CHAPTER 9: SHIPMENTS ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 9: SHIPMENTS ANALYSIS

9.1 INTRODUCTION

An estimate of the rate at which transformers are purchased and replaced is a key input to the Department's estimate of the national impacts of candidate standards for distribution transformers. This estimate is provided by the shipments model developed by the Department. The shipments model provides an estimate of the rate at which an in-service stock of old, less-efficient transformers may be replaced by more-efficient transformers meeting the candidate standard. The core of the shipments analysis is an accounting model that the Department developed to simulate how existing and future purchases are incorporated into an in-service stock of aging transformers that are gradually replaced.

In addition to using estimates of distribution transformer shipments as an input for the National Energy Savings (NES) analysis for the Advance Notice of Proposed Rulemaking (ANOPR), the Department will use the shipments estimates as input to the manufacturer impact analysis (MIA). That analysis, which DOE will undertake after the ANOPR, will estimate the impact of potential efficiency standards on businesses. The Department will report the results of the MIA in the Notice of Proposed Rulemaking (NOPR).

9.2 MODEL OVERVIEW

The Department uses the forecasts of shipments for the base case and the standards case to provide an estimate of the annual sales and in-service stock of transformers in any given year during the forecast period. The estimate includes the age distribution of transformers for each transformer type (classified according to product classes) and each transformer size. The model uses the annual transformer sales and the age distribution of the in-service stock to calculate equipment costs for the net present value (NPV) and energy use for the NES, respectively. The Department chose an accounting model method to prepare shipment scenarios for the base case and several candidate standard cases. The model keeps track of the age and replacement of transformer capacity given a projection of future transformer sales growth.

Figure 9.2.1 presents a graphical flow diagram of the shipments model portion of the distribution transformer national impact (NES and NPV) model and spreadsheet. In the diagram, the arrows show the direction of information flow of the calculation. The information begins with inputs that are shown as parallelograms. As information flows from these inputs, it may be integrated into intermediate results (shown as rectangles) or through integrating sums or differences (shown as circles) into major outputs that are shown as boxes that have a curved bottom edge.

As illustrated in the flow diagram, the Department organized shipments into two categories: replacements and new capacity. Replacements occur when old transformers break down, corrode, are struck by lightning, or otherwise need to be replaced. New capacity purchases occur due to increases in electricity use that may be driven by increasing population, commercial and industrial activity, or growth in electricity distribution systems. The model starts with an estimate of the overall growth in transformer capacity and then estimates shipments for particular design lines using estimates of the relative market share for different design and size categories. The steps of the shipments calculation include the following:

1. Collection of available data – This step comprised acquiring and processing of the information that is available to the Department regarding transformer shipments.
2. Construction of aggregate shipments backcast – The construction of an aggregate shipments backcast uses the available shipments and electricity consumption data to provide an annual estimate of historical total capacity shipped.
3. Construction of aggregate shipments forecast – The construction of an aggregate shipments forecast applies a shipments growth rate to provide a base case annual shipments estimate for the future.
4. Development of liquid-immersed and dry-type market shares – The market share estimate disaggregates the total capacity shipped into liquid-immersed and dry-type transformers.
5. Modeling of purchase price elasticity – The modeling of the purchase price elasticity provides an estimate of how higher purchase prices due to a candidate standard can impact the future capacity shipped.
6. Accounting of sales and in-service stocks – This accounting step uses the shipments estimates and a retirement function to derive an annual age distribution of in-service transformer stock.
7. Consistency check with purchase and replacement data – The final consistency check confirms that the estimates of the shipments model are consistent with available data on utility transformer purchases and replacements.

9.3 MODEL INPUTS

The shipments model inputs correspond closely to the steps of the shipments calculation described in the previous section. Some inputs come from outside the shipments calculations, while other inputs for later stages of the calculation are intermediate inputs that are calculated from earlier inputs. The final outputs of the shipments calculation are the annual shipments estimates and the annual estimates of the age distribution of in-service transformer stock. The list of specific inputs is as follows:

1. Shipments Data – The shipments data input consists of external estimates of transformer shipments, quantity of transformers manufactured, or of electricity consumed that the Department uses to construct an annual shipments estimate.

2. Shipments Backcast – The shipments backcast consists of an estimate of total transformers capacity shipped before 2001.
3. Shipments Forecast – The shipments forecast consists of the estimate of total transformers shipped after 2001.
4. Long-Term Purchase Elasticity – This is an estimate of the price sensitivity of transformers shipped over the long term.
5. Dry-type/Liquid-Immersed Market Shares – The market shares are defined as the relative capacity of dry-type and liquid-immersed transformers shipped in any year.
6. Stock Accounting – Stock accounting consists of the equations that provide the age distribution of a next year's in-service transformer stock given the previous year's in-service transformer stock and shipments.
7. Retirement Function – The retirement function provides an estimate of the probability that a transformer will be replaced as a function of the age of the transformer.
8. Initial Stock – The initial stock is the age distribution of the in-service stock of transformers at the start of the stock accounting calculation (i.e., in 1950).

9.3.1 Shipments Data

The Department uses historical transformer shipments data to calibrate a forecast of future transformer shipments and in-service stocks. These data are a key input to the national impact analysis because changes in shipments and in-service stock create nearly proportional changes in the estimate of the energy savings from a candidate standard.

The Department's contractors provided an estimate of sales for the year 2001, disaggregated by product class and kilovolt-ampere (kVA) rating. The historical series of the power distribution and specialty transformer manufacturing (North American Industry Classification System (NAICS) code 335311) quantity index for 1977 to 2001 is available from the U.S. Bureau of Economic Affairs (BEA).[2] The BEA transformer manufacturing quantity index provides information on how the aggregate shipments of transformers has changed over the 1977 to 2001 period. The Department used the 2001 shipments estimate by product class and kVA rating to determine the market shares for both liquid-immersed and dry-type distribution transformers. The Department used the BEA quantity index data to estimate aggregate transformer shipments from 1977 to 2001, using the sales estimates for 2001 as the starting point.

Table 9.3.1 presents the shipment estimates in both units shipped and megavolt-amperes (MVA) shipped, and the approximate value of these shipments, showing that the distribution transformer industry totaled about $1.6 billion dollars in 2001 (2001 dollars).

Table 9.3.1 Distribution Transformer Shipment Estimates for 2001

Distribution Transformer Product Class	Units Shipped	MVA Capacity Shipped	Shipment Value ($million)
Liquid-immersed, medium-voltage, single-phase, (PC 1)	977,388	36,633	698.8
Liquid-immersed, medium-voltage, three-phase, (PC 2)	79,367	42,887	540.4
Dry-type, low-voltage, single-phase, (PC 3)	23,324	983	17.8
Dry-type, low-voltage, three-phase, (PC 4)	290,818	21,909	235.0
Dry-type, medium-voltage, single-phase, 20-45 kV BIL, (PC 5)	119	18	0.5
Dry-type, medium-voltage, three-phase, 20-45 kV BIL, (PC 6)	650	776	13.5
Dry-type, medium-voltage, single-phase, 46-95 kV BIL, (PC 7)	121	22	0.6
Dry-type, medium-voltage, three-phase, 46-95 kV BIL, (PC 8)	2,371	3,913	68.1
Dry-type, medium-voltage, single-phase, ≥96 kV BIL, (PC 9)	20	4	0.1
Dry-type, medium-voltage, three-phase, ≥96 kV BIL, (PC 10)	187	367	6.4
Total	1,374,366	107,512	1,581.2

Tables 9.3.2 through 9.3.4 present the disaggregated shipment estimates for 2001 by product class and kVA rating.

Table 9.3.2 Liquid-Immersed Distribution Transformer Shipment Estimates, 2001

Liquid-Immersed, Medium-Voltage, Single-Phase		Liquid-Immersed, Medium-Voltage, Three-Phase	
kVA	**Units Shipped**	**kVA**	**Units Shipped**
10	114,594	15	-
15	167,234	30	-
25	277,581	45	605
37.5	66,977	75	1,816
50	242,931	112.5	4,842
75	44,214	150	9,078
100	49,696	225	9,078
167	9,762	300	17,552
250	2,158	500	17,552
333	1,188	750	6,219
500	1,040	1000	4,523
667	4	1500	3,769
833	8	2000	1,884
-	-	2500	2,450
Total Units	977,388	Total Units	79,367
Total MVA	36,633	Total MVA	42,887

Table 9.3.3 Dry-Type, Low-Voltage Distribution Transformer Shipment Estimates, 2001

Dry-Type, Low-Voltage, Single-Phase*		Dry-Type, Low-Voltage, Three-Phase	
kVA	**Units Shipped**	**kVA**	**Units Shipped**
15	2,554	15	24,484
25	4,573	30	56,511
37.5	4,396	45	65,474
50	9,759	75	85,354
75	1,108	112.5	24,150
100	929	150	17,265
167	-	225	9,505
250	4	300	5,460
333	-	500	2,190
-	-	750	420
-	-	1000	5
Total Units	23,324	Total Units	290,818
Total MVA	983	Total MVA	21,909

*Note: These estimates do not include sand-resin (epoxy-potted) units shipped.

Table 9.3.4 Dry-Type, Medium-Voltage Distribution Transformer Shipment Estimates 2001

Dry-Type, Medium-Voltage, Single-Phase Units Shipped				Dry-Type, Medium-Voltage, Three-Phase Units Shipped			
kVA	20-45kV BIL	46-95kV BIL	≥96kV BIL	kVA	20-45kV BIL	46-95kV BIL	≥96kV BIL
15	3	2	-	15	2	1	-
25	7	3	-	30	4	2	-
37.5	10	5	-	45	4	2	-
50	17	8	-	75	7	3	-
75	20	25	5	112.5	20	11	-
100	20	25	5	150	18	11	-
167	12	15	3	225	20	19	1
250	6	8	1	300	59	60	2
333	12	15	3	500	76	150	5
500	12	15	3	750	80	177	5
667	-	-	-	1000	80	320	10
833	-	-	-	1500	80	390	32
-	-	-	-	2000	100	575	56
-	-	-	-	2500	100	650	76
Total Units	119	121	20	Total Units	650	2,371	187
Total MVA	18.4	22.1	4.1	Total MVA	776	3,913	367

There are at least two major assumptions inherent in the Department's use of the available shipments data. The first major assumption is that the relative market shares of the different transformer product classes and size categories are constant over time. In actuality, there is probably a gradual increase in the average size of transformers as the electricity demand per customer increases, but the Department does not have sufficient data to characterize such transformer size trends.

The second major assumption concerns the use of the BEA quantity index data. The BEA index data actually include shipments of transformers other than those covered by this rulemaking. The use of the BEA Standard Industrial Classification (SIC) code 3612 (NAICS code 335311) quantity index to estimate shipments for products under this rulemaking assumes that the quantity market share of distribution transformers relative to all NAICS code 335311 transformers is relatively constant over the period from 1977 to 2001. The Department made this assumption because more disaggregated quantity index data were not available.

9.3.2 Shipments Backcast

The shipments backcast is the estimate of previous aggregate transformer shipments based on limited historical data. The backcast of transformers shipments is a key element of estimating age distributions in future in-service transformer stocks.

The shipments backcast begins with the estimate of transformer shipments in the year 2001[1] and uses BEA's NAICS code 3612 quantity index to estimate total shipments in the period 1977 to 2001. Specifically, the Department used the following equation to backcast shipments from 2001 to 1977:

$$TotShip(y) = TotShip(2001) \times BEA(y) \,/\, BEA(2001) \qquad \textbf{Eq. 9.1}$$

where:

TotShip(y)	=	the total capacity of shipments estimated for year *y* where 1977 < *y* < 2001,
TotShip(2001)	=	the total transformer capacity shipped, in units of megavolt-amps (MVA), from the shipment estimate, and
BEA(y)	=	the BEA quantity index for year *y*.

Annual shipments of transformer capacity for years previous to 1977 are backcast to 1950 using annual growth of electricity consumption as a proxy for growth of transformer sales during this period. Using this method, the shipments for the years 1950 to 1977 are given by the following equation:

$$TotShip(y) = TotShip(1977) \times AllElec(y) \,/\, AllElec(1977) \qquad \textbf{Eq. 9.2}$$

where:

TotShip(y)	=	the total capacity of shipments estimated for year *y* where 1950 ≤ *y* < 1977, and
AllElec(y)	=	national electricity consumption in year *y* by *AEO 2003*.

9.3.3 Shipments Forecast

Once the Department constructed a shipments backcast that was calibrated with transformer shipments data, it constructed a forecast of future transformers shipments that provides necessary input for equipment expense and in-service transformer stock accounting.

The Department constructed a simplified forecast of transformer shipments for the base case scenario based on the idea that long-term growth in transformer shipments will be driven by long-term growth in electricity consumption. The detailed dynamics of transformer shipments is highly complex. This complexity can be seen in the fluctuations in the total quantity of transformers manufactured as expressed by the BEA transformer quantity index. The Department examined the possibility of modeling the fluctuations in transformers shipped using a bottom-up model where the shipments are triggered by retirements and new capacity additions, but found that there were no sufficient data to calibrate model parameters within an acceptable margin of error. Hence, the Department de-coupled the overall shipments and retirement in the construction of the shipments forecast and maintained the age distribution of the in-service transformer stock using the retirement function. Figure 9.3.1 shows the estimated age distribution of the in-service stock of liquid-immersed transformers in 2002. The Department developed similar age distributions for low voltage (LV) and megavolt (MV) dry-type transformers.

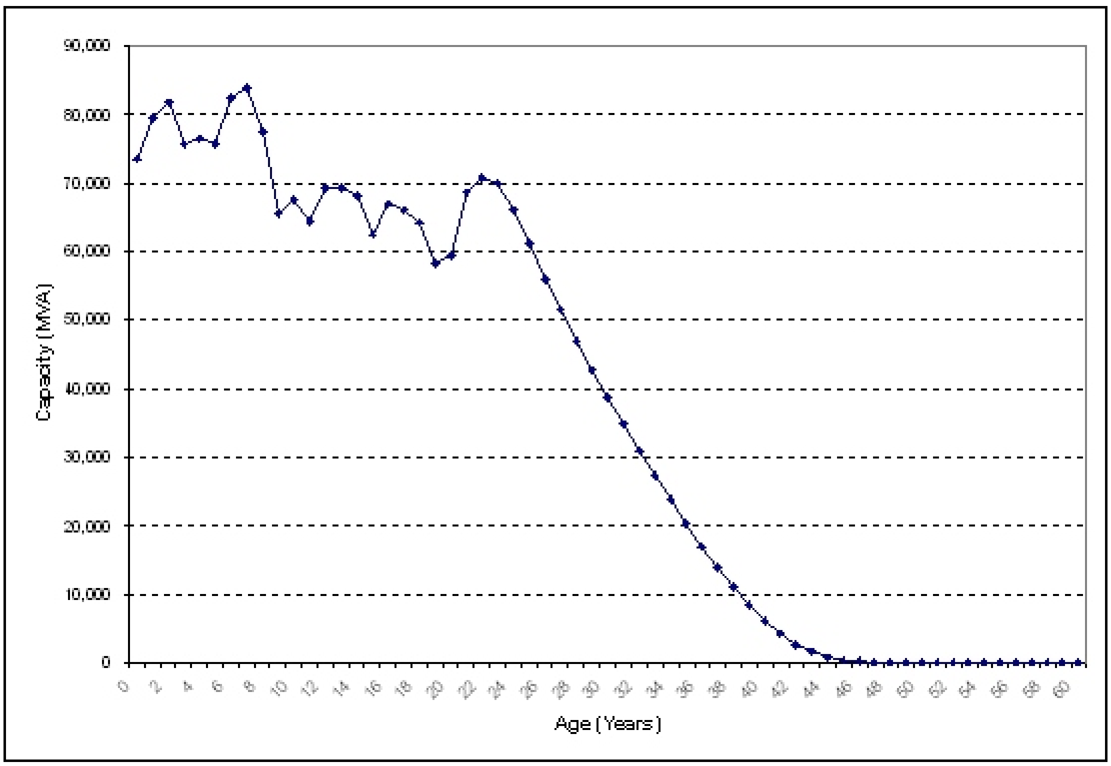

Figure 9.3.1 Age Distribution of Liquid-Immersed In-service Transformer Stock in 2002

The Department constructed the transformer shipments forecast assuming that transformer shipments growth is equal to forecasted growth in electricity consumption as given by Energy Information Administration (EIA's) *Annual Energy Outlook (AEO 2003)*[3] forecast up to the year 2025. For the years from 2026 to 2035, DOE extrapolated *AEO 2003* forecast with the growth rate of electricity consumption from 2015 to 2025. Specifically, the Department used the following equation for the shipments forecast:

$$TotShip(y) = TotShip(2001) \times AllElec(y) / AllElec(2001) \quad \textbf{Eq. 9.3}$$

where:

TotShip(y)	=	the total capacity of shipments estimated for year *y* where $2001 \le y < 2035$, and
AllElec(y)	=	national electricity consumption forecasted for year *y* by *AEO 2003* (or by an extrapolation of *AEO 2003* data).

The next section describes how the base case scenario forecast can be adjusted to account for price increases from a candidate standard.

9.3.4 Long-Term Purchase Elasticity

The Department used a purchase elasticity to adjust the base case shipments forecasts for potential transformer price increases from a candidate standard. The long-term purchase elasticity is a measure of how sensitive transformer shipments are to potential increases in price. Elasticity is defined as the percentage change in quantity divided by the percentage change in price (or some other factor that influences purchase behavior).

The basic formula used to determine price elasticity is:

$$e = (dQ/Q) / (dP/P) \quad \textbf{Eq. 9.4}$$

where:

dQ/Q	=	a small percentage change in quantity (Q), and
dP/P	=	a small percentage change in price.

If the elasticity is constant, then the quantity purchased can be written in terms of the price, a reference price, a reference quantity, and the elasticity. Specifically, the following equation holds true when the elasticity is constant:

$$Q(P) = Q_0 \, x \, (P/P_0)^{e} \quad \textbf{Eq. 9.5}$$

where:

$Q(P)$	=	the quantity purchased as a function of price,
Q_0	=	a reference quantity at a reference price P_0, and
e	=	the elasticity which is almost always negative or zero (i.e., non-positive) with respect to price.

For the forecast, the reference price and the reference quantity are the price and quantity from the base case scenario. A change in price due to a candidate standard then has an impact on the quantity shipped, *Q(P)*, as described by the above equation.

Once the shipments backcast, forecast, and long-term purchase elasticity provide the estimate of the total capacity of transformers shipped, it is necessary to disaggregate the transformer shipments into liquid-immersed and dry-type transformers.

9.3.5 Dry-type/Liquid-immersed Market Shares

The shipments forecast and backcast described above provide an aggregate estimate of the total capacity of transformers shipped from 1950 to 2035. In order to disaggregate the total capacity into the capacity for different types of transformers, the Department applied a capacity market share estimate. To distinguish between liquid-immersed and dry-type transformers, the Department applied a liquid-immersed and dry-type market share, respectively. To distinguish between different product classes and size categories within each product class, the Department used the 2001 market shares estimates.

The Department used trends in electricity consumption from EIA retail sales data[4] to estimate market share trends for dry-type and liquid-immersed transformers. Assuming that transformer sales over the long term track electricity sales for the sectors served by those transformers, the following market share model can be derived:

$$LiqShip(y) = CL \times AllElec(2001); \quad where\ CL = LiqShip(2001) / AllElec(2001) \qquad \textbf{Eq. 9.6}$$

$$DryShip(y) = CD \times CIElec(2001); \quad where\ CD = DryShip(2001) / CIElec(2001) \qquad \textbf{Eq. 9.7}$$

$$DryMS(y) = CD \times CIElec(y) / (CL \times AllElec(y) + CD \times CIElec(y)) \qquad \textbf{Eq. 9.8}$$

$$LiqMS(y) = 1 - DryMS(y) \qquad \textbf{Eq. 9.9}$$

where:

CL	=	the constant of proportionality between the electricity consumption and the sales of liquid-immersed transformers in the year 2001,
CD	=	the constant of proportionality between the electricity consumption and the sales of dry-type transformers in the year 2001,
LiqShip(2001)	=	the capacity of liquid-immersed transformers shipped in 2001,
DryShip(2001)	=	the capacity of dry-type transformers shipped in 2001,
AllElec(y)	=	the total consumption of electricity in year *y*,
CIElec(y)	=	the consumption of electricity by the commercial and industrial sectors in year *y,*
DryMS(y)	=	the capacity market share of dry-type transformers in year *y*, and

LiqMS(y) = the capacity market share of liquid-immersed transformers in year *y*.

The key assumption behind the market share equations is that transformer capacity market shares follow the relative electricity consumption of the end-users of the electricity that passes through the transformers. The dynamics of liquid-immersed and dry-type market shares are likely to be fairly complicated, but the Department believes this is the best way to capture long-term average trends in market share given the lack of detailed market share data over long time periods.

For the market shares of different kVA ratings and product classes, the Department assumed that the relative market share within each transformer type (i.e., liquid-immersed or dry-type) is constant over time. Given a lack of detailed, long-term market share data, an alternative assumption regarding kVA ratings and product class market shares may not be feasible.

Once the shipments backcast, forecast, elasticity, and market shares are fully specified, then the characteristics of transformer shipments are completely specified. The next step is to provide an accounting of in-service transformer stocks, as described in the next section.

9.3.6 Stock Accounting

The stock accounting takes transformer shipments, a retirement function, and initial in-service transformer stock as inputs and provides an estimate of the age distribution of in-service transformers stocks for all years. The age distribution of in-service transformer stocks is a key input to both the NES and NPV calculations, since the operating costs for any year depend on the age distribution. The dependence of operating cost on the transformer age distribution occurs because under a candidate standard scenario that produces increasing efficiency over time, older, less-efficient transformers may have higher operating costs, while younger, more-efficient transformers will have lower operating costs.

The Department calculated total in-service stock of distribution transformers by integrating historical shipments starting from the year 1950. As transformers are added to the in-service stock, some of the older ones retire and exit the stock.

In order to estimate the shipment forecasts, the Department developed a series of equations that define the dynamics and accounting of in-service transformer stocks. For new units, the equation is:

$$Stock(y, age = 1) = Ship(y - 1) \qquad \textbf{Eq. 9.10}$$

where:

Stock (y, age) = the population of in-service transformers of a particular age,
y = the year that the in-service stock is being estimated, and

Ship (y)	=	the number of transformer purchases in a particular year.

This equation says that the number of one-year-old units is simply equal to the number of new transformer units purchased the previous year. The slightly more complicated accounting equations are those which describe the accounting of the existing in-service stock of transformer units:

$$Stock(y+1, age+1) = Stock(y, age) \times \left[1 - Prob_{Retire}(age)\right] \quad \textbf{Eq. 9.11}$$

This equation says that as time goes on, only a fraction of the in-service stock exists in the next year. As the year is incremented and goes from y to $y+1$, the age is also incremented from age to $age+1$. Also as time moves forward, a fraction of the in-service stock is removed, and that fraction is determined by a retirement probability function, $Prob_{Retire}(age)$, that is described in the next section.

9.3.7 Retirement Function

The accounting of in-service transformer stock requires specification of a retirement probability function. The Department derived the retirement probability function from a modified version of a transformer reliability function. The reliability function for determining the lifetime of the transformer is adapted from *ORNL 6804/R1*, p. D-1.[5]

$$r(age) = \exp\left[-\left(\frac{age}{d}\right)^{e}\right] \times \left((1 - constfail)^{age} \times (1 - corrfail)^{age-15}\right) \quad \textbf{Eq. 9.12}$$

where:

r(age)	=	the reliability of a transformer of a certain age, where reliability is defined as the probability that a transformer will last to a particular age,
d and *e*	=	parameters used for fitting the reliability data,
constfail	=	a constant failure rate of 0.65% per year[a], and
corrfail	=	a corrosive failure rate of 0.65% per year at year 15 and above.

The parameters of the Weibull distribution are adjusted to maintain an average life of 32 years. The failure rates and the lifetime are adapted from *ORNL 6804/R1*, p. D-1.[5]

[a] Constant failure could be due to lightning or other random events.

The Department converted the reliability function into an annual retirement probability function by dividing the incremental reliability at a given age by the fraction of transformers that last to that age as shown below:

$$Prob_{Retire}(age) = [r(age - 1) - r(age)] / r(age) \qquad \textbf{Eq. 9.13}$$

where:

$Prob_{Retire}(age)$ = the probability that a transformer of a particular age will be retired.

Once the retirement probability function is specified, the remaining input to the stock accounting equation is the initial in-service stock of transformers as described in the next section.

Figures 9.3.2 and 9.3.3 show the cumulative failure rate and the retirement rate of distribution transformers, respectively.

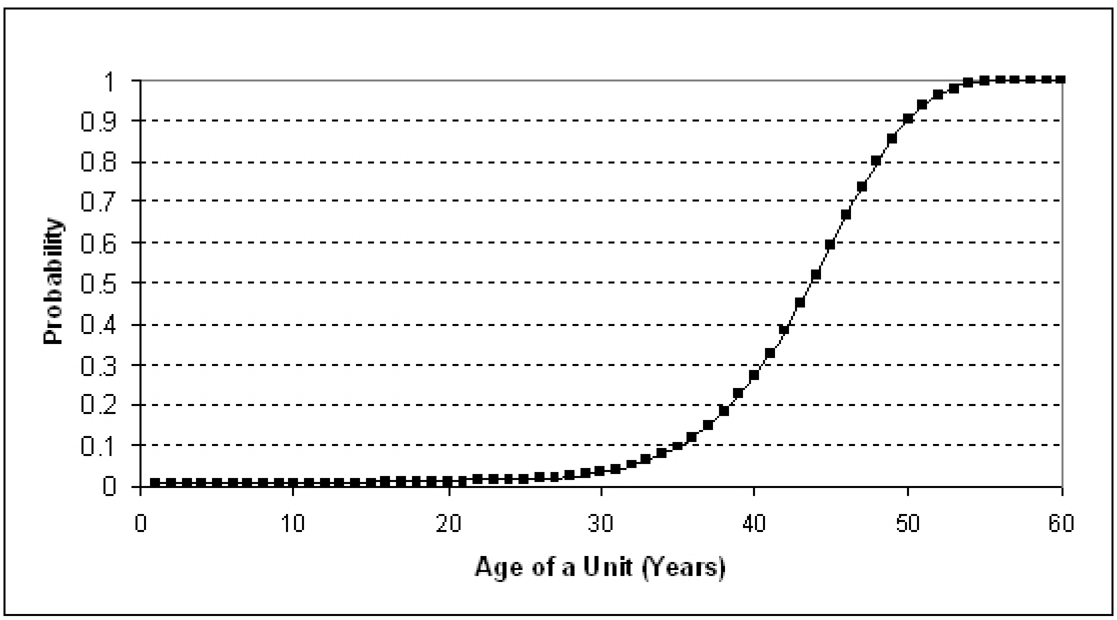

Figure 9.3.2 Cumulative Failure Rate of Distribution Transformers

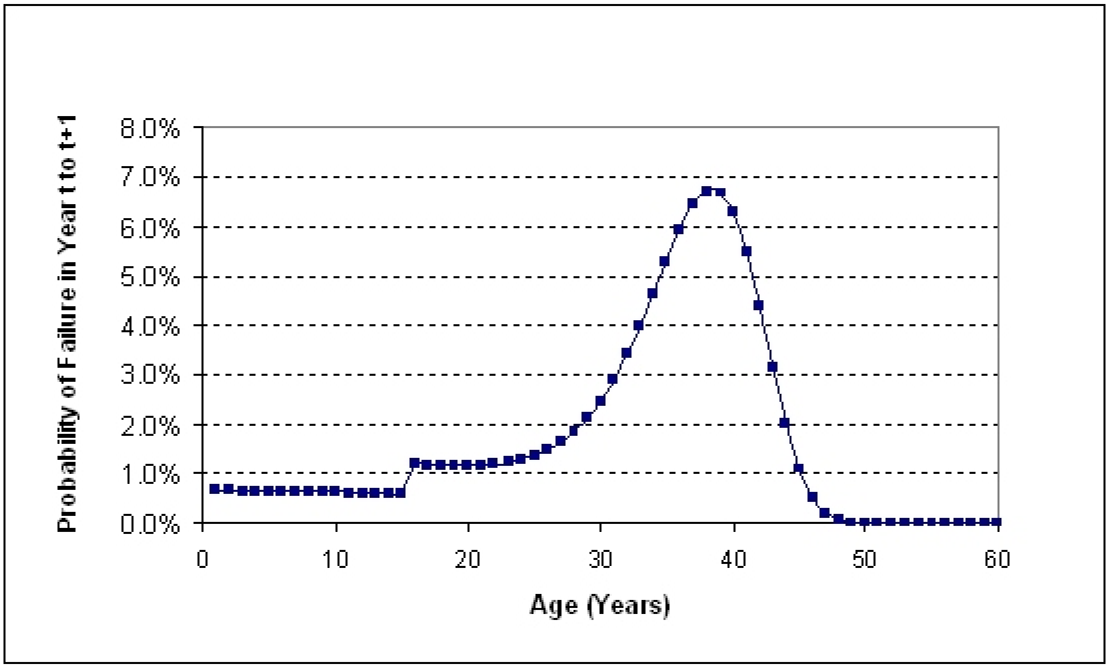

Figure 9.3.3 Fraction of Original Shipment Retiring at an Age

9.3.8 Initial Stock

The Department constructed the in-service stock age distribution with a stock accounting model that needs to be initialized. The model starts in 1950 where the initial age distribution of in-service transformers needs to be specified by both the total number of transformers and their age distribution. However, because the Department initialized the stock accounting at such an early date, the in-service stock of transformers in 1950 has very little impact on NES or NPV results. In addition, because of the growth of electricity use from 1950 to the year 2001, the transformer stocks in 1950 are quite small compared to transformer stocks in 2001. For simplicity, the Department initialized the in-service transformer stock in 1950 at zero. This number does not affect the analysis because most of transformer stock in 1950 will no longer be in service post-2001.

9.3.9 Effective Date of Standard

A key output of the shipments model is the in-service stock of transformers that may be affected by a standard. To calculate this 'affected stock,' the effective date of the candidate standard must be defined. The Department assumed for this analysis that any new energy-efficiency standard for distribution transformers will become effective in 2007. The effective date of the standard is January 1, 2007, so that all distribution transformers purchased starting in the year 2007 are affected by the standard.

Once the shipments and in-service stocks of transformers have been completely specified, it is possible to proceed to the NES and NPV models and calculations, as described in Chapter 10.

9.3.10 Affected Stock

The affected stock is an output of the shipments model and a key input for the NES and NPV calculations. The affected stock consists of that portion of the in-service transformer stock that is potentially impacted by a candidate standard level. It therefore consists of those in-service transformers that are purchased in or after the year the candidate standard level has taken effect, as described by the following equation:

$$Aff\_Stock(y) = Ship(y) + \sum_{age=1}^{y-Std\_year} Stock(age) \qquad \textbf{Eq. 7.14}$$

where:

Aff_Stock(y)	=	stock of transformers of all vintages that are operational in year *y;*
Ship (y)	=	Shipments in year *y,* and
age	=	the age of the transformer in years.

Once the shipments, in-service stocks, and affected stocks of transformers have been completely specified, it is possible to proceed to the NES and NPV models and calculations, as described in the Chapter 10.

9.4 RESULTS

The main output of the shipments model is the total capacity of distribution transformers shipped in each year from 2007 through 2035. Total shipments depend on assumptions regarding the lifetime of a transformer and the growth in new electricity demand. The Department does not expect any direct effect on total shipments in the long term from energy-efficiency standards. Total shipments for all candidate standard levels (CSLs) for liquid-immersed and dry-type distribution transformers are shown in Table 9.4.1.

Table 9.4.1 Cumulative Shipments of Transformers between 2007-2035 by Candidate Standard Level

Distribution Transformers	Transformer Capacity Shipments in Billion kVA					
	Base case	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
Liquid-immersed	3.06	3.06	3.05	3.04	3.03	3.01
Dry-type	1.23	1.23	1.23	1.23	1.23	1.23

Figure 9.4.1 shows the relative impact on forecasted liquid-immersed shipments for different standard levels. The shipment impacts for the five candidate standard levels are well within 2 percent of the base case scenario. The Department assumed zero elasticity for dry-type transformers, and thus there is no impact on shipments of dry-type transformers across standard levels.

The biggest **factor** that influences the size of the potential standards-induced change is the actual equipment price increase due to standards. If price increases are large, the shipments volume decreases almost proportionally to the price increase, but because the price elasticity of transformers is less than 1, price increases result in increased gross sales dollar volume to the transformer manufacturer. The Department will examine the net financial impact of these opposing effects in more detail in the manufacturer impact analysis of the NOPR.

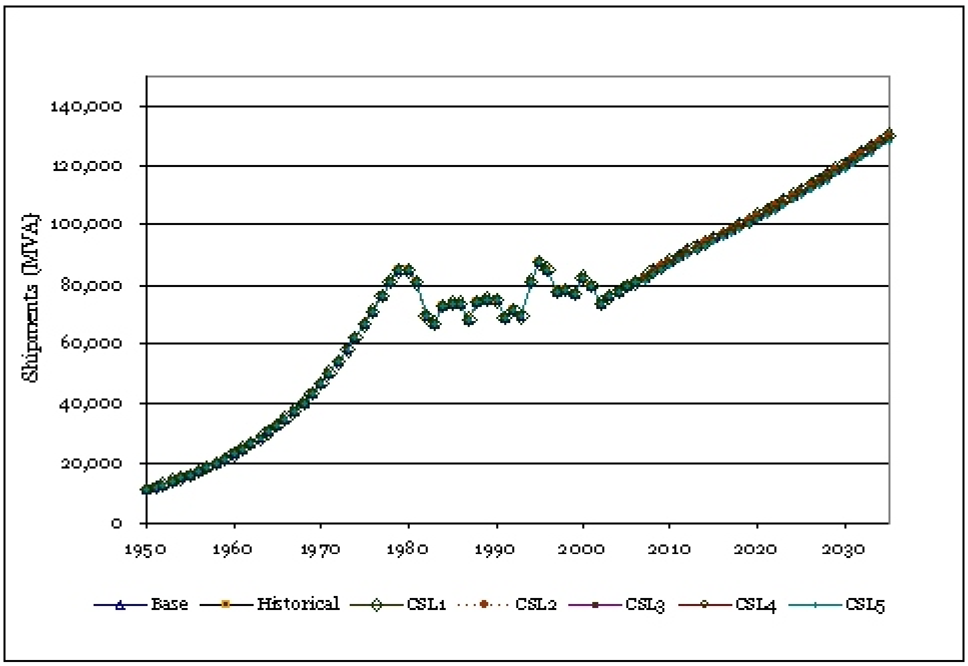

Figure 9.4.1 Liquid-Immersed Transformer Shipments Backcast and Forecast

REFERENCES

1. HVOLT Consultants Inc., P. Hopkinson, and J. Puri, *Distribution Transformer Market Shipment Estimates for 2001,* February 17, 2003. 3704 High Ridge Road, Charlotte, NC, 28270, tel: (704) 846-3290, e-mail: P.Hopkinson@hotmail.com. Prepared for Navigant Consulting, Inc.,Washington DC.

2. U.S. Department of Commerce - Bureau of Economic Analysis, *Industry Economic Division Information Guide, II. Gross Domestic Product by Industry Accounts, 1977-2001 Shipments of Manufacturing Industries,* 2002. (Last accessed February, 2003). <For Readme page, see http://www.bea.gov/bea/dn2/readves.htm For data, go to http://bea.gov/bea/pn/ndn0304.exe>

3. U.S. Department of Energy - Energy Information Administration, *Annual Energy Outlook 2003: With Projections Through 2025,* January, 2003. Washington, DC. Report No. DOE/EIA-0383(2003). <http://www.eia.doe.gov/oiaf/aeo>

4. U.S. Department of Energy-Energy Information Administration, *Annual Energy Review 2001, Chapter 8: Electricity, Table 8.5 Electricity End Use, 1949-2001,* 2002. (Last accessed May 29, 2003). <http://www.eia.doe.gov/emeu/aer/txt/stb0805.xls>

5. Barnes, P. R., J. W. Van Dyke, B. W. McConnell, S. M. Cohn, and S. L. Purucker, *The Feasibility of Replacing or Upgrading Utility Distribution Transformers During Routine Maintenance*, 1995, Oak Ridge National Laboratory. Oak Ridge, TN. Report No. ORNL-6804/R1. < http://www.ornl.gov/~webworks/cpr/v823/rpt/78562.pdf>