ENERGY STAR® Portfolio Manager®

Technical Reference

Swimming Pools and the ENERGY STAR Score in the United States and Canada

OVERVIEW

The ENERGY STAR score provides a fair assessment of the energy performance of a property relative to its peers, taking into account the climate, weather, and business activities at the property. Stand alone swimming pools are not eligible to earn the ENERGY STAR score. However, because swimming pools are a common, energy-intensive amenity at other commercial building types (i.e., hotels and schools), the ENERGY STAR score does make adjustments to accommodate for the presence of swimming pools. The goal of the ENERGY STAR score is to rate the energy performance of the primary use of the building, not the swimming pool.

- **Technical Approach.** An engineered model is developed to estimate the energy use for the swimming pool. This estimated energy use is subtracted from the building's actual energy use, yielding an estimate of energy use of the building without a pool. This allows the building to be evaluated as though it does not have a pool.
- **Property Types.** Heated swimming pools located inside or outside of a building can be entered for all property types and will be incorporated into the ENERGY STAR score for eligible property types. There are no calculations or adjustments for pools that are not heated, because heated pools use significantly more energy than pools that are not heated, and are more likely to have a noticeable effect on energy use for the whole property.
- **Adjustments.** The swimming pool model is based on engineered assumptions regarding basic energy requirements for swimming pools and includes:
    - **Heating Energy.** To account for maintaining a constant temperature while accounting for heat loss due to convection, evaporation, and radiation.
    - **Pumping Energy.** To account for energy associated with circulating the pool water.
- **Release Date.** The model is updated periodically as industry standards for design and operation are updated and as better engineering data becomes available:
    - Most Recent Update: February 2009
    - Original Release: January 2004

This document presents details on how the ENERGY STAR score accounts for swimming pools. More information on the overall approach to develop ENERGY STAR scores is covered in our Technical Reference for the ENERGY STAR Score, available at www.energystar.gov/ENERGYSTARscore.

The subsequent sections of this document offer specific details on the development of the pool model:

THEORETICAL BACKGROUND

The engineered model to predict pool energy use is based on the fundamental rules of physics involved in heated pools and their interaction with the surrounding space. The total energy consumed by a heated pool is the sum of pool heating energy consumption and pool pump electrical energy consumption. Heat loss from a pool includes evaporation loss, convection loss, long wave radiation loss to cold sky, and conduction through the lateral surfaces to the ground. For outdoor pools, heat loss is offset by heat gains due to solar irradiation. Pool pump electrical consumption can be estimated as a function of head loss, pool size, pump efficiency, and pump circulation time. The heating energy consumption represents a far larger contribution to total energy use than the pump energy consumption.

Pool energy consumption can be expressed using the equation below. Specific calculations for each term are detailed in the Appendix.

$$Energy_{pool} = Energy_{evaporation} + Energy_{convection} + Energy_{radiation} - Solar\ Irradiation + Energy_{pump}$$

The model uses the following assumptions:

- **Indoor Pool Heating.** For indoor pools, only evaporation and convection are considered significant contributors to heat loss.
- **Outdoor Pool Heating.** For outdoor pools, evaporation, convection, and radiation are considered significant contributors to heat loss.
- **Conduction Losses.** Conduction loss through the lateral and bottom surfaces are small and hence is ignored.
- **Temperature.** Pools operate at a fixed temperature throughout the year.
- **Make-up Water Heating.** Make-up water heating load is ignored.
- **Convection.** A fixed convection heat transfer coefficient is used.
- **Source Energy**. Calculations assume that natural gas is used to heat the pool water and that electricity is used for pumping. Conversions from site to source energy are applied accordingly based on country (U.S. or Canada).[1]
- **Equation Inputs.** Fixed values are used for most of the input variables in order to minimize user inputs. The values are based on engineering judgments and parametric sensitivity analysis.

INDOOR POOLS

Using standard engineering references, the Appendix presents a summary of equations that can be used to compute each element that contributes to energy use (e.g., convection). These standard equations require several assumed

[1] The pool adjustment was revised in 2018 for U.S. properties, and in 2023 for Canadian properties, to account for updated ratios used in Portfolio Manager to convert site energy to source energy.

inputs for factors such pool temperature. The input parameters used by EPA for the equations are shown in ***Figure 1***, along with an explanation of the values used. Some of values are known quantities, and others were estimated based on recommended operating practices and engineering estimates. For some of the input variables (e.g., pool water temperature, swimming pool area relative humidity), values can vary based on pool operation. A sensitivity analysis was performed to test multiple values for several variables. The impact of each variable on total pool energy consumption was examined, as well as the resulting ENERGY STAR scores for buildings in Portfolio Manager with indoor pools. A combination of values was chosen that resulted in a reasonable adjustment to the ENERGY STAR score.

Using the values in ***Figure 1,*** a simple form of each equation in the Appendix is generated; these are summarized in ***Figure 2***. At the bottom of ***Figure 2*** there is a final combined equation, which includes all contributions to energy consumption. This equation is a general equation for the annual source energy consumption of an indoor pool, based on three factors: the Pool Area, the Activity Factor, and the Source-Site Ratio.

In Portfolio Manager, users have a choice of three standard pool sizes (recreational, short course, or Olympic). Portfolio Manager will assume a certain Pool Area based on the selected size. Activity Factor is based on the property type, which does not require a separate input. The property type is designated by Portfolio Manager based as the property use type which accounts for more than 50% of the total floor area. The Activity Factor values are included in ***Figure 1***. Accounting for the three available pool sizes and the three activity factors, ***Figure 3*** presents the exact pool adjustments.

Note that the swimming pool energy adjustments in ***Figure 3*** are presented in different units for the U.S. and Canada. The ENERGY STAR score for the U.S. is developed using units of kBtu for energy, while the ENERGY STAR score for Canada is developed using units of gigajoules (GJ) for energy. While the calculations within Portfolio Manager occur in different units, ultimately the results for the any property (U.S. or Canadian) can be displayed in Portfolio Manager in either kBtu or GJ.

Figure 1 – Summary of Input Parameters for Indoor Pools

Parameter	Definition	Description	Value
V	Wind speed, mph	Still air is assumed for indoor pool evaporation calculation.	0
T_w	Pool water temperature, °F	ASHRAE (2007) recommends different values depending on the application. 80°F was chosen based on a sensitivity analysis.	80
T_a	Swimming pool space dry bulb temperature, °F	ASHRAE (2007) recommends 75°F – 85°F.	75
φ	Swimming pool space relative humidity, %	ASHRAE (2007) recommends 50% – 60%. Selected slightly higher value since the lower end of the dry bulb temperature is used, and based on a sensitivity analysis.	65%
t_o	Hours pool is open, hours/year	Indoor pools assumed to be open all year round	8,760

Parameter	Definition	Description	Value
$\square_h$	Heater efficiency, %	Heater and fuel utilization efficiency. Depends on the heater design and fuel type. Selected based on engineering experience and sensitivity analysis.	75%
h_c	Convection Coefficient, Btu/h ft^2 °F	Depends on room air speed, Duffie and Beckman (1993).	0.70
$\square_{Loss}$	Head Loss, ft-lbf/lbm	Head loss accounts for straight friction loss, bends, fittings and filter. It is site specific. Estimated based on engineering judgment and sensitivity analysis.	36
η_p	Pump Efficiency, %	Includes hydraulic efficiency of the pump, pump and motor-coupling efficiency and electric motor efficiency. Based on engineering experience and sensitivity analysis.	70%
ρ	Pool water density, lbm/ft^3	Density of water	64.02
L_D	Average Pool Depth, ft	Estimate based on experience	6
$\square$	Time required purging a pool, hours/day	Engineering estimate, used for sizing the pump capacity	8
t_P	Pump run time, hours/year	Assumed to run 6 hours/day, based on engineering experience and sensitivity analysis	2190
AF	Activity Factor	Corrects evaporation loss depending on the pool application (ASHRAE, 2007).	School and Ice / Curling Rink = 1.036 Hotel = 0.800 Others = 0.650
S_{gas}	Source-Site Ratio for Natural Gas	These factors are used to convert from site energy to source energy. Conversions depend on the country (U.S. or Canada). For more on these conversions visit www.energystar.gov/SourceEnergy	U.S – 1.05 Canada – 1.06
S_{elec}	Source-Site Ratio for Electricity		U.S. – 2.80 Canada – 1.83

Figure 2 – Calculation of Indoor Pool Energy Adjustment

Energy Contribution	Full Equation	Simple Equation
Evaporation	$\text{Energy}_{\text{evaporation}} = (68.3 + 32 \times 0)(1.044 - 0.582) \times \text{AF} \times 8760 \times \text{A}_\text{P} \times \frac{1}{0.75} \times \frac{1}{1000} \times \text{S}_{\text{gas}}$	$368.56 \times \text{AF} \times \text{A}_\text{P} \times \text{S}_{\text{gas}}$
Convection	$\text{Energy}_{\text{convection}} = (0.7)(80 - 75) \times 8760 \times \text{A}_\text{P} \times \frac{1}{0.75} \times \frac{1}{1000} \times \text{S}_{\text{gas}}$	$40.88 \times \text{A}_\text{P} \times \text{S}_{\text{gas}}$
Radiation	Assumed to be zero for an Indoor Pool	0
Pumping	$\text{Energy}_{\text{pump}} = \frac{1}{778.26} \times 36 \times \frac{1}{0.7} \times \frac{64.02 \times \text{A}_\text{P} \times 6}{8} \times 2190 \times \frac{1}{1000} \times \text{S}_{\text{elec}}$	$6.95 \times \text{A}_\text{P} \times \text{S}_{\text{elec}}$
Total Indoor Pool Energy Consumption	$368.56 \times (\text{AF} \times \text{A}_\text{p} \times \text{S}_{\text{gas}}) + 40.88 \times (\text{A}_\text{p} \times \text{S}_{\text{gas}}) + 6.95 \times (\text{A}_\text{p} \times \text{S}_{\text{elec}})$	

Figure 3 – Indoor Pool Energy Adjustments

Country	Property Type	Recreational (20 yds x 15 yds) A_P = 2700 ft²	Short Course (25 yds x 20 yds) A_P = 4500 ft²	Olympic (50 m x 25 m) A_P = 13,456 ft²
United States	School	1,250,920 kBtu/yr	2,084,866 kBtu/yr	6,234,213 kBtu/yr
	Hotel	1,004,331 kBtu/yr	1,673,885 kBtu/yr	5,005,288 kBtu/yr
	All Other Property Types	847,601 kBtu/yr	1,412,668 kBtu/yr	4,224,191 kBtu/yr
Canada	School and Ice / Curling Rink	1,313 GJ/yr (1,244,131 kBtu/yr)	2,188 GJ (2,073,551 kBtu/yr)	6,542 GJ/yr (6,200,379 kBtu/yr)
	Hotel	1,050 GJ/yr (995,193 kBtu/yr)	1,750 GJ/yr (1,658,656 kBtu/yr)	5,233 GJ/yr (4,959,750 kBtu/yr)
	All Other Property Types	883 GJ/yr (836,971 kBtu/yr)	1,472 GJ/yr (1,394,951kBtu/yr)	4,401 GJ/yr (4,171,214 kBtu/yr)

OUTDOOR POOLS

Energy consumption in outdoor pools is more difficult to calculate than indoor pools, because there is more variability in the input parameters for the equations in the Appendix. In particular, the following parameters can vary significantly:

- **V.** Wind speed
- **T_w.** Pool water temperature
- **T_a.** Temperature of outdoor air
- ***Φ*.** Relative humidity for outdoor air
- **Solar Radiation.** which is dependent on assumptions for surface shading level
- **t_o.** The time a pool is in operation throughout the year

To understand the range of energy consumption in outdoor pools, a parametric sensitivity analysis was conducted, calculating estimates for energy consumption using several values for each of the input parameters included above. For the variables that vary by climate, six different locations were examined: Boston, Chicago, Denver, Miami, Phoenix and Portland (OR). Outdoor pools in the two warmest cities in the analysis (Miami and Phoenix) were assumed to be open April through October. Pools in the other four cities were assumed to be open June through August.

A wide range of energy consumption estimates was observed. Given this variability, the most accurate assessment of pool energy consumption would require several additional questions in Portfolio Manager. Because the intent of Portfolio Manager is to assess the energy performance of the building, not the pool, this approach was deemed to be overly complex for the application. Instead, it is recommended that you install sub-meters to track energy use at outdoor pools. This pool energy should be subtracted from the main meter and excluded from Portfolio Manager, enabling an assessment of the building only.

In some cases it may not be possible to sub-meter and exclude outdoor pool energy consumption. For these cases, Portfolio Manager will still permit the building to benchmark, and will apply a conservative estimate for outdoor pool energy consumption. The estimate is based on the minimum adjustment determined through the parametric sensitivity analysis, averaged across the locations included in the analysis as shown in ***Figure 4***. Because this is a conservative estimate, the most accurate option is to sub-meter pool energy consumption, subtract it from total energy use, and enter only the main building energy consumption into Portfolio Manager.

Figure 4 – Outdoor Pool Energy Adjustments

	Recreational (20 yds x 15 yds) A_P = 2700 ft^2	**Short Course (25 yds x 20 yds)** A_P = 4500 ft^2	**Olympic (50 m x 25 m)** A_P = 13,456 ft^2
United States (All Property Types)	118,536 kBtu/yr	197,560 kBtu/yr	590,753 kBtu/yr
Canada (All Property Types)	122 GJ/yr (115,627 kBtu/yr)	203 GJ/yr (192,710 kBtu/yr)	608 GJ/yr (576,246 kBtu/yr)

EXAMPLE CALCULATION

As detailed in our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore, there are five steps to compute a score. The following is an example for a school in the U.S. with a swimming pool:

1 User enters building data into Portfolio Manager

- 12 months of energy use information for all energy types (annual values, entered in monthly meter entries)
- Physical building information (size, location, etc.) and use details describing building activity (hours, etc.)

Energy Data	Value
Electricity	800,000 kWh
Natural gas	30,000 therms

School Property Use Details	Value
Gross floor area (ft^2)	100,000
High School	1 (Yes)
Open weekends	1 (Yes)
Number of workers	70
Presence of cooking	0 (No)
Percent of the building that is heated	100
Percent of the building that is cooled	100
HDD (provided by Portfolio Manager, based on Zip code)	4,937
CDD (provided by Portfolio Manager, based on Zip code)	1,046

Swimming Pool Use Details	Value
Pool Size	Short Course
Pool Location	Indoor
Property Type (Set by Portfolio Manager based on use types entered)	K-12 School

2 Portfolio Manager computes the actual source EUI

- Billed Source Energy is computed
  - Total energy consumption for each fuel is converted from billing units into site and source energy
  - Source energy values are added across all fuel types

Fuel	Billing Units	Site kBtu Multiplier	Site kBtu	Source kBtu Multiplier	Source kBtu
Electricity	800,000 kWh	3.412	2,729,600	2.80	7,642,880
Natural gas	30,000 therms	100	3,000,000	1.05	3,150,000
				Total Source Energy	10,792,880 kBtu

- Predicted Pool Energy is determined
  - Based on Figures 3 and 4
  - Energy use for an Indoor, Short Course Pool at a K-12 school in the U.S. = 2,084,866 kBtu

- Actual Source energy for the purposes of the ENERGY STAR score is equal to billed source energy minus predicted pool energy
  - The energy estimate for the pool is subtracted to enable a score for the K-12 school only.
  - 10,792,880 – 2,084,880 = 8,708,014 kBtu Source

- Actual Source EUI is equal to source energy divided by total floor area
  - 8,708,444 kBtu / 100,000 ft^2
  - **Actual Source EUI = 87.08 kBtu/ft^2**

3 Portfolio Manager computes the predicted source EUI

- Using the property use details from Step 1, Portfolio Manager computes each building variable value in the regression model (determining the natural log or density, or applying any minimum or maximum values used in regression model, as necessary).
- The centering values are subtracted to compute the centered variable for each operating parameter.
- The centered variables are multiplied by the coefficients from the Office regression equation to obtain a predicted source EUI.
- Refer to www.energystar.gov/ScoreDetails for the equation used to predict energy at K-12 schools.

Computing Predicted Source EUI

Variable	Actual Building Value	Reference Centering Value	Building Centered Variable	Coefficient	Coefficient * Centered Variable
Constant	--	--	--	101.7	101.7
High School	1.000	--	1.000	14.08	14.08
Open Weekends (yes/no)	1.000	--	1.000	15.66	15.66
Number of Workers per 1,000 ft^2	0.7000	0.7967	-0.09670	25.61	-2.476
Presence of Cooking (yes/no)	0.000	--	0.000	8.182	0
HDD x Percent Heated	4,937	3,597	1,340	0.008370	11.22
CDD x Percent Cooled	1,046	1,472	-426	0.02059	-8.771
				Predicted Source EUI (kBtu/ft^2)	**131.4**

4 Portfolio Manager computes the energy efficiency ratio

- The ratio equals the actual source EUI (Step 2) divided by predicted source EUI (Step 3)
- Ratio = 87.08 / 131.4 = 0.6627

5 Portfolio Manager uses the efficiency ratio to assign a score via a lookup table

- The ratio from Step 4 is used to identify the score from the lookup table for schools
- A ratio of 0.6627 is greater than 0.6532 and less than 0.6640
- ***The ENERGY STAR score is 81***

APPENDIX

Figures A-1 through A-4 list the equations used to estimate swimming pool energy use.

Figure A – 1: Energy Contribution from Evaporation Loss

Contribution to Pool Energy	Equation	Input Parameters
Rate of Evaporation Loss *(Site Energy/ft²/hr)*	$\dot{q}''_{evap} = (68.3 + 32V)(P_{pw} - P_{dp}) \times AF$	$\dot{q}''_{evap}$ = heat loss by evaporation, Btu/ft² h V = room air speed, mph P_{pw} = saturation pressure at pool water temperature, in. Hg[2] P_{dp} = saturation pressure at air dew point temperature, in. Hg AF = Activity factor (varies by facility type)
Total Annual Evaporation Loss *(Source Energy/yr)*	$\text{Energy}_{evaporation} = \dot{q}''_{evap} = t_o \times A_P \times \frac{1}{\eta_h} \times \frac{\text{kBtu}}{1000\ \text{kBtu}} \times S_{gas}$	t_o = hours pool is open, hrs/yr A_p = pool surface area, ft² η_h = efficiency of pool heater S_{gas} = source-site ratio for gas

Figure A – 2: Energy Contribution from Convection Loss

Contribution to Pool Energy	Equation	Input Parameters
Rate of Convection Loss *(Site Energy/ft²/hr)*	$\dot{q}''_{conv} = h_c(T_w - T_a)$	$\dot{q}''_{conv}$ = heat loss by convection, Btu/ft²·h h_c = convection coefficient, Btu/ft²·h·°F[3] T_w = pool water temperature, °F T_a = air temperature, °F

[2] The saturation pressure over liquid water for the temperature range of 32 to 392°F (ASHRAE, 2005) is given by:

$$ln(P_{ws}) = -1044.039/T - 11.29465 - 0.02702355T + 1.289036x10^{-5}T^2 - 2.478068x10^{-9}T^3 + 6.5459673\ ln(T)$$

Where: P_{ws} is the saturation pressure at temperature T; and T is absolute temperature (°R = °F+459.67)

This can be computed specifically at the dew point (Tdp) as follows (ASHRAE, 2005):

$$T_{do} = 100.45 + 33.193\ ln(P_w) + 2.319\ (ln(P_w))^2 + 0.1707\ (ln(P_w))^3 + 1.2063\ P_w^{0.1984}$$

Where: Pw is the water vapor partial pressure in psia; and T is absolute Temperature

The partial vapor pressure of unsaturated air at a given dry bulb temperature and relative humidity is given by: $P_w = \phi x P_a$

Where ϕ=relative humidity of air, %; and P_a = saturation pressure of water vapor at the dry bulb temperature of air

[3] Convection coefficients from flat surfaces can be estimated using the following correlation: *hc=0.5+0.235V*

Where: V is the air wind speed, mph.

Total Annual Convection Loss *(Source Energy/yr)*	$\text{Energy}_{\text{convection}} = \dot{q}''_{\text{conv}} \times t_o \times A_P \times \frac{1}{\eta_h} \times \frac{\text{kBtu}}{1000\ \text{Btu}} \times S_{gas}$	t_o = hours pool is open, hrs/yr A_p = pool surface area, ft^2 η_h = efficiency of pool heater S_{gas} = source-site ratio for gas

Figure A – 3: Energy Contribution from Radiation Loss

Contribution to Pool Energy	Equation	Input Parameters
Rate of Radiation Loss *(Site Energy/ft²/hr)*	$\dot{q}''_{\text{rad}} = h_{\text{rad}}(T_w - T_s)$	$\dot{q}''_{\text{rad}}$ = heat loss by radiation, Btu/ft^2·h T_w = pool water temperature, °F T_s = air temperature, °F h_{rad} = radiation loss coefficient, Btu/ft^2·h·°F[4]
Total Annual Radiation Loss *(Source Energy/yr)*	$\text{Energy}_{\text{radiation}} = \dot{q}''_{rad} \times t_o \times A_P \times \frac{1}{\eta_h} \times \frac{\text{kBtu}}{1000\ \text{Btu}} \times S_{gas}$	t_o = hours pool is open, hrs/yr A_p = pool surface area, ft^2 η_h = efficiency of pool heater S_{gas} = source-site ratio for gas

Figure A – 4: Energy Contribution from Water Pumping

Contribution to Pool Energy	Equation	Input Parameters
Hourly Pumping Energy *(Site Energy/hr)*	$P_P = \frac{1}{C}\frac{H_{\text{Loss}} \times \dot{m}}{\eta_P}$	P_P = pump energy consumption rate, Btu/h C = 778.28, conversion factor from ft-lb$_f$/lb$_m$ to Btu/h H_{Loss} = Head loss, ft-lb$_f$/lb$_m$ $\dot{m}$ = Pool water circulation rate, lb$_m$/h[5] η_p = pump overall efficiency

[4] The linearized radiation loss is formulated with the assumption that the temperature difference between the pool surface and the sky is small and can be represented by an average value. A conservative radiation coefficient can be calculated using the pool surface temperature as follows

$$h_{\text{rad}} = 4\sigma\overline{T}_w^3$$

where s is the Stefan Boltzman constant and T_w is the pool surface Temperature (a value of 1.0 Btu/f is used for h_{rad})

[5] The pool-water circulation rate is approximated as follows,

$$\dot{m} = \frac{\rho \times A_P \times L_D}{\tau}$$

where ρ= Pool water density, lb$_m$/ft^3; A_p = Pool surface area, ft^2; L_D = Pool depth, ft; and τ= Pool water circulation time, hr

Annual Pumping Energy *(Source Energy/yr)*	$\mathrm{Energy}_{\mathrm{pump}} = \mathrm{P_P} \times \mathrm{t_P} \times \frac{\mathrm{kBtu}}{1000\mathrm{Btu}} \times S_{elec}$	t_P = pump run time, hrs/yr S_{elec} = source-site ratio for electricity

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