

CHAPTER 7. ENERGY AND WATER USE ANALYSIS

TABLE OF CONTENTS

| | | |
|-------|---|-----|
| 7.1 | INTRODUCTION | 7-1 |
| 7.2 | ANNUAL ENERGY CONSUMPTION..... | 7-1 |
| 7.2.1 | Equipment Class Energy Use and Harvest Rate Capacity..... | 7-2 |
| 7.2.2 | Utilization Factor | 7-2 |
| 7.3 | ANNUAL WATER CONSUMPTION..... | 7-3 |

LIST OF TABLES

| | | |
|-------------|-------------------------------------|-----|
| Table 7.2.1 | Total Annual Energy Usage..... | 7-3 |
| Table 7.3.1 | Total Annual Water Consumption..... | 7-4 |

CHAPTER 7. ENERGY AND WATER USE ANALYSIS

7.1 INTRODUCTION

This chapter presents the U.S. Department of Energy's (DOE's) analysis of annual energy and water usage at various efficiency levels of automatic commercial ice makers. These estimated values of annual energy consumption (AEC) in kilowatt-hours per year (kWh/yr) and annual water consumption (AWC) in gallons of water per year are key inputs to the life-cycle cost and payback period analysis (chapter 8 of the preliminary technical support document (preliminary TSD)) and national impacts analysis (chapter 10 of the preliminary TSD).

The goal of the energy use analysis is to generate a mean value and a range of energy use values that reflect actual use of an automatic commercial ice maker in commercial applications. Actual energy usage in the field often differs from that estimated by the test procedure because of variations in the system capacities chosen to serve the estimated load, operating conditions, user behaviors, and other factors. The remainder of this chapter discusses the methodology used to estimate the annual energy and water consumption for representative sized units for each automatic commercial ice maker equipment class.

7.2 ANNUAL ENERGY CONSUMPTION

For the preliminary analysis, DOE estimated the AEC for every combination of equipment class and efficiency level considered in the analysis. Estimated energy use per 100 pounds of ice, assumed equipment utilization factor, and rated maximum daily harvest rates for each combination are used to calculate a daily energy consumption value for the ice-making related function of the equipment. In addition to the ice-making related energy consumption, estimated daily standby energy usage is also added to yield a total energy consumption value for a single 24-hour period. Multiplying the sum of the daily ice-making related energy and standby energy use by 365 results in the total AEC for each specific equipment class and efficiency level combination.

For automatic commercial ice makers, the equation for AEC is:

$$AEC_{i,j} = (E_{i,j} \div 100 \times H_i \times U_i + SE_i \times (1 - U_i)) \times 365$$

Eq. 7.1

Where:

$AEC_{i,j}$ = calculated annual energy consumption for equipment class i , at efficiency level j (kWh/year),

$E_{i,j}$ = estimated energy use for equipment class i , at efficiency level j (kWh/100 lb ice),

H_i = harvest rate for equipment class i (pounds of ice produced per 24 hours),

U_i = assumed utilization for equipment class i (percent of time producing and harvesting ice),
and

SE_i = estimated "standby" energy use for equipment class i (kWh/24 hours).

7.2.1 Equipment Class Energy Use and Harvest Rate Capacity

For each equipment class, a baseline energy use value is estimated, noted as Efficiency Level 1. Level 1 is the initial value against which energy saving percentages are based. A more complete breakdown of how the incremental percentage savings values are derived is also described in chapter 5 of the preliminary TSD. Harvest rate capacity, which provides a representative value for the pounds of ice that can be produced for each ice-making equipment class, does not vary by efficiency level within an equipment class. The values used as estimates for energy use ($E_{i,j}$), and harvest rate (H_i) are taken from the engineering analysis presented in chapter 5 and are designed to be representative of a given equipment class.

7.2.2 Utilization Factor

Ice-making equipment is not assumed to be making ice 24 hours out of every day. Instead, a utilization factor (U_i) is used as the estimate for the percent of time the ice maker is actively producing ice. In the preliminary analysis, this value is consistent across all equipment classes and efficiency levels, and is estimated at 50 percent. The complement to the amount of time the ice-making equipment is actively producing is the time that the ice-making equipment is not actively producing or harvesting ice. Energy used during non-producing periods is referred to as standby use energy. Preliminary test data indicates that standby use represents an extremely small level of usage. As a conservative assumption, DOE used a value of 5 watts for all equipment classes, but believes the average value is actually lower. The standby loss assumption yields a daily energy consumption of 0.12 kWh/24 hours.

Calculated values for each equipment class and available efficiency levels are provided in Table 7.2.1. For each equipment class listed, AEC for the maximum available energy efficiency levels are also included in the table, and are found in column with the highest numbered efficiency level for that equipment class.

Table 7.2.1 Total Annual Energy Usage

| Equipment Class* | Total Annual Energy Usage <i>kWh/year</i> | | | | | | |
|------------------|--|--------|--------|--------|-------|-------|-------|
| | EL 1** | EL 2 | EL 3 | EL 4 | EL 5 | EL 6 | EL 7 |
| IMH-W-Small-B | 4,292 | 3,865 | 3,695 | | | | |
| IMH-W-Med-B | 7,825 | 7,044 | | | | | |
| IMH-W-Large-B | 10,972 | 9,877 | 9,767 | | | | |
| IMH-A-Small-B | 5,639 | 5,078 | 4,797 | 4,516 | | | |
| IMH-A-Large-B | 9,366 | 8,432 | 7,964 | 7,497 | | | |
| RCU-Small-B | 11,328 | 10,310 | 9,632 | 9,462 | | | |
| RCU-Large-B | 13,983 | 12,727 | 11,889 | 11,680 | | | |
| SCU-W-Small-B | 2,310 | 2,150 | 1,967 | 1,853 | 1,761 | | |
| SCU-W-Large-B | 4,183 | 3,892 | 3,559 | 3,351 | 3,143 | 3,018 | 2,560 |
| SCU-A-Small-B | 3,635 | 3,382 | 3,093 | 2,913 | 2,732 | 2,624 | |
| SCU-A-Large-B | 3,599 | 3,349 | 3,062 | 2,884 | 2,705 | | |
| IMH-W-Small-C | 11,848 | 10,665 | 10,074 | 9,483 | 8,891 | 7,945 | |
| IMH-W-Large-C | 9,329 | 8,399 | 7,933 | 7,468 | 7,096 | | |
| IMH-A-Small-C | 5,849 | 5,266 | 4,975 | 4,684 | 4,392 | 4,101 | |
| IMH-A-Large-C | 11,519 | 10,370 | 9,795 | 9,220 | 8,645 | 8,070 | 7,495 |
| RCU-Small-C | 12,158 | 11,272 | | | | | |
| RCU-Large-C | 15,078 | 13,979 | 12,594 | | | | |
| SCU-W-Small-C*** | | | | | | | |
| SCU-W-Large-C | 3,471 | 3,350 | | | | | |
| SCU-A-Small-C | 3,635 | 3,382 | 3,093 | 2,985 | | | |
| SCU-A-Large-C | 5,387 | 5,012 | 4,583 | 4,314 | 4,046 | 3,778 | 3,456 |

*See chapter 5, Tables 5.2.1 and 5.2.2, for a description of these abbreviations.

** EL = efficiency level; EL1 is the baseline efficiency level; EL2 through EL7 represent increased efficiency levels.

*** DOE was not able to identify any existing products of this equipment class in ice maker databases. Hence, this equipment class was not analyzed, directly or by extrapolation.

7.3 ANNUAL WATER CONSUMPTION

DOE estimated the AWC for each ice-making equipment similar to the method used for calculating the AEC, the difference being that for the preliminary analysis DOE assumes that water consumption, potable or condenser, does not vary with efficiency levels within a given equipment class. Results for this method, therefore, are only provided at the equipment class level. To calculate the AWC, first the estimated potable water use and condenser water use per 100 pounds of ice are summed to provide a total water use per 100 pounds of ice. Factoring the total water use per 100 pounds of ice produced with the assumed equipment utilization factor and representative maximum daily harvest rates yields a total daily water use figure for each equipment class. Multiplying the daily use values by 365 days in a year provides the total AWC.

For automatic commercial ice makers, the equation for AEC is:

$$AWC_i = (PW_i + CW_i) \div 100 \times H_i \times U_i \times 365$$

Eq. 7.2

Where:

AWC_i = calculated total annual water consumption for equipment class i (gal/year),

PW_i = estimated potable water use for equipment class i (gal/100 lb ice),

CW_i = estimated condenser water use for equipment class i (gal/100 lb ice),
 U_i = assumed utilization for equipment class i (percent of time producing and harvesting ice),
 and
 H_i = harvest rate for equipment class i (pounds of ice produced per 24 hours).

Estimates for the potable water and condenser water use to produce 100 pounds of ice come from preliminary TSD chapter 5, Engineering Analysis, and are summarized in Table 7.3.1.

Table 7.3.1 Total Annual Water Consumption

| Equipment Class* | Condenser Water Use gal/100 lb | Condenser Water Use gal/yr** | Potable Water Use gal/100 lb | Potable Water Use gal/yr** | Total Water Use gal/100 lb | Total Water Use gal/yr* |
|------------------|--------------------------------|------------------------------|------------------------------|----------------------------|----------------------------|-------------------------|
| IMH-W-Small-B | 156 | 85,410 | 22 | 12,045 | 178 | 97,455 |
| IMH-W-Med-B | 148 | 229,585 | 21 | 32,576 | 169 | 262,161 |
| IMH-W-Large-B | 137 | 375,038 | 20 | 54,750 | 157 | 429,788 |
| IMH-A-Small-B | 0 | 0 | 22 | 12,045 | 22 | 12,045 |
| IMH-A-Large-B | 0 | 0 | 20 | 29,200 | 20 | 29,200 |
| RCU-Small-B | 0 | 0 | 21 | 26,828 | 21 | 26,828 |
| RCU-Large-B | 0 | 0 | 20 | 54,750 | 20 | 54,750 |
| SCU-W-Small-B | 165 | 33,124 | 29 | 5,822 | 194 | 38,946 |
| SCU-W-Large-B | 165 | 90,338 | 28 | 15,330 | 193 | 105,668 |
| SCU-A-Small-B | 0 | 0 | 30 | 6,023 | 30 | 6,023 |
| SCU-A-Large-B | 0 | 0 | 26 | 9,490 | 26 | 9,490 |
| IMH-W-Small-C | 110 | 160,600 | 12 | 17,520 | 122 | 178,120 |
| IMH-W-Large-C | 110 | 200,750 | 12 | 21,900 | 122 | 222,650 |
| IMH-A-Small-C | 0 | 0 | 12 | 6,789 | 12 | 6,789 |
| IMH-A-Large-C | 0 | 0 | 12 | 21,900 | 12 | 21,900 |
| RCU-Small-C | 0 | 0 | 12 | 15,330 | 12 | 15,330 |
| RCU-Large-C | 0 | 0 | 12 | 32,850 | 12 | 32,850 |
| SCU-W-Small-C*** | — | — | — | — | — | — |
| SCU-W-Large-C | 110 | 60,225 | 12 | 6,570 | 122 | 66,795 |
| SCU-A-Small-C | 0 | 0 | 12 | 2,409 | 12 | 2,409 |
| SCU-A-Large-C | 0 | 0 | 12 | 6,570 | 12 | 6,570 |

*See chapter 5, Table 5.2.1 and 5.2.2, for a description of these abbreviations.

**Total number is adjusted by the appropriate utilization factor.

***DOE was not able to identify any existing products of this equipment class in ice maker databases. Hence, this equipment class was not analyzed, directly or by extrapolation.