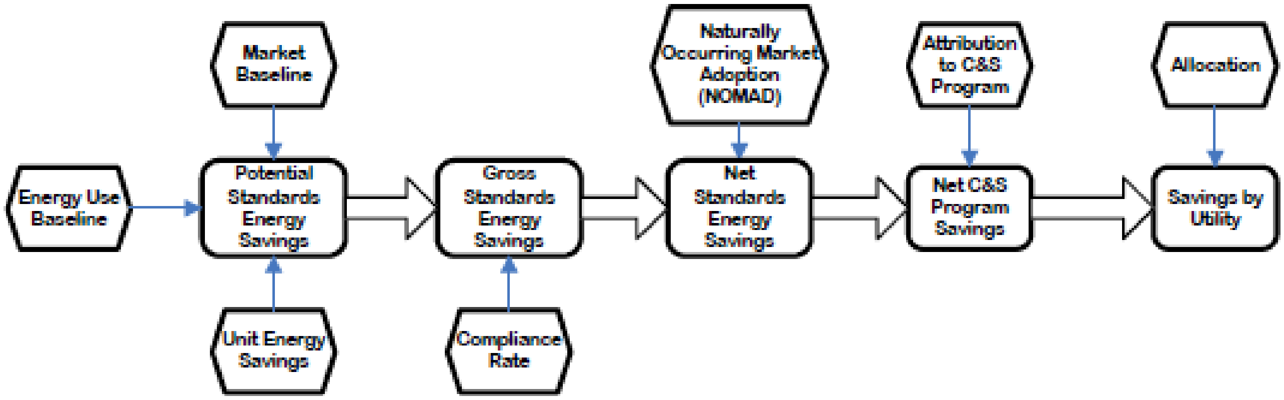


**Figure 1: C&S Program Evaluation Protocol (Lee, A. et al., 2008)**

This paper presents the analyses of residential and commercial codes separately and according to the format outlined below, using the most recent data from Arizona Public Service (APS) service territory to provide examples for each calculation that the evaluators must develop, which feed into the final savings analysis.

- **Description of the Code** – a qualitative description of the code and how it affects energy use in the utility service territory
- **Potential Energy Savings** – the total energy savings from the code or standard change in the utility territory, derived from market data and assuming 100 percent compliance
- **Gross Energy Savings** – potential energy savings adjusted for compliance rates
- **Net Energy Savings** – gross energy savings adjusted for normally occurring market adoption (NOMAD) of efficient building practices, and normally occurring standards adoption (NOSAD) of codes that require efficient building practices
- **Net Codes and Standards Program Savings** – net energy savings from the utilities' codes programs, adjusted for the regulatory-prescribed one-third allowance

Error! Reference source not found. is an illustrative summary of the various savings concepts in the C&S evaluation process contained in this paper. The cumulative savings are represented by the area(s) under each of the curves, and the values of each curve at a given point in time represent the apportionment of the savings in that year resulting from the original adoption.

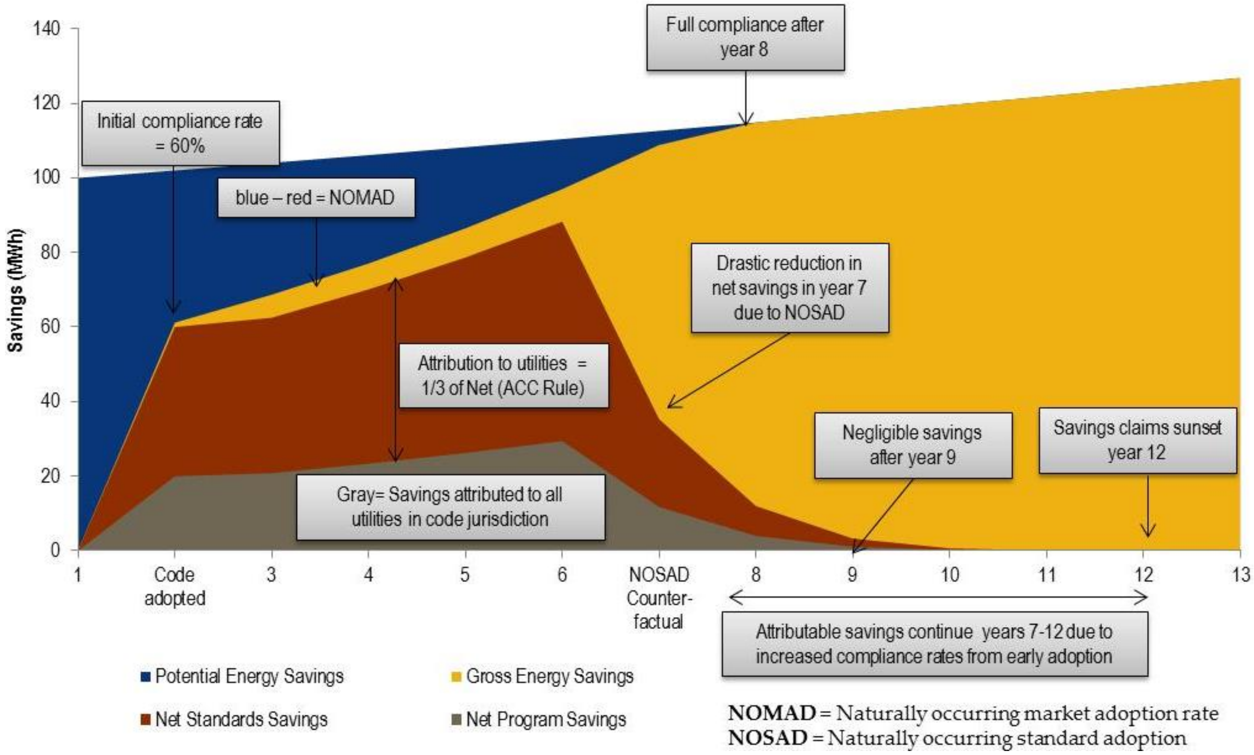


**Figure 2. Illustration of C&S Savings Types over Time**

Error! Reference source not found. illustrates energy savings for a hypothetical building code adopted in year 2 with an initial compliance rate of 60 percent. Potential energy savings increase every year as the market size of new buildings grows at 2 percent per year. In this example, it takes seven years[2] for the market of new buildings to comply completely with the adopted code (100 percent compliance), at which point gross savings equals potential savings. Discounting gross savings by NOMAD yields net savings. Net savings are determined by applying an attribution factor, which yields net C&S program savings. These net program savings would then need to be allocated among the utilities that serve the area within the jurisdictional code authority (allocation not shown).

Error! Reference source not found. also represents NOSAD—when the code or standard would have been adopted absent the influence of the utilities. In this example, NOSAD occurs in year 7, five years after the code was actually adopted. However, C&S savings continue after NOSAD, due to the increased code compliance rates that were "banked" in years 2 to 6 as a result of the utilities' efforts to encourage code adoption earlier than it would have occurred otherwise. In other words, NOSAD does not immediately cancel all C&S savings, since it is assumed that the NOSAD would have begun with only a 60 percent compliance rate in the first year of code adoption.

[2] Even though building codes are adopted on a three year timescale, Navigant extended the timescale in this figure to more appropriately illustrate all the temporal code evaluation considerations.

## Residential New Construction

### Description of the Code

Throughout the United States, each state or jurisdictions within a state adopts a version of the International Energy Conservation Code (IECC) (or their own code if equivalent or better). The IECC code is updated at three-year intervals, and covers energy-related aspects of new construction practices. As a home rule state, each jurisdiction (i.e., county or city) in Arizona has the option to adopt its own version of the IECC. Consequently, in each utility service territory, there is a mixture of IECC code vintages from 2003 to 2012. Navigant's energy savings analysis is based on a combination of proposed code changes within each service territory and energy simulation modeling.

### Potential Energy Savings

Navigant's calculation of the potential energy savings represents a hypothetical scenario in which a new building code in a particular jurisdiction is 100 percent effective on the day the code is implemented (i.e. full compliance). Potential energy savings were calculated using **Equation 1**:

**Equation 1. Territory-Wide Potential Energy Savings from Residential Building Codes (kWh)**

$$\sum (NewMeters\ x\ (kWh/year_{oldcode} - kWh/year_{newcode}) * Factors$$

Where:

| | |
|---|---|
| $NewMeters$ | = The number of new meters installed in a particular jurisdiction as a percent of the total residential (single-family or multifamily) meters installed by the utility in 2014. |
| $kWh/year_{oldcode}$ | = Annual consumption (kWh) of code-compliant homes in a jurisdiction prior to adoption of a more stringent code |
| $kWh/year_{newcode}$ | = Annual consumption (kWh) of code-compliant homes in a jurisdiction after the adoption of a more stringent code |
| $Factors$ | = Technical factors such as the line loss factor coincident demand ratio (for demand calculations only), and capacity reserve adjustment |

A list of new meters installed by APS was used as a proxy for new home construction. **Equation 1** applies to both single-family and multifamily new meters, summed across all jurisdictions within the utility service territory.

**Unit Energy Savings** – ($kWh/year_{oldcode}$ and $kWh/year_{newcode}$) – After examining the breakdown of new meters installed by climate zone (**Table 1**), Navigant used calibrated energy models for single-family and multifamily homes in climate zone 2B to represent the typical home in Arizona.

**Table 1. 2014 APS New Residential Meter Installations by Climate Zone**

| Climate Zone | Single-Family Meters | Multifamily Meters | Total New Meters | New Meters as a Percent of Total |
|---|---|---|---|---|
| **2B** | 5,782 | 2,500 | 8,282 | 86.1% |
| **3B** | 19 | 5 | 24 | 0.2% |
| **4B** | 943 | 24 | 967 | 10.0% |
| **5B** | 324 | 27 | 351 | 3.6% |
| **Total** | **7,068** | **2,556** | **9,624** | **100.0%** |

To determine unit energy savings per new meter by code vintage, Navigant used a suite of EnergyPlus energy models with typical Arizona house dimensions and code-compliant inputs, calibrated to monthly APS billing data with Phoenix weather. The simulated consumption of each code-compliant home is shown in **Table 2**.

**Table 2. Modeled Annual Residential Electricity Consumption in Phoenix by Code Vintage**

| Code Version | Single-Family Annual Consumption (kWh) | Multifamily Annual Consumption (kWh) |
|---|---|---|
| 2003 IECC | 19,663 | 8,427 |
| 2006 IECC | 18,743 | 8,088 |
| 2009 IECC | 17,068 | 7,749 |
| 2012 IECC[3] | 13,380 | 7,411 |

**Quantity of New Homes** – $(NewMeters)$ – Navigant requested a list of new residential meters installed by APS in 2014 from their billing database. Navigant investigated the code adoption schedules of all 104 jurisdictions in which APS installed new meters in 2014. Navigant considered a code effective in 2014 if the jurisdiction enforced the code before July 1. If the code was enforced after July 1, Navigant considered the code effective in 2015 and beyond.

To calculate demand savings, Navigant applied a coincident demand ratio derived from energy models created for measurement and evaluation of APS's ENERGY STAR Homes Program according to **Equation 2**.

**Equation 2. Calculating Annual Demand Savings from the Residential Building Codes**

$$\left(\frac{kWh\,savings}{8760}\right) * (1 + LLF) * CDR * (1 + CRM) = kWsavings$$

Where:

| | |
|---|---|
| $\frac{kWh\ savings}{8760}$ | = Total energy savings (kWh) divided by the number of hours in a year |
| $1 + LLF$ | = accounting for the demand line loss factor |
| $CDR$ | = accounting for the coincident demand ratio |

[3] There is a significant increase in efficiency between IECC 2012 and IECC 2009 in the Arizona climate.

$1 + CRM$ = accounting for the capacity reserve margin

## Gross Energy Savings

Through interviews with APS staff familiar with building practices in Arizona, and a survey of code compliance studies conducted throughout the United States, Navigant developed a compliance rate to account for the fact that building practices can take significant time to adapt to a code change. Navigant assumes 50 percent compliance in the first year of adoption, with full compliance achieved by the fourth year after adoption. **Table 3** shows the effect of compliance rate on consumption. The compliance rate increases each year after adoption of a new code. The compliance rate affects the modeled consumption of each code-compliant home according to **Equation 3**.

**Table 3. Modeled Code Consumption Adjusted for Compliance Rates for Single-Family Homes**

| Old Code and New Code | Compliance Adjusted Consumption (kWh) | | | |
|---|---|---|---|---|
| | **Year 1** | **Year 2** | **Year 3** | **Year 4** |
| 2003 to 2006 | 19,203 | 18,973 | 18,881 | 18,743 |
| 2003 to 2009 | 18,365 | 17,717 | 17,457 | 17,068 |
| 2003 to 2012 | 16,521 | 14,950 | 14,322 | 13,380 |
| 2006 to 2009 | 17,906 | 17,487 | 17,319 | 17,068 |
| 2006 to 2012 | 16,061 | 14,720 | 14,184 | 13,380 |
| 2009 to 2012 | 15,224 | 14,302 | 13,933 | 13,380 |
| **Compliance Rates** | 50% | 75% | 85% | 100% |

**Equation 3. Calculation of Compliance Adjusted Consumption**

$$kWh_{newcode} + ((kWh_{oldcode} - kWh_{newcode}) * Compliance\ Rate)$$

Where:

$kWh_{oldcode}$ = Modeled consumption (kWh) of a home compliant with the old code
$kWh_{newcode}$ = Modeled consumption (kWh) of a home compliant with the new code
$Compliance\ Rate$ = Degree to which building practices comply with the new code on an energy use basis, expressed as a percentage

## Net Energy Savings

Net to gross ratios in a code savings evaluation require consideration of the normally occurring market adoption (NOMAD) of efficient building practices, and normally occurring standards adoption (NOSAD) of codes mandating efficiency. In some jurisdictions, such as California, there is precedent that allows a utility to claim savings from a standard as long as that standard is not superseded by a more stringent standard (Cadmus, 2014). For example, there are two standards that affect linear fluorescents, the 2012 EISA standard (Public Law 110-140, 2007), and the 2018 Department of Energy (DOE) standard (U.S. Department of Energy, 2014). It is common practice in California to acknowledge that utilities may claim savings from the 2012 EISA standard for linear fluorescents from the time the standard is introduced through

2017. Once the 2012 standard is superseded, utilities may no longer claim savings from this standard. In other words, the 2012 EISA standard would have normally been adopted by the market anyway, without utility influence, by 2018 at the latest.

Applying this logic to the codes model in Arizona is a difficult process, because each jurisdiction adopts different codes on various timescales. The minimum timescale for adoption of a new code is 3 years, because IECC codes are released by the International Code Council on a triennial basis. Navigant assumes that the influence of the utility accelerates each jurisdictions code adoption process by three years, so for the purposes of determining savings in each jurisdiction, we examine the code that was in effect three years ago as the "baseline" consumption from which energy savings are measured. In other words, the NOSAD of codes in each jurisdiction is a three-year lag from what is actually happening due to Arizona utilities' influence on their constituent jurisdictions.

### Net Code Program Savings

Navigant estimated net C&S program savings for all codes and standards under consideration in 2014 as one-third of net energy savings, as permitted under ACC R-14-2. Navigant calculated net annual energy and demand savings shown in **Table 4** using the values and adjustments noted above in conjunction with the equations listed in this section.

**Table 4. 2014 APS Net Energy and Demand Savings at Generator from Residential Building Codes**

| | **MWh** |
|---|---|
| Net Energy Savings – Single-Family | 6,976 |
| Net Energy Savings - Multifamily | 640 |
| Total Net Energy Savings | 7,617 |
| **Net C&S Program Energy Savings** | **2,539** |
| | **MW** |
| Net Demand Savings – Single-Family | 3.8 |
| Net Demand Savings - Multifamily | 0.35 |
| Total Net Demand Savings | 4.14 |

In 2014 APS claimed 2,539MWh from residential new construction codes accounting for code changes across 104 jurisdictions. The following seciont describes a similar approach for the commercial sector.

## Commercial New Construction

### Description of the Code

The commercial equivalent of IECC is ASHRAE 90.1. The 2004, 2007, and 2010 versions of ASHRAE 90.1 accompany the 2006, 2009, and 2012 versions of IECC respectively[4]. As a home rule state, each jurisdiction in Arizona (i.e., county or city) has the option to adopt its own version of IECC/ASHRAE 90.1. Consequently, in APS territory, there is a mixture of all ASHRAE 90.1 code vintages from 2004 to 2010.

### Potential Energy Savings

Navigant's calculation of the potential energy savings represents a hypothetical scenario in which a new building code in a particular jurisdiction is 100 percent effective on the day the code is implemented (i.e. full compliance). Potential energy savings were calculated using **Equation 4**:

**Equation 4. APS-Territory-Wide Potential Energy Savings from Commercial Building Codes (kWh)**

$$\sum\left(\frac{kWh}{year}/sqft_{oldcode,Btype} - \frac{kWh}{year}/sqft_{newcode,Btype}\right) * Factors_{Btype}$$

Where:

| | |
|---|---|
| $\frac{kWh}{year}/sqft_{oldcode,Btype}$ | = The Energy Use Intensity (EUI) in kWh per square foot of floor space subject to the code, by building type, in a jurisdiction prior to adoption of a more stringent code |
| $\frac{kWh}{year}/sqft_{newcode,Btype}$ | = The EUI in kWh per square foot of floor space subject to the code, by building type, in a jurisdiction after adoption of a more stringent code |
| $Factors_{Btype}$ | = Technical factors such as the line loss factor coincident demand ratio (for demand calculations only), and capacity reserve adjustment |

The equation applies to 23 different building types, summed across all building types and jurisdictions within APS territory.

**Unit Energy Savings** To determine unit energy savings per square foot of new commercial floor space by building type, climate zone, and code vintage; Navigant used a suite of commercial prototype building energy models with code-compliant inputs provided by DOE (U.S. Department of Energy, 2012).

APS provided Navigant with a list of new meters installed in commercial facilities in 2014. This list included a building type designation determined by APS. By examining the APS definition and DOE definition of each building type, Navigant assigned corresponding DOE building types to each APS designation as shown in **Table 5**.

The DOE prototype models are also built to national average sizes by each building type. In order to

[4] For a detailed discussion of the parallels between IECC and ASHRAE90.1, see:
US Department of Energy. "Building Energy Codes 101: An Introduction." February 2010. PNNL-SA-70586.

obtain region-specific size data for each building type, Navigant used a combination of data from third-party databases maintained by Dodge Construction and CoStar. When lacking sufficient building size data, Navigant used the DOE prototype sizes, as shown in **Table 5**.

Navigant investigated the code adoption schedules of 75 jurisdictions in which APS installed new meters in 2014. From the 75 jurisdictions examined, 21 contributed to C&S program savings in 2014. In each jurisdiction, the new meters were further disaggregated by building type, and the appropriate EUIs were applied according to climate zone, building type, and code vintage.

**Table 5. Summary of APS and DOE Building Types and Sizes**

| APS Designation | DOE Prototype Model | DOE Building Area (sq ft) | AZ Building Area (sq ft) |
|---|---|---|---|
| College/University | Secondary School | 210,886 | 153,985 |
| Department Store | Strip Mall | 22,500 | 18,225 |
| Elementary School | Primary School | 73,959 | 114,960 |
| Grocery/Convenience Store | Stand-alone Retail | 24,692 | 18,225 |
| Halls | Medium Office | 53,628 | 28,190 |
| High School | Secondary School | 210,886 | 114,960 |
| Hotel | Large Hotel | 122,120 | 73,712 |
| Indust/Mfg/Process | Full Service Restaurant | 5,502 | 4,668 |
| Inpatient Facility | Hospital | 241,501 | 126,965 |
| Jr High/Middle School | Secondary School | 210,886 | 114,960 |
| Laundry/Cleaning Service | Quick Service Restaurant | 2,501 | 2,501 |
| Motel | Small Hotel | 40,096 | 73,712 |
| Office | Medium Office | 53,628 | 28,190 |
| Outpatient Facility | Outpatient Healthcare | 40,946 | 40,946 |
| Resort | Large Hotel | 122,120 | 73,712 |
| Restaurant or Bar | Full Service Restaurant | 5,502 | 5,407 |
| Retail – Exterior Entry | Stand-alone Retail | 24,692 | 15,002 |
| Retail – Int/Ext Entry | Stand-alone Retail | 24,692 | 15,002 |
| Retail – Interior Entry | Strip Mall | 22,500 | 15,002 |
| Spa/Gymnasium | Small Hotel | 40,096 | 73,712 |
| Take-Out Food | Quick Service Restaurant | 2,501 | 2,501 |
| Warehouse | Warehouse | 52,045 | 55,704 |
| Wholesale-Type Store | Warehouse | 52,045 | 55,704 |

**Factors** – Energy and demand savings calculations included line loss, coincidence factors (by building type), and capacity reserve margins. Navigant derived coincidence factors from the hourly output of the DOE prototype energy models, using APS coincident peak hours. Navigant determined a coincidence factor by building type and multiplied energy savings by the coincidence factor to calculate demand savings.

**Gross Energy Savings**

Through interviews with APS staff familiar with building practices in Arizona, and a survey of code compliance studies conducted throughout the United States, Navigant developed a compliance rate to account for the fact that building practices can take significant time to adapt to a code change. As shown in **Table 6**, the analysis assumes 65 percent compliance in the first year of adoption, with full compliance achieved by the fourth year after adoption. Annual EUI adjustments are based on the increasing compliance rates, as calculated using the same methodology detailed in the Residential New Construction section (**Equation 3**).

**Table 6. Compliance Rate Assumptions for Commercial New Construction Codes**

| | **Year 1** | **Year 2** | **Year 3** | **Year 4** |
|---|---|---|---|---|
| Compliance Rates | 65% | 75% | 90% | 100% |

**Net Energy Savings**

Navigant applied a consistent methodology for the NOMAD/NOSAD adjustment across sectors, as ASHRAE codes also have a three-year code design cycle. Please see the Net Energy Savings discussion in the Residential New Construction section for details and justification for this methodology.

**Net Code Program Savings**

Navigant calculated net C&S program savings for all codes and standards under consideration in 2014 as one-third of net energy, which is permitted under ACC R-14-2. Navigant calculated net annual energy and demand savings, and net C&S program savings shown in
**Table** 7 using the methodology and factors discussed above.

**Table 7. 2014 APS Net Energy and Demand Savings at Generator from Commercial Building Codes**

| | **MWh** |
|---|---|
| Total Net Energy Savings | 8,325 |
| **Net C&S Program Annual Energy Savings** | **2,775** |
| | **MW** |
| Total Net Demand Savings | 1.9 |
| **Net C&S Program Demand Savings** | **0.6** |

## Conclusion

Determining savings from C&S is a relatively new practice that is still under development throughout the United States. So far, only a few state utility commissions allow constituent utilities to claim savings from C&S upgrades, but support for fulfilling statewide efficiency goals through C&S programs is on the rise[5]. This unique situation provides Navigant and Arizona utilities with a challenge and an opportunity. Arizona utilities are faced with the challenge of pioneering a methodology for appropriately measuring and attributing C&S savings—a process that involves multiple assumptions that must be carefully determined so as not to overestimate or underestimate savings claims. On the other hand, our work on C&S represents an opportunity to develop a methodology that may be applied in Arizona and nationally. As C&S programs in Arizona and nationwide become more established, Navigant will continue to refine the C&S evaluation methodology based on best practices and available data.

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[5] For a review of the developments in C&S programs by state see Misuriello, H. *Building Energy Code Advancement through Utility Support and Engagement.* ACEEE Report number A126, December 2012.