CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

Automatic commercial ice maker shipments are key inputs to the national energy savings, net present value, and manufacturer impact analyses. This chapter describes the U.S. Department of Energy's (DOE's) methodology for estimating automatic commercial ice maker shipments and annual equipment stocks for 2010 through 2045.

DOE's shipments model predicts automatic commercial ice-making (ACIM) equipment stock flows as a function of year and age. Historical shipment data for the 21 primary ACIM equipment classes under consideration are key inputs to the shipments model. Figure 9.1.1 outlines the structure of the shipments model.

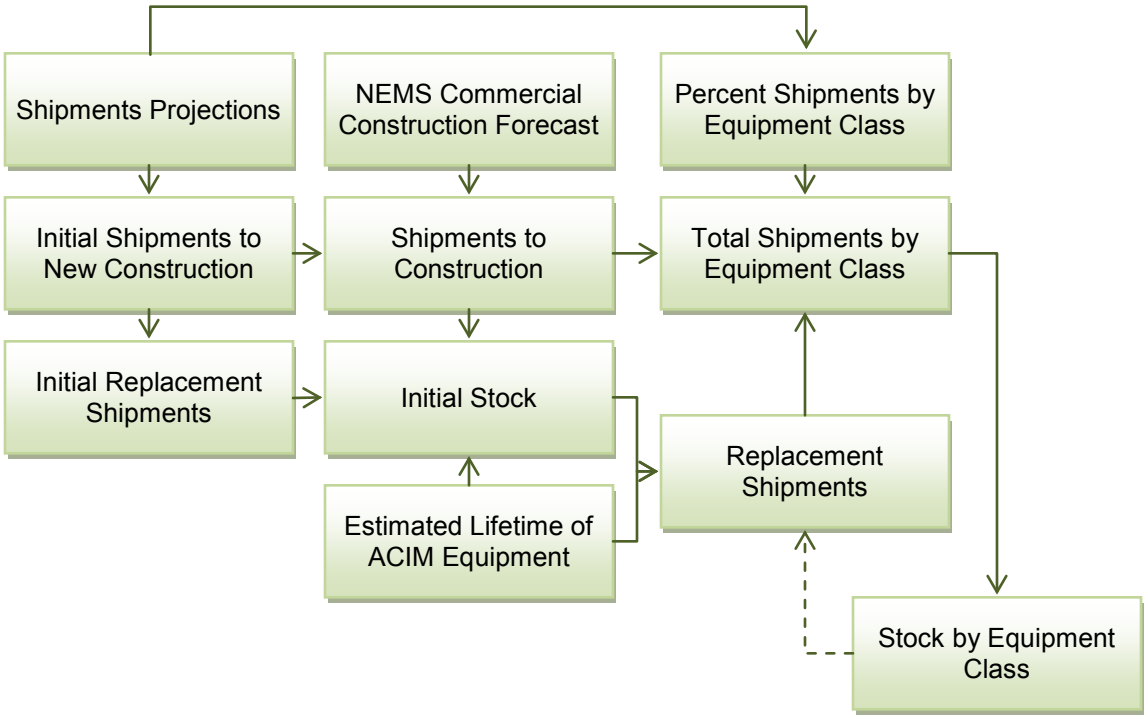

Figure 9.1.1 Flow Chart Showing Inputs to the Shipments Model

The model assumes that, in each year, the existing stock of automatic commercial ice makers either ages by 1 year or fails, and that failed equipment is replaced. It also assumes that new equipment can be installed in new commercial floor space, and old equipment can be removed through demolitions (not shown in the diagram).

Section 9.2 presents the mathematical formulation of the model; section 9.3 describes the data input to the model; and section 9.4 presents the results for the base-case energy conservation standard-level scenario and discusses the development of higher standard scenarios.

9.2 SHIPMENTS MODEL

DOE examined 21 equipment classes using the shipments model. DOE assumed that there is no interdependence between the shipments of the various equipment classes, so the equations are applicable to each equipment class independently.

As described in sections 9.3.1 and 9.3.2, DOE collected historical automatic commercial ice maker shipment data from 1994 through 2010. Using the historical data aggregated over 8-½-year periods, DOE developed a multi-year series of estimates of ACIM equipment stocks. DOE used the estimates of existing stock and the expected life of the equipment as a basis for calculating the portion of historical shipments that replaced existing stock. With estimates of historical stock, total shipments, and replacement shipments, DOE developed a stock accounting model to track equipment stocks through time.

To estimate historic shipments for new installations, DOE subtracted the estimated replacement sales from historical total sales. DOE then combined the estimated historical sales for new installations with indexes of historical and forecasted construction activity in seven building types to estimate future shipments for new installations. DOE forecasted new installations as a function of new construction of floor space in seven building types: health care, lodging, foodservice, retail, education, food sales, and office.

DOE then applied this stock accounting model across the 2016 to 2045 forecast period by adding new shipments and replacement shipments, and accounting for depreciated stock that was either replaced or demolished (*i.e.,* removed permanently from the stock). In doing so, DOE projected sales of new and replacement equipment by the year sold for the forecast period. In the final step, DOE allocated sales in each year to the 21 equipment classes in proportion to their relative historical sales.

9.2.1 Shipments Model Equations

DOE formulated the shipments model equations to update the stock from year t to year $t+1$ as a function of age a.

As discussed in chapter 8 of the preliminary technical support document (preliminary TSD), DOE estimates that the average lifetime of a unit is 8-½ years. DOE assumes that all units receive normal repairs that do not affect the lifetime of the equipment. The stock of age a in a given year t is represented by

$$U(t,a)$$

Eq. 9.1

Where:

$U(t,a)$ = stock of age a in a given year t,
a = age of stock (year), and
t = year.

The shipments of new stock in a given year is *Uship(t)*. By definition, the age of the equipment is zero in the year that it is shipped, so that *Uship(t) = U(t,0)*.

9.2.2 Stock Events

In the transition from year *t* to year *t +1*, three things could happen to the stock of automatic commercial ice makers:

1. existing equipment could fail, or be removed during a building renovation and be replaced,
2. existing equipment could be retired permanently, generally in a building demolition or renovation during which the business type(s) situated in the building changes, or
3. the stock could simply age by 1 year.

In the shipments model, DOE did not consider early replacements (*i.e.*, existing equipment that is replaced before it fails), and DOE assumed all failed equipment was replaced. The following sections present the equations used to represent each possible event.

9.2.2.1 Replacing Equipment

DOE determined the probability that ACIM equipment of age *a* from stock U_0 will fail or will be replaced using a Weibull survival distribution function. The Weibull function describes a series of probabilities of equipment failure in a given year, starting with a minimum lifetime of about 4 years and ending with a maximum lifetime of about 13 years. The distribution produces an average time of equipment failure of roughly 8-½ years, and results in 88 percent of stock being replaced in the 7- to 10-year lifetime range, and 99 percent replaced between 6 and 11 years. DOE defined the quantities of replaced equipment as follows:

$$UB(t,a) = PB_0(a) \times U_0(t,a)$$

Eq. 9.2

Where:

$UB(t,a)$ = quantity of units of age *a* in year *t* replaced,
$PB_0(a)$ = probability that stock of existing units of age *a* will fail or will be replaced,
$U_0(t,a)$ = original stock of units of age *a* in year *t* (*i.e.,* the probability of failure is applied against the original new stock installed in the historical year, yielding an age *a* in year *t*, not against the remaining stock),
a = age of stock (years), and
t = year.

9.2.2.2 New Equipment

Available information suggests that the purchase of new equipment for use in new buildings is driven by the rate of new construction in proportion to new floor space.

By definition, for each type of building:

$$EFS(t+1) = EFS(t) + NFS(t) - DFS(t)$$

Eq. 9.3

Where:

EFS(t) = existing floor space in year *t* (ft^2),
NFS(t) = new floor space added in year *t* (ft^2), and
DFS*(t)* = floor space demolished in year *t* (ft^2).

The number of units installed in new buildings is:

$$UN(t) = UN(t-1) \times NFS(t)/ NFS(t-1)$$

Eq. 9.4

Where:

UN(t) = the number of units installed in new buildings in year *t*.

DOE has little information on the variation in the market saturation of automatic commercial ice makers by building type or over time. Therefore, in the model, DOE assumed that the purchase of new equipment is driven by the construction of new floor space, and that failed or removed equipment is replaced on a one-for-one basis.

9.3 DATA INPUTS

9.3.1 Historical Shipments

Historical shipments data came from two main sources. The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) provided automatic commercial ice maker shipment data for 2010, which provided a distribution of shipments by equipment class. AHRI also provided a 10-year history of total shipments. Additionally, DOE collected the U.S. Census Bureau's Current Industrial Reports (CIR) data for the 1973 to 2009 period, including total ice maker shipments. DOE reviewed the total shipments in the AHRI and CIR data, and noted that the CIR-reported shipments were consistently higher than the AHRI-reported shipments. DOE considered the possibility that these discrepancies were associated with net exports. However, the CIR data did not present export information at a level of aggregation making it possible to identify ice maker exports. In the executive summary of this preliminary TSD, DOE requests input to aid in understanding the differences between the AHRI and CIR shipments data.

DOE identified one source with identifiable export information, the North American Association of Food Equipment Manufacturers (NAFEM). NAFEM data for two recent calendar years (2007 and 2008) showed approximately 20 percent of total ice maker shipments associated with food service equipment as exports. Applying a 20 percent export factor to the CIR shipments data brought the CIR data into approximate agreement with the AHRI data. For the preliminary analysis, DOE relied on the CIR shipment values, reduced 20 percent for exports.

Using adjusted CIR data DOE created a rolling estimate of total existing stock by aggregating historical shipments across 8-½ -year historical periods. DOE used the CIR data to estimate a time series of shipments and total stock for 1994 to 2006. For each year, using shipments, stock, and the estimated 8-½-year life of the equipment, DOE estimates that, on average, 14 percent of shipments were for new construction and the remainder for replacement of existing stock.

DOE then used the split between of shipments to new buildings and shipments for stock replacement to derive new shipments using the 2009 historical shipments. The 2009 shipments to new stock were then linked to 2009 and future building construction estimates to forecast shipments for new installations over a 2010–2045 forecast period. Starting with the 2009 stock estimates, adding shipments and subtracting estimated stock retirements, DOE also developed a forecast of surviving stock for the 2010–2045 period.

To identify appropriate building construction estimates for future growth in the forecast step, DOE distributed the estimated total 2009 existing ice maker stock across building types using distributions from a 2009 commercial refrigeration equipment report from Navigant Consulting, Inc.[1] Thus divided, the projections of new construction activity for each building type derived from National Energy Modeling System (NEMS) input files was used to project shipments for each building type.[a] Ice maker shipment and stock projections were then aggregated across building types by year, and the totals ultimately were distributed across all 21 equipment classes using distributions derived from the AHRI 2010[2] data.

9.3.2 Historical Shipments and Projected Building Stock Additions

DOE converted the estimated 2010 shipment data in each equipment class to percentages of total shipped units of automatic commercial ice makers for use in the shipments model. This established the ACIM equipment market share attributed to each equipment class for a base, historical data year.

DOE developed the forecast from the base historical data using projections of building construction derived from the *2011 Annual Energy Outlook* (*AEO2011*).[3] Table 9.3.1 shows the forecast square footage of new construction used to scale annual new ACIM equipment shipments. As the data in Table 9.3.1 show, forecast square-footage additions to the building stocks vary from year to year, with the first few years exhibiting lower levels of growth due to the lingering impacts of the current U.S. economic recession. The forecast ACIM equipment shipments therefore show some variability as well, tracking the forecast floor space additions. DOE used the growth rates over the last 10 years of the *AEO2011* forecast (2026−2035) to extrapolate the *AEO* forecast through the year 2045 to develop the full 30-year forecast needed for the national impacts analysis (see preliminary TSD chapter 10).

[a] For some types of consumer products and commercial equipment, specific classes of equipment are often linked to specific types of buildings. Hence, the step of dividing the equipment stock among building types captures crucial information for the forecast of specific equipment classes. In the case of ACIM, DOE is currently unaware of such specific linkages between types of buildings and equipment classes. However, because building stocks for each of the seven building types are projected to grow at varying rates, projecting shipments by building type enables DOE to capture as much information as possible from the NEMS commercial building construction projections.

Table 9.3.1 *AEO2011* Forecast of Commercial Floor Space Additions by Building Type

Year	New Construction of Commercial Floor Space *million ft²*						
	Health Care	Lodging	Foodservice	Retail	Education	Food Sales	Office
2011	69.194	113.946	39.320	406.927	313.378	28.162	205.734
2016	71.093	170.671	51.604	506.012	244.800	37.180	333.037
2020	72.744	168.989	53.026	514.581	261.367	38.159	402.214
2025	74.954	179.904	57.487	564.551	256.838	41.384	386.741
2030	76.834	184.135	59.748	599.171	273.840	42.946	388.644
2035	79.432	191.012	62.723	635.403	289.617	45.032	392.928
Annual Growth Factor, 2026-2035	0.58%	0.60%	0.88%	1.19%	1.21%	0.85%	0.16%

Source: U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2011*, data file kdbout.

DOE used the AHRI shipments data to derive the percentage of units shipped for each of the 21 primary equipment classes. Table 9.3.2 shows the fraction of the units shipped for each of the 21 equipment classes.

Table 9.3.2 ACIM Equipment Shipments, Percent by Equipment Class

Equipment Class	Percentage of Shipments	Equipment Class	Percentage of Shipments
IMH-W-Small-B	4.540%	IMH-W-Small-C	0.780%
IMH-W- Med -B	2.919%	IMH-W-Large-C	0.076%
IMH-W-Large-B	0.461%	IMH-A-Small-C	4.447%
IMH-A-Small-B	27.075%	IMH-A-Large-C	0.160%
IMH-A-Large-B	16.137%	RCU-Small-C	1.216%
RCU-Small-B	5.428%	RCU-Large-C	0.477%
RCU-Large-B	6.077%	SCU-W-Small-C	0.000%
SCU-W-Small-B	0.679%	SCU-W-Large-C	0.149%
SCU-W-Large-B	0.216%	SCU-A-Small-C	4.611%
SCU-A-Small-B	13.853%	SCU-A-Large-C	4.139%
SCU-A-Large-B	6.560%		

9.3.3 Building Space and Market Saturation

The amount of commercial floor space is the main driver for automatic commercial ice maker shipments and is one of the basic inputs to the shipments model. As discussed in section 9.2.2, the model divides commercial floor space into new construction floor space (*NFS*) and existing floor space (*EFS*).

For this analysis, "commercial square footage with automatic commercial ice-making equipment" refers to both the new and the existing stock of buildings.

9.3.3.1 Floor Space: New Construction

DOE used the projected floor space construction after the year 2009 from the NEMS projection underlying *AEO2011*. DOE extracted annual estimates of new floor space additions from an *AEO2011* data file (kdbout) for the 2009 through 2035 period. As stated in section 9.3.2,

DOE used the last 10 years of the *AEO* forecast to develop growth rates used to extend the forecast to 2045.

DOE projected the shipments of ice makers for new buildings by multiplying the estimated shipments to new buildings in 2009 by future indices of new construction for each building type. DOE developed the index for each building type by dividing floor space projections in each future year by the prior year's floor space projection.

As discussed in section 9.3.1, future shipments for new buildings were factored into the stock accounting model. Future shipments to replace existing stock were developed using the Weibull function described in section 9.2.2.1.

9.3.3.2 Market Shipments

DOE combined the shipments for new buildings and replacement of existing stock to yield total shipments in year *t.* DOE used total shipments to estimate shipments for each ACIM equipment class *y*, *MKTSHIP(t,y)*, as shown with Eq. 9.5. Because DOE assumed that the percent of shipments in each class was constant over time and the lifetime of each class was the same, the ratio of shipments of a specific equipment class indicates the market share for that class, *MKT(y)*. DOE assumed the *MKT(y)* for a particular equipment class to be a constant value equal to the percent historical shipments to that class. Table 9.3.2 reports these percentages.

$$MKTSHIP(t, y) = MKT(y) \times (UN(t) + UB(t))$$

Eq. 9.5

Where:

MKTSHIP(t,y) = total market shipments of equipment class *y* in year *t*,
MKT(y) = percentage of total market shipments in equipment class *y* (%),
UN(t) = total shipments for new construction in year *t*, and
UB(t) = total replacement shipments in year *t*.

9.4 RESULTS

Table 9.4.1 shows DOE's shipments forecast for the ACIM equipment by type of commercial building.

Table 9.4.2 shows DOE's shipments forecast for the ACIM equipment classes at the base-case energy consumption level (or Level 1) by equipment type.

Table 9.4.1 Forecast Shipments of New and Replacement Automatic Commercial Ice Makers by Building Type, 2016–2045 (Base Case)

Building Sector	Number of Units (for selected years, and cumulative)							
	2016	2020	2025	2030	2035	2040	2045	Cumulative (2016 to 2045)
Health Care								
– New	11,800	12,074	12,441	12,753	13,184	14,160	15,120	392,180
– Replacement *	90,163	78,604	100,308	97,093	106,814	112,089	114,283	2,987,182
Lodging								
– New	8,317	8,236	8,767	8,974	9,309	9,928	10,542	274,548
– Replacement*	50,861	44,240	56,999	56,216	61,839	66,529	67,715	1,727,652
Food Service								
– New	4,937	5,073	5,500	5,716	6,001	6,393	6,791	173,677
– Replacement *	32,366	28,186	36,470	35,571	39,521	42,081	43,265	1,099,160
Retail								
– New	2,859	2,908	3,190	3,386	3,591	3,843	4,104	102,628
– Replacement *	20,807	18,102	23,127	22,506	24,804	26,401	27,007	694,632
Education								
– New	1,610	1,719	1,689	1,801	1,904	1,987	2,078	54,878
– Replacement*	18,495	16,080	19,779	19,120	20,406	21,367	21,317	582,985
Food Sales								
– New	1,417	1,454	1,577	1,637	1,716	1,827	1,939	49,716
– Replacement *	9,247	8,053	10,426	10,168	11,301	12,033	12,372	314,225
Office								
– New	1,424	1,720	1,654	1,662	1,680	1,784	1,879	51,282
– Replacement*	9,247	8,026	10,053	10,451	11,077	12,279	12,235	313,669
Total								
– New	32,365	33,184	34,819	35,928	37,386	39,921	42,453	1,098,909
– Replacement *	231,187	201,292	257,162	251,126	275,762	292,779	298,195	7,719,505
– Total	263,552	234,476	291,981	287,055	313,147	332,700	340,648	8,818,414

* Replacement includes equipment replaced from original stock (installed before standards) and the standards-level equipment replaced in subsequent years.

Table 9.4.2 Forecast Shipments of Automatic Commercial Ice Makers, 2016–2045, by Equipment Type (Base Case)

Equipment Class	Number of Units by Equipment Class (for selected years, and cumulative)							
	2016	2020	2025	2030	2035	2040	2045	Cumulative (2016 – 2045)
IMH-W-Small-B	11,966	10,646	13,257	13,033	14,218	15,106	15,467	400,387
IMH-W- Med -B	7,693	6,844	8,522	8,379	9,140	9,711	9,943	257,392
IMH-W-Large-B	1,215	1,081	1,347	1,324	1,444	1,534	1,571	40,669
IMH-A-Small-B	71,357	63,484	79,054	77,720	84,785	90,079	92,230	2,387,589
IMH-A-Large-B	42,530	37,838	47,118	46,323	50,533	53,689	54,971	1,423,049
RCU-Small-B	14,306	12,728	15,849	15,582	16,998	18,060	18,491	478,681
RCU-Large-B	16,016	14,249	17,743	17,444	19,029	20,218	20,701	535,879
SCU-W-Small-B	1,789	1,592	1,982	1,949	2,126	2,258	2,312	59,862
SCU-W-Large-B	570	507	632	621	678	720	737	19,084
SCU-A-Small-B	36,510	32,482	40,448	39,765	43,380	46,089	47,190	1,221,605
SCU-A-Large-B	17,290	15,382	19,155	18,831	20,543	21,826	22,347	578,506
IMH-W-Small-C	2,056	1,829	2,277	2,239	2,442	2,595	2,657	68,779
IMH-W-Large-C	200	178	221	218	237	252	258	6,688
IMH-A-Small-C	11,721	10,428	12,985	12,766	13,926	14,796	15,149	392,177
IMH-A-Large-C	422	376	468	460	502	533	546	14,136
RCU-Small-C	3,204	2,851	3,550	3,490	3,807	4,045	4,142	107,219
RCU-Large-C	1,256	1,118	1,392	1,368	1,492	1,586	1,624	42,029
SCU-W-Small-C*	0	0	0	0	0	0	0	0
SCU-W-Large-C	392	348	434	427	465	494	506	13,103
SCU-A-Small-C	12,151	10,811	13,462	13,235	14,438	15,340	15,706	406,585
SCU-A-Large-C	10,908	9,705	12,085	11,881	12,961	13,770	14,099	364,992
Total	263,552	234,476	291,981	287,055	313,147	332,700	340,648	8,818,414

IMH: ice-making head; RCU: remote condenser unit; SCU: self-contained unit; A: Air cooled; W: Water cooled; B: Batch; C: Continuous

***** Data available to DOE shows there are no existing SCU-Water-Small-Continuous products available, so this class is not currently defined in the models.

Equipment purchase price increases associated with lower energy consumption levels could cause shipments to drop relative to the base case. DOE acknowledges that the shipment projections under the standards cases could be lower than those in the base case because the higher installed costs could cause some customers to forego or delay discretionary equipment purchases. DOE calculated an average impact factor of -0.625, -6.25 percent for a 10-percent price increase, based on an average of input received during manufacturer interviews. This information was compiled after DOE completed the work underlying this preliminary TSD. DOE will consider performing sensitivity analyses during the notice of proposed rulemaking (NOPR) stage of the rulemaking to analyze the impact of higher prices on shipment. In the executive summary of this preliminary TSD, DOE requests comment on the potential impacts on future shipments in standards-case scenarios.

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