COLUMBIA STATEMENT NO. 103-R

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

Pennsylvania Public Utility Commission	)	
vs.	)	Docket No. R-2015-2468056
Columbia Gas of Pennsylvania, Inc.	)	

REBUTTAL TESTIMONY OF
CHUN-YI LAI
ON BEHALF OF
COLUMBIA GAS OF PENNSYLVANIA, INC.

July 16, 2015

I. <u>Introduction</u>

Q. Please state your name and business address.

A. Chun-Yi Lai, 240 West Nationwide Blvd., Columbus, Ohio 43215.

Q. By whom are you employed and in what capacity?

A. I am employed by NiSource Corporate Services Company ("NCSC") as a Lead Regulatory Analyst. My responsibilities include providing support for various informational and rate filings, general rate case preparation and support, and other duties as assigned. NCSC provides, among other services, accounting and regulatory-related services for the NiSource Gas Distribution ("NGD") companies, including Columbia Gas of Pennsylvania, Inc. ("Columbia" or the "Company").

Q. Are you the same Chun-Yi Lai that filed direct testimony in this proceeding?

A. Yes.

Q. What is the purpose of your rebuttal testimony in this proceeding?

A. The purpose of my testimony is to address the customer attrition treatment proposed by Lafayette K. Morgan Jr. on behalf of the Office of Consumer Advocate ("OCA"). Mr. Morgan recommends the use of the most recent three-year average, 2012 through 2014, as the basis for residential and commercial customer attrition. I will also address the revenue presentation of the weather normalization adjustment of $707,914 as proposed in Schedule LKM-1.

Q. Do you agree with Mr. Morgan's treatment of customer attrition?

A. No, I do not agree with Mr. Morgan's recommendation. The customer attrition based upon the most recent three-year average, 2012 through 2014, would produce a change in customer count in the forecast that is deemed high compared to recent years.

Q. Please explain.

A. Mr. Morgan suggests a -.02% residential average which would produce customer attrition of (769) and (774) for 2015 and 2016, respectively. Mr. Morgan also recommends a -0.9% commercial average which would produce customer attrition of (336) and (336) for 2015 and 2016, respectively. This would cause the forecast to produce a net change in customer counts (projected additions less projected attrition) that is higher than the historic average. As shown in Table 1R below, Mr. Morgan's recommendation of the three-year average for customer attrition would result in an annual customer count change of 0.7% for residential and 0.3% for commercial. This results in a customer count change of 2,891 and 118 for residential and commercial, respectively, for the Fully Forecasted Rate Year ("FFRY").

Table 1R

OCA Witness Morgan

Class	Year	Year-End Customers	Change in Customer	% Change	Expected Additions	Expected Attrition	% Attrition
Residential	2015	387,147	2,840	0.7%	3,609	(769)	-0.2%
Residential	2016	390,038	2,891	0.7%	3,665	(774)	-0.2%
Commercial	2015	37,394	110	0.3%	446	(336)	-0.9%
Commercial	2016	37,512	118	0.3%	454	(336)	-0.9%

Q. How does Mr. Morgan's adjustment compare to the historic averages?

As presented in Table-2R, the residential change would be higher than any year since 2006 and 84% higher than the average for 2007 through 2014. The change in commercial customer count from 2007 through 2014 has averaged a net loss of (114) which is significantly lower than Mr. Morgan's calculation of a net addition of 118.

Table - 2R

	RESIDENTIAL					
CPA	Year-End Customers	Change	% Change	Additions	Attrition	% Total Attrition
2006	371,692	3,454	0.9%	4,863	(1,409)	-0.4%
2007	373,928	2,236	0.6%	3,258	(1,022)	-0.3%
2008	375,051	1,123	0.3%	2,932	(1,809)	-0.5%
2009	375,225	174	0.0%	2,361	(2,187)	-0.6%
2010	377,103	1,878	0.5%	2,465	(587)	-0.2%
2011	377,530	427	0.1%	2,260	(1,833)	-0.5%
2012	379,679	2,149	0.6%	2,712	(563)	-0.1%
2013	381,727	2,048	0.5%	3,210	(1,162)	-0.3%
2014	384,232	2,505	0.7%	3,333	(828)	-0.2%
Average (2007 - 2014)		1,568				
OCA Adjustment		2,891				
Variance %		84.43%				

	COMMERCIAL					
CPA	Year-End Customers	Change	% Change	Additions	Attrition	% Total Attrition
2006	38,139	(262)	-0.7%	461	(723)	-1.9%
2007	38,002	(137)	-0.4%	453	(590)	-1.5%
2008	37,712	(290)	-0.8%	514	(804)	-2.1%
2009	37,363	(349)	-0.9%	375	(724)	-1.9%
2010	37,283	(80)	-0.2%	329	(409)	-1.1%
2011	37,122	(161)	-0.4%	363	(524)	-1.4%
2012	37,171	49	0.1%	325	(276)	-0.7%
2013	37,137	(34)	-0.1%	389	(423)	-1.1%
2014	37,225	88	0.2%	424	(336)	-0.9%
Average (2007 - 2014)		(114)				

Furthermore, the national average of -0.5% of total housing stock eliminated annually as presented in the Residential Demand Module by U.S. Energy Information Administration ("EIA") in June 2014 closely aligns with the Company's adjusted four-year residential attrition rate of -0.4%. Page 5 of my Exhibit CYL-1R provides the insert regarding residential housing stock loss.[1]

Q. Do you still recommend the attrition rates for residential and commercial customers as filed in Exhibit 103 for the Fully Forecasted Rate Year?

A. Yes, I recommend the use of the adjusted four-year average, 2010 through 2013, as the basis for residential and commercial customer attrition presented in Exhibit 103.

Q. Do you agree with Mr. Morgan's presentation of the weather normalization adjustment of $707,914 in Schedule LKM-1?

A. No, I do not agree with how the operating revenue adjustment of $707,914 is presented in Schedule LKM-1. It should be pointed out that the amount of $707,914 consists of base rate revenue, gas cost revenue and other rider revenues such as Universal Service Plan ("USP"), Gas Procurement Charge, Merchant Function Charge, Customer Choice ("CC") and Customer Administrative Charge ("CAC"). The impact to base rate revenue is $288,409 instead of the $707,914 as shown in Mr. Morgan's Schedule LKM-1. Table-3R shows the proper

[1] A full copy of the EIA's June 2014 Report *Assumptions to the Annual Energy Outlook 2014* is available at http://www.eia.gov/forecasts/aeo/assumptions/.

presentation of the weather normalization adjustment proposed by Mr. Morgan.

Table - 3R

Line No.		Company Amounts at Present Rates	OCA Adjustment for Weather Norm.	Amounts After OCA Adjustments
	Operating Revenues [1]			
1	Base Revenues (Incl. Transportation)	$ 310,753,903	$ 288,409	$ 311,042,312
2	Fuel Revenues	190,479,760	331,851	190,811,611
3	Rider USP	27,644,938	77,865	27,722,803
4	Gas Procurement Charge	2,322,967	4,281	2,327,248
5	Merchant Function Charge	1,752,694	5,454	1,758,148
6	Rider CC	41,900	54	41,954
7	Rider CAC	-	-	-
8	Total Sales and Transportation Revenues	$ 532,996,162	$ 707,914	$ 533,704,076
9	Off System Sales Revenue	-		
10	Late Payment Fees	1,318,074	-	1,318,074
11	Other Operating Revenues (Excl. Transport.)	584,914	-	584,914
12	Total Operating Revenues	$ 534,899,150	$ 707,914	$ 535,607,064

1./ Source data provided in OCA's response to CPA Set I-1.

Q. What is the corresponding increase in the cost of gas expense?

A. There should be a corresponding increase of $331,851 in the cost of gas expense for the additional gas.

Q. Does this complete your rebuttal testimony?

A. Yes, it does.

Independent Statistics & Analysis
U.S. Energy Information Administration

Assumptions to the Annual Energy Outlook 2014

June 2014

Residential Demand Module

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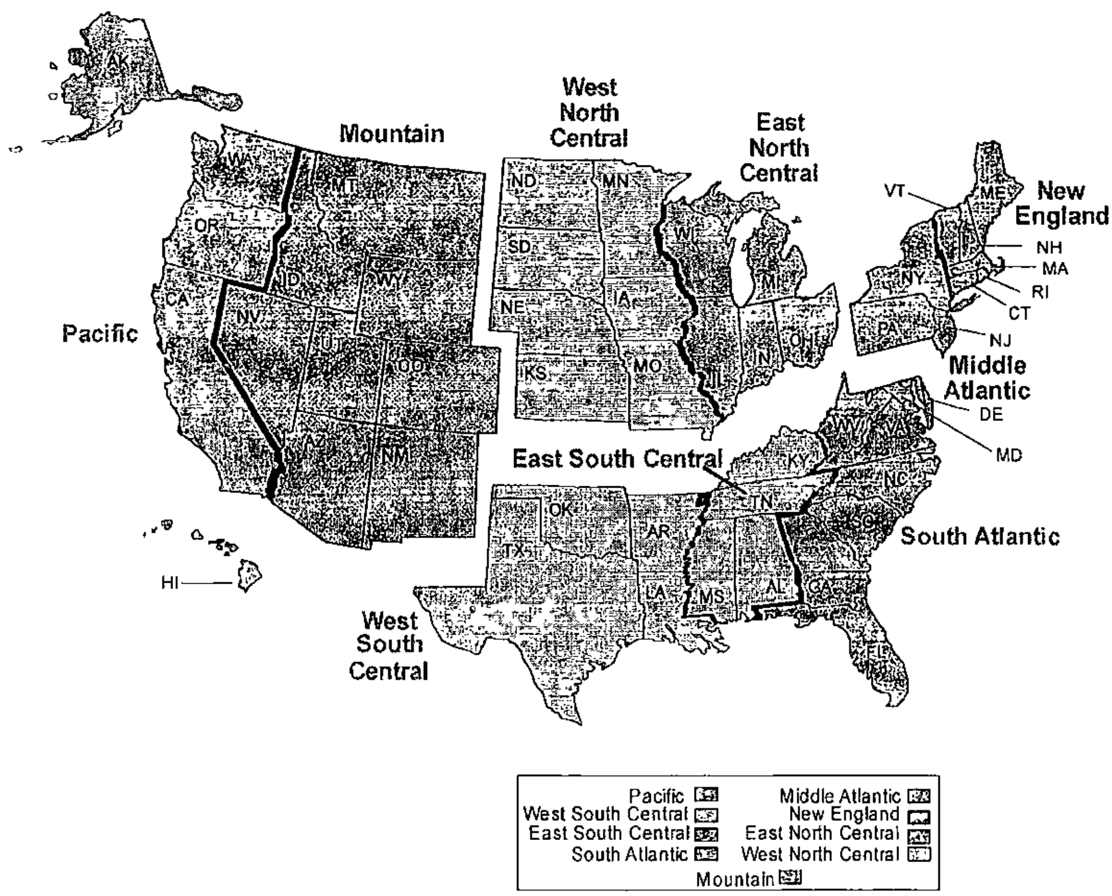
The NEMS Residential Demand Module projects future residential sector energy requirements based on projections of the number of households and the stock, efficiency, and intensity of energy-consuming equipment. The Residential Demand Module projections begin with a base year estimate of the housing stock, the types and numbers of energy-consuming appliances servicing the stock, and the "unit energy consumption" (UEC) by appliance (in million Btu per household per year). The projection process adds new housing units to the stock, determines the equipment installed in new units, retires existing housing units, and retires and replaces appliances. The primary exogenous drivers for the module are housing starts by type (single-family, multifamily and mobile homes) and by Census division, and prices for each energy source for each of the nine Census divisions (see Figure 5).

The Residential Demand Module also requires projections of available equipment and their installed costs over the projection horizon. Over time, equipment efficiency tends to increase because of general technological advances and also because of federal and/or state efficiency standards. As energy prices and available equipment change over the projection horizon, the module includes projected changes to the type and efficiency of equipment purchased as well as projected changes in the usage intensity of the equipment stock.

Figure 5. United States Census Divisions



Source: U.S. Energy Information Administration, Office of Energy Analysis.

Residential Demand Module

The end-use equipment for which stocks are modeled include those major end uses that often span several fuels, such as space conditioning (heating and cooling) equipment, water heaters, refrigerators, freezers, dishwashers, clothes washers, cookstoves, clothes dryers, light bulbs, furnace fans, as well as several miscellaneous electric loads: televisions and related equipment (set-top boxes, home theater systems, DVD players, and video game consoles), computers and related equipment (desktops, laptops, monitors, networking equipment), rechargeable electronics, ceiling fans, coffee makers, dehumidifiers, microwaves, pool heaters and pumps, home security systems, and portable electric spas. In addition to the modeled end uses previously listed, the average energy consumption per household is projected for other electric and nonelectric uses. The fuels represented are distillate fuel oil, liquefied petroleum gas, natural gas, kerosene, electricity, wood, geothermal, and solar energy. The module's output includes number of households, equipment stock, average equipment efficiencies, and energy consumed by service, fuel, and geographic location.

One of the implicit assumptions embodied in the residential sector Reference case projections is that, through 2040, there will be no radical changes in technology or consumer behavior. No new regulations of efficiency beyond those currently embodied in law or new government programs fostering efficiency improvements are assumed. Technologies which have not gained widespread acceptance today will generally not achieve significant penetration by 2040. Currently available technologies will evolve in both efficiency and cost. In general, future technologies at the same efficiency level will be less expensive, in real dollar terms, than those available today. When choosing new or replacement technologies, consumers will behave similarly to the way they now behave, and the intensity of end uses will change moderately in response to price changes.

Key assumptions

Housing Stock submodule

An important determinant of future energy consumption is the projected number of households. Base year estimates for 2009 are derived from the U.S. Energy Information Administration's (EIA) Residential Energy Consumption Survey (RECS) (Table 4.1). The projection for occupied households is done separately for each Census division. It is based on the combination of the previous year's surviving stock with projected housing starts provided by the NEMS Macroeconomic Activity Module. The Housing Stock submodule assumes a constant survival rate (the percentage of households which are present in the current projection year, which were also present in the preceding year) for each type of housing unit: 99.7% for single-family units, 99.5% for multifamily units, and 96.6% for mobile home units.

Projected fuel consumption is dependent not only on the projected number of housing units, but also on the type and geographic distribution of the houses. The intensity of space heating energy use varies greatly across the various climate zones in the United States. Also, fuel prevalence varies across the country—oil (distillate) is more frequently used as a heating fuel in the New England and Middle Atlantic Census divisions than in the rest of the country, while natural gas dominates in the Midwest. An example of differences by housing type is the more prevalent use of liquefied petroleum gas in mobile homes relative to other housing types.

Table 4.1. 2009 Households

Census	Single-Family Units	Multifamily Units	Mobile Homes	Total Units
New England	3,374,597	2,052,063	84,437	5,511,097
Middle Atlantic	9,287,267	5,536,739	435,344	15,259,350
East North Central	13,077,414	4,217,199	558,802	17,853,414
West North Central	6,153,386	1,406,903	503,817	8,064,106
South Atlantic	15,162,865	4,656,262	2,405,757	22,224,884
East South Central	5,480,023	945,846	658,471	7,084,340
West South Central	9,095,440	2,822,348	853,143	12,770,931
Mountain	5,983,945	1,258,517	662,813	7,905,276
Pacific	10,937,616	5,226,838	778,377	16,942,832
United States	78,552,553	28,122,715	6,940,961	113,616,230

Source: U.S. Energy Information Administration, 2009 Residential Energy Consumption Survey.

Technology Choice submodule

The key inputs for the Technology Choice submodule are fuel prices by Census division and characteristics of available equipment (installed cost, maintenance cost, efficiency, and equipment life). The Integrating Module of NEMS estimates fuel prices through an equilibrium simulation that balances supply and demand and passes the prices to the Residential submodule.

Prices combined with equipment UEC (a function of efficiency) determine the operating costs of equipment. Equipment characteristics are exogenous to the model and are modified to reflect both federal standards and anticipated changes in the market place. Table 4.2 lists capital costs and efficiency for selected residential appliances for the years 2010 and 2020.

Table 4.2. Installed cost and efficiency ratings of selected equipment

Equipment Type	Relative Performance[1]	2010 Installed Cost (2010$)[2]	2010 Efficiency[3]	2020 Installed Cost (2010$)[2]	2020 Efficiency[3]	Approximate Hurdle Rate
	Minimum	$4,800	7.7	$4,950	8.2	
Electric Heat Pump (heating component)	Best	$6,708	10.7	$8,125	10.8	25%
	Minimum	$2,500	0.78	$2,750	0.90	
Natural Gas Furnace[4]	Best	$2,625	0.98	$3,750	0.98	15%
	Minimum	$275	9.8	$295	11.0	
Room Air Conditioner	Best	$455	12.0	$515	13.0	42%
	Minimum	$3,200	13.7	$3,550	14.0	
Central Air Conditioner	Best	$4,500	21.0	$5,750	24.0	25%
	Minimum	$500	511	$525	408	
Refrigerator[5]	Best	$1,050	342	$1,250	327	10%
	Minimum	$600	0.90	$675	0.95	
Electric Water Heater	Best	$1,370	2.35	$2,050	2.35	50%
Solar Water Heater[6]	N/A	$5,320	N/A	$7,300	N/A	30%

[1]Minimum performance refers to the lowest-efficiency equipment available. Best refers to the highest-efficiency equipment available.
[2]*Installed costs are given in 2010 dollars in the original source document.*
[3]Efficiency measurements vary by equipment type. Electric heat pumps are based on Heating Seasonal Performance Factor (HSPF); natural gas furnaces are based on Annual Fuel Utilization Efficiency (AFUE); central air conditioners are based on Seasonal Energy Efficiency Ratio (SEER); room air conditioners are based on Energy Efficiency Ratio (EER); refrigerators are based on kilowatt-hours per year; and water heaters are based on Energy Factor (delivered Btu divided by input Btu).
[4]Values are for northern regions of United States.
[5]Reflects refrigerator with top mounted freezer with 20.6 cubic feet nominal volume.
[6]Values are for southern regions of United States.
Source: Updated Buildings Sector Appliance and Equipment Costs and Efficiency reports prepared for U.S. Energy Information Administration, Navigant Consulting, Inc. and SAIC (2013) www.eia.gov/analysis/studies/buildings/equipcosts/.

Table 4.3 provides the cost and performance parameters for representative distributed generation technologies. The model also incorporates endogenous "learning" for the residential distributed generation technologies, allowing for declining technology costs as shipments increase. For fuel cell and photovoltaic systems, learning parameter assumptions for the Reference case result in a 13%-reduction in capital costs each time the number of units shipped to the buildings sectors (residential and commercial) doubles. Capital costs for small wind, a relatively mature technology, only decline 3% with each doubling of shipments.

The Residential Demand Module projects equipment purchases based on a nested choice methodology. The first stage of the choice methodology determines the fuel and technology to be used. The equipment choices for cooling and water heating are linked to the space heating choice for new construction. Technology and fuel choice for replacement equipment uses a nested methodology similar to that for new construction, but includes (in addition to the capital and installation costs of the equipment) explicit costs for fuel or technology switching (e.g., costs for installing gas lines if switching from electricity or oil to gas, or costs for adding ductwork if switching from electric resistance heat to central heating types). Also, for replacements, there is no linking of fuel choice for water heating and cooking as is done for new construction. Technology switching across fuels upon replacement is allowed for space heating, air conditioning, water heating, cooking and clothes drying.

Once the fuel and technology choice for a particular end use is determined, the second stage of the choice methodology determines efficiency. In any given year, there are several available prototypes of varying efficiency (minimum standard, some intermediate levels, and highest efficiency). Efficiency choice is based on a functional form and coefficients which give greater or lesser importance to the installed capital cost (first cost) versus the operating cost. Generally, within a technology class, the higher the first cost, the lower the operating cost. For new construction, efficiency choices are made based on the costs of both the heating and cooling equipment and the building shell characteristics.

Once equipment efficiencies for a technology and fuel are determined, the installed efficiency for its entire stock is calculated.

Appliance Stock submodule

The Appliance Stock submodule is an accounting framework which tracks the quantity and average efficiency of equipment by end use, technology, and fuel. It separately tracks equipment requirements for new construction and existing housing units. For existing units, this module calculates the number of units which survive from previous years, allows certain end uses to further penetrate into the existing housing stock and calculates the total number of units required for replacement and further penetration. Air conditioning, dishwashing, and clothes drying are three major end uses not considered to be "fully penetrated."

Table 4.3. Capital cost and performance parameters of selected residential distributed generation technologies

Technology Type	Year of Introduction	Average Generating Capacity (kW_{DC})	Electrical Efficiency	Combined Efficiency (Elec. + Thermal	Installed Capital Cost (2009 $ per kW_{DC})[1]	Service Life (Years)
Solar Photovoltaic						
	2010	3.5	0.150	N/A	$7,117	30
	2015	4.0	0.175	N/A	$4,243	30
	2025	5.0	0.197	N/A	$3,266	30
	2035	5.0	0.200	N/A	$2,907	30
Fuel Cell						
	2010	10	0.364	0.893	$14,837	20
	2015	10	0.429	0.859	$14,837	20
	2025	10	0.456	0.842	$14,837	20
	2035	10	0.479	0.828	$14,837	20
Wind						
	2010	2	0.13	N/A	$7,802	30
	2015	3	0.13	N/A	$6,983	30
	2025	3	0.13	N/A	$6,234	30
	2035	4	0.13	N/A	$5,903	30

[1]The original source documents presented solar photovoltaic costs in 2008 dollars, fuel cell and wind costs in 2010 dollars.
Source: EIA analysis, as well as technology-specific reports: Solar photovoltaic: Photovoltaic (PV) Cost and Performance Characteristics for Residential and Commercial Applications (ICF International, 2010). Fuel cell: Commercial and Industrial CHP Technology Cost and Performance Data Analysis for EIA (SENTECH Incorporated, 2010). Wind: The Cost and Performance of Distributed Wind Turbines, 2010-35 (ICF International, 2010).

Once a piece of equipment enters into the stock, an accounting of its remaining life begins. The decay function is based on Weibull distribution shape parameters that approximate linear decay functions. The estimated maximum and minimum equipment lifetimes used to inform the Weibull shape parameters are shown in Table 4.4. Weibull shapes allow some retirement before the listed minimum lifetime, as well as allow some equipment to survive beyond its listed maximum lifetime. It is assumed that, when a house is retired from the stock, all of the equipment contained in that house retires as well; i.e., there is no second-hand market for this equipment.

Table 4.4. Minimum and maximum life expectancies of equipment

Equipment	Minimum Life	Maximum Life
Heat Pumps	7	21
Central Forced-Air Furnaces	10	25
Hydronic Space Heaters	20	30
Room Air Conditioners	8	16
Central Air Conditioners	7	21
Gas Water Heaters	4	14
Electric Water Heaters	5	22
Cooking Stoves	16	21
Clothes Dryers	11	20
Refrigerators	7	26
Freezers	11	31

Source: Lawrence Berkeley National Laboratory. Baseline Data for the Residential Sector and Development of a Residential Forecasting Database, May 1994, and analysis of RECS 2001 data.

Fuel Consumption submodule

Energy consumption is calculated by multiplying the vintage equipment stocks by their respective UECs. The UECs include adjustments for the average efficiency of the stock vintages, short-term price elasticity of demand and "rebound" effects on usage (see discussion below), the size of new construction relative to the existing stock, people per household, shell efficiency and weather effects (space heating and cooling). The various levels of aggregated consumption (consumption by fuel, by service, etc.) are derived from these detailed equipment-specific calculations.

Equipment efficiency

The average energy consumption for most technology types is initially based on estimates derived from RECS 2009. As the stock efficiency changes over the projection period, energy consumption decreases in inverse proportion to efficiency. Also, as efficiency increases, the efficiency rebound effect (discussed below) will offset some of the reductions in energy consumption by increased demand for the end-use service. For example, if the stock average for electric heat pumps is now 10% more efficient than in 2005, then all else constant (weather, real energy prices, shell efficiency, etc.), energy consumption per heat pump would average about 9% less.

Miscellaneous electric loads (MELs)

Unlike the technology choice submodule's accounting framework, the energy consumption projection of several miscellaneous electric loads is characterized by assumed changes in per-unit consumption multiplied by assumed changes in the number of units. In this way, stock and UEC concepts are projected, but without the decision-making parameters or investment calculations of the technology choice submodule. The UECs of certain MELs may be further modified beyond their input assumption by factors such as income, square footage, and/or degree days, where relevant.

Adjusting for the size of housing units

Estimates for the size of each new home built in the projection period vary by type and region, and are determined by a projection based on historical data from the U.S. Bureau of the Census [3]. For existing structures, it is assumed that about 1% of households that existed in 2009 add about 600 square feet to the heated floor space in each year of the projection period [4]. The energy consumption for space heating, air conditioning, and lighting is assumed to increase with the square footage of the structure. This results in an increase in the average size of a housing unit from 1,644 to 1,858 square feet from 2009 through 2040.

Adjusting for weather and climate

Weather in any given year always includes short-term deviations from the expected longer-term average (or climate). Recognition of the effect of weather on space heating and air conditioning is necessary to avoid inadvertently projecting abnormal weather conditions into the future. The residential module adjusts space heating and air conditioning UECs by Census division using data on heating and cooling degree-days (HDD and CDD). Short-term projections are informed by the National Oceanic and Atmospheric Administration's (NOAA) 15-month outlook from their Climate Prediction Center[5], which often encompasses the first forecast year. Projections of degree days beyond that are informed by a 30-year linear trend of each state's degree days, which are then population-weighted to the Census division level. In this way, the projection accounts for projected population migrations across the nation and continues any realized historical changes in degree days at the state level.

Short-term price effect and efficiency rebound

It is assumed that energy consumption for a given end-use service is affected by the marginal cost of providing that service. That is, all else equal, a change in the price of a fuel will have an opposite, but less than proportional, effect on fuel consumption. The current value for the short-term elasticity parameter for non-electric fuels is -0.15 [6]. This value implies that for a 1% increase in the price of a fuel, there will be a corresponding decrease in energy consumption of -0.15%. Changes in equipment efficiency also affect the marginal cost of providing a service. For example, a 10% increase in efficiency will reduce the cost of providing the end-use service by 10%. Based on the short-term efficiency rebound parameter, the demand for the service will rise by 1.5%(-10% multiplied by -0.15). Only space heating, cooling, and lighting are assumed to be affected by both elasticities and the efficiency rebound effect. For electricity, the short-term elasticity parameter is set to -0.30 to account for successful deployment of smart grid projects funded under the American Recovery and Reinvestment Act of 2009.

Shell efficiency

The shell integrity of the building envelope is an important determinant of the heating and cooling load for each type of household. In the NEMS Residential Demand Module, the shell integrity is represented by an index, which changes over time to reflect improvements in the building shell. The shell integrity index is dimensioned by vintage of house, type of house, fuel type, service (heating and cooling), and Census division. The age, type, location, and type of heating fuel are important factors in determining the level of shell integrity. Homes are classified by age as new (post-2009) or existing. Existing homes are represented by the most recent RECS survey and are assigned a shell index value based on the mix of homes that exist in the base year. The improvement over time in the shell integrity of these homes is a function of two factors—an assumed annual efficiency improvement and improvements made when real fuel prices increase. No price-related adjustment is made when fuel prices fall. For new construction, building shell efficiency is determined by the relative costs and energy bill savings for several levels of heating and cooling equipment, in conjunction with the building shell attributes. The packages represented in NEMS range from homes that meet the International Energy Conservation Code (IECC) [7] to homes that are built with the most efficient shell components. Shell efficiency in new homes increases over time when energy prices rise, or the cost of more efficient equipment falls, all else equal.

Legislation and regulations

American Recovery and Reinvestment Act of 2009 (ARRA09)

The ARRA09 legislation passed in February 2009 provides energy efficiency funding for Federal agencies, State Energy Programs, and block grants, as well as a sizable increase in funding for weatherization. To account for the impact of this funding, it is assumed that the total funding is aimed at increasing the efficiency of the existing housing stock. The assumptions regarding the energy savings for heating and cooling are based on evaluations of the impact of weatherization programs over time. Further,

it is assumed each house requires a $2,600 investment to achieve the heating and cooling energy savings cited in [8] and that the efficiency measures last approximately 20 years. Assumptions for funding amounts and timing were revised downward and further into the future based on analysis of the weatherization program by the Inspector General of the U.S. Department of Energy [9].

The ARRA09 provisions remove the cap on the 30% tax credit for ground-source heat pumps, solar PV, solar thermal water heaters, and small wind turbines through 2016. Additionally, the cap for the tax credits for other energy efficiency improvements, such as windows and efficient furnaces, was increased to $1,500 through the end of 2010. Several tax credits were extended at reduced credit levels through the end of 2011 as part of the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010. These tax credits were further extended through the end of 2013 as part of the American Taxpayer Relief Act of 2012, but since those tax credits were not in existence during 2012 and thus were not part of consumers' decision-making process, these tax credits were only modeled for 2013, not for 2012.

Successful deployment of smart grid projects based on ARRA09 funding could stimulate more rapid investment in smart grid technologies, especially smart meters on buildings and homes, which would make consumers more responsive to electricity price changes. To represent this, the price elasticity of demand for residential electricity was increased for the services that have the ability to alter energy intensity (e.g., lighting).

Energy Improvement and Extension Act of 2008 (EIEA 2008)

EIEA 2008 extends and amends many of the tax credits that were made available to residential consumers in EPACT 2005. The tax credits for energy-efficient equipment can now be claimed through 2016, while the $2,000 cap for solar technologies has been removed. Additionally, the tax credit for ground-source (geothermal) heat pumps was increased to $2,000. The production tax credits for dishwashers, clothes washers, and refrigerators were extended by one to two years, depending on the efficiency level and product. See the EPACT 2005 section below for more details about product coverage.

Energy Independence and Security Act of 2007 (EISA 2007)

EISA 2007 contains several provisions that impact projections of residential energy use. Standards for general service incandescent light bulbs are phased in over 2012-2014, with a more restrictive standard specified in 2020. It is estimated that these standards require 29% less watts per bulb in the first phase-in, increasing to 67% in 2020. General service incandescent bulbs become substandard in the 2012-2014 period and during this time halogen bulbs serve as the incandescent option. These halogen bulbs then become substandard in the 2020 specification, reducing general service lighting options to compact fluorescent and light-emitting diode (LED) technologies.

Energy Policy Act of 2005 (EPACT05)

The passage of the EPACT05 in August 2005 provides additional minimum efficiency standards for residential equipment and provides tax credits to producers and purchasers of energy-efficient equipment and builders of energy-efficient homes. The standards contained in EPACT05 include: 190 watt maximum for torchiere lamps in 2006; dehumidifier standards for

2007 and 2012; and ceiling fan light kit standards in 2007. For manufactured homes that are 30% better than the latest code, a $1,000 tax credit can be claimed in 2006 and 2007. Likewise, builders of homes that are 50% better than code can claim a $2,000 credit over the same period. The builder tax credits and production tax credits are assumed to be passed through to the consumer in the form of lower purchase cost. EPACT05 includes production tax credits for energy-efficient refrigerators, dishwashers, and clothes washers in 2006 and 2007, with dollar amounts varying by type of appliance and level of efficiency met, subject to annual caps. Consumers can claim a 10% tax credit in 2006 and 2007 for several types of appliances specified by EPACT05, including: energy-efficient gas, propane, or oil furnaces or boilers, energy-efficient central air conditioners, air and ground source heat pumps, hot water heaters, and windows. Lastly, consumers can claim a 30% tax credit in 2006 and 2007 for purchases of solar PV, solar water heaters, and fuel cells, subject to a cap.

Residential alternative cases

Technology cases

In addition to the Reference case, the Residential Demand Module contributes alternate assumptions to three side cases developed to examine the effect of different assumptions of technology on energy use. These cases are devoted to technology assumptions in the demand sectors: the 2013 Demand Technology case, a High Demand Technology case, and a Buildings Best Available Technology case.

The 2013 Technology assumptions specify that all future equipment purchases are made based only on equipment available in 2013. These cases further assume that existing building shell efficiencies will not improve beyond 2013 levels. The 2013 Technology assumptions are implemented in the 2013 Integrated Demand Technology case.

The High Technology assumptions include earlier availability, lower costs, and/or higher efficiencies for more advanced equipment than the Reference case. Equipment assumptions developed by engineering technology experts reflect the potential impact on technology given increased research and development into more advanced technologies [10]. In the High Technology cases, compliance efforts are increased after 2013 and all new construction is assumed to meet Energy Star specifications after 2023. In addition, consumers are assumed to evaluate energy efficiency investments at a discount rate of 7% (in real dollar terms). The High Technology assumptions are implemented in the Integrated High Demand Technology case.

The Best Available Demand Technology case assumptions require that all equipment purchases from 2014 forward are based on the highest available efficiency in the High Technology case in a particular modeled year, disregarding the economic costs of such a case. This case is designed to show how much the choice of the highest-efficiency equipment could affect energy consumption. In this case, all new construction is built to the most efficient specifications after 2013. In addition, consumers are assumed to evaluate energy efficiency investments at a discount rate of 7%.

Policy cases

The No Sunset case assumes the extension of all existing energy policies and legislation that contain sunset provisions. For the residential sector, this primarily involves tax credits for distributed generation and efficient end-use equipment. The Extended Policy case assumes additional rounds of appliance standards for most end-use equipment while maintaining the No Sunset tax credit assumptions for distributed generation, solar water heaters, and geothermal heat pumps. Standard levels are established based on current Energy Star guidelines. The Extended Policy case also adds multiple rounds of building codes by 2028.

Notes and sources

[1] The Model Documentation Report contains additional details concerning model structure and operation. Refer to Energy Information Administration, Model Documentation Report: Residential Sector Demand Module of the National Energy Modeling System, DOE/EIA-M067(2013), (November 2013). http://www.eia.gov/forecasts/aeo/nems/documentation/residential/pdf/m067(2013).pdf.

[2] Among the explanations often mentioned for observed high average implicit discount rates are: market failures, (i.e., cases where incentives are not properly aligned for markets to result in purchases based on energy economics alone); unmeasured technology costs (i.e., extra costs of adoption which are not included or difficult to measure, like employee down-time); characteristics of efficient technologies viewed as less desirable than their less-efficient alternatives (such as equipment noise levels or lighting quality characteristics); and the risk inherent in making irreversible investment decisions. Examples of market failures/barriers include: decision-makers having less than complete information, cases where energy equipment decisions are made by parties not responsible for energy bills (e.g., landlord/tenants, builders/ home buyers), discount horizons which are truncated (which might be caused by mean occupancy times that are less than the simple payback time and that could possibly be classified as an information failure), and lack of appropriate credit vehicles for making efficiency investments. The use of high implicit discount rates in NEMS merely recognizes that such rates are typically found to apply to energy-efficiency investments.

[3] U.S. Bureau of Census, Series C25 Data from various years of publications.

[4] Sources: U.S. Bureau of Census, Annual Housing Survey 2001 and Professional Remodeler, 2002 Home Remodeling Study.

[5] National Oceanic and Atmospheric Administration, National Weather Service, Experimental Monthly Degree Day Forecast, http://www.cpc.ncep.noaa.gov/pacdir/DDdir/ddforecast.txt. Explanation of forecast available at http://www. cpc.ncep.noaa.gov/pacdir/DDdir/N1.html.

[6] See Dahl, Carol, A Survey of Energy Demand Elasticities in Support of the Development of the NEMS, October 1993.

[7] The IECC established guidelines for builders to meet specific targets concerning energy efficiency with respect to heating and cooling load.

[8] Oak Ridge National Laboratory, Estimating the National Effects of the U.S. Department of Energy's Weatherization Assistance Program with State-Level Data: A Metaevaluation Using Studies from 1993 to 2005, September 2005.

[9] U.S. Department of Energy, Office of Inspector General, Office of Audit Services, Special Report: Progress in Implementing the Department of Energy's Weatherization Assistance Program under the American Recovery and Reinvestment Act, February 2010.

[10] The high technology assumptions are based on U.S. Energy Information Administration, Technology Forecast Updates-Residential and Commercial Building Technologies-Advanced Adoption Case (Navigant Consulting, September 2011).