ENERGY STAR® Performance Ratings
Technical Methodology for Swimming Pool

This document presents specific details on the EPA's approach to handling space defined as Swimming Pool when computing energy performance ratings in Portfolio Manager. For background on the technical approach to development of the energy performance ratings, refer to *Energy Performance Ratings – Technical Methodology* (http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf).

Note that the Swimming Pool space type is not included as one of the space types eligible to receive an energy performance rating in Portfolio Manager. However, eligible space types can define a portion of their floor area as Swimming Pool, and Portfolio Manager will perform an adjustment to estimate the energy use of the pool and enable a rating of the main portion of the building (e.g. K-12 School). The Swimming Pool space model was developed by EPA using engineered calculations, as opposed to the statistical models that are used for space types eligible to receive an energy performance rating.

Model Release Date[1]

Most Recent Update: February 2009
Original Release Date: January 2004

Portfolio Manager Definition

Swimming Pool applies to heated swimming pools that operate on the premises and on the same energy-use meter as the primary facility. This category applies to any heated swimming pools located inside or outside of the facility. Swimming pools are categorized by size, and whether they are an indoor or outdoor pool.

Theoretical Background

The engineered pool model 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 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.

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

$$Energy_{Pool} = Energy_{evaporation} + Energy_{convection} + Energy_{radiation} - SolarIrradiation + Energy_{pump}$$

[1] Periodic updates to the model occur to reflect the most current available market data and analytical methodology.

The model uses the following assumptions:

- For indoor pools, only evaporation and convection are considered significant contributors to heat loss.
- For outdoor pools, evaporation, convection, and radiation are considered significant contributors to heat loss.
- Conduction loss through the lateral surface and bottom surfaces are small and hence are ignored.
- Pools operate at a fixed temperature throughout the year.
- Make-up water heating load is ignored.
- A fixed convection heat transfer coefficient is used.
- Source energy consumption calculations assume that a natural gas heater is used to heat the pool water.
- 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 Pool Adjustment

Using standard engineering references, **Appendix A** 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 inputs for factors such pool temperature. The input parameters used by EPA for the equations are shown in **Table 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 performance ratings for buildings in Portfolio Manager with indoor pools. A combination of values was chosen that resulted in a reasonable adjustment to energy performance ratings.

Using the values in **Table 1,** a simple form of each equation in **Appendix A** is generated; these are summarized in **Table 2**. At the bottom of **Table 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 two factors – the Pool Area and the Activity Factor.

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 building type, which does not require a separate input. The building type is designated by Portfolio Manager based as the space type which accounts for more than 50% of the total floor area. The Activity Factor values are included in **Table 1**. Accounting for the three available pool sizes and the three activity factors, **Table 3** presents the exact pool adjustments.

Table 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	8760
η_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
H_{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
τ	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 = 1.036 Hotel = 0.800 Hospital = 0.650 Others = 0.650

Table 2 Calculation of Indoor Pool Energy Adjustment		
Energy Contribution	**Full Equation**	**Simple Equation**
Evaporation	$Energy_{evaporation} = (68.3 + 32 \times 0)(1.044 - .582) \times AF \times 8760 \times A_p \times \frac{1}{0.75} \times \frac{1}{1000} \times 1.047$	385.78 x AF x A_p
Convection	$Energy_{convvection} = (0.7)(80 - 75) \times 8760 \times A_p \times \frac{1}{0.75} \times \frac{1}{1000} \times 1.047$	42.8 x A_p
Radiation	Assumed to be zero for an Indoor Pool	0
Pumping	$Energy_{pump} = \frac{1}{778.26} \times 36 \times \frac{1}{0.7} \times \frac{64.02 \times A_p \times 6}{8} \times 2190 \times \frac{1}{1000} \times 3.34$	23.21 x A_p
Total Indoor Pool Energy Consumption	385.78 x AF x A_p + 42.8 x A_p + 23.21 x A_p	

Table 3 Indoor Pool Energy Adjustments (Source kBtu/year)			
Space Type	**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
School	1,257,338	2,095,564	6,266,202
Hotel	1,011,394	1,685,656	5,040,487
Hospital (and all other space types)	855,193	1,425,322	4,262,028

Outdoor Pool Adjustment

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 **Appendix A**. 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 Portfolio Manager users 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. **Table 4** below includes the energy use adjustments for outdoor pools that are applied in Portfolio Manager. Because this is a conservative estimate, it is recommended that Portfolio Manager users sub-meter pool energy consumption, subtract it from total energy use, and enter only the main building energy consumption into Portfolio Manager.

Table 4
Outdoor Pool Energy Adjustments (Source kBtu/year)

	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
All Space Types	120,420	200,699	600,136

Example Calculation
The following is a list of steps to compute a rating for buildings with Swimming Pool space.

<u>Step 1 – User enters building data into Portfolio Manager</u>
For the purposes of this example, sample data is provided.

- Pool data
    - Pool Size = Short Course
    - Pool Location = Indoor
    - Space Type = K-12 School (This is not a Portfolio Manager input. It is based on the space type which accounts for more than 50% of the total floor area of the facility.)
- Energy data
    - Total annual electricity = 800,000 kWh
    - Total annual natural gas = 30,000 therms

    - Note that this data is actually entered in monthly meter entries
- K-12 School data
    - Gross floor area (ft2) = 100,000
    - High School = 1 (yes)
    - Open Weekends = 1
    - Walk-In Refrigerators = 0
    - Cook = 0
    - Number of personal computers = 200
    - Percent heated = 100
    - Percent cooled = 100
    - HDD (provided by Portfolio Manager, based on zip code) = 4937
    - CDD (provided by Portfolio Manager, based on zip code) = 1046

<u>Step 2 – Portfolio Manager calculates the Predicted Source Energy for the Swimming Pool space</u>
Using Table 3, look up the annual source energy consumption for a Short Course pool in a K-12 School.

- Predicted Source Energy = 2,095,564 kBtu

<u>Step 3 – Portfolio Manager computes the Actual Source Energy Use Intensity for the K-12 Space</u>
Portfolio Manager must convert each fuel from the specified units (e.g. kWh) into Site kBtu, and must convert from Site kBtu to Source kBtu. Then the Predicted Source Energy for the Swimming Pool is subtracted to determine the Source Energy and resulting Source EUI for the K-12 School space.

- Convert the meter data entries into site kBtu
    - Electricity: (800,000 kWh)*(3.412kBtu/kWh) = 2,729,600 kBtu Site
    - Natural gas: (30,000 therms)*(100kBtu/therm) = 3,000,000 kBtu Site
- Apply the source-site ratios to compute the source energy
    - Electricity:
      2,729,600 Site kBtu*(3.34 Source kBtu/Site kBtu) = 9,116,864 kBtu Source
    - Natural Gas:
      3,000,000 Site kBtu *(1.047 Source kBtu/Site kBtu) = 3,141,000 kBtu Source
- Combine source kBtu across all fuels
    - 9,116,864 kBtu + 3,141,000 kBtu = 12,257,864 kBtu
- Subtract the Predicted Source Energy for the Swimming Pool
    - K-12 Source Energy = 12,257,864 kBtu - 2,095,564 kBtu = 10,162,300 kBtu
- Divide total source energy by gross floor area
    - Source EUI for K-12 School = 10,162,300 kBtu/100,000ft^2 = 101.6 kBtu/ft^2

Step 4 – Portfolio Manager computes the Predicted Source Energy for the K-12 space

Portfolio Manager uses the K-12 School data entered under Step 1 to compute the predicted Source Energy Use Intensity for the K-12 space using the appropriate regression equation. See the technical methodology for K-12 School for details.

- Predicted Source EUI = 125.9 kBtu/ft^2

Step 5 – Portfolio Manager computes the energy efficiency ratio for the K-12 space

The energy efficiency ratio is equal to: Actual Source EUI/ Predicted Source EUI

- Ratio = 101.6/125.9 = 0.8070

Step 6 – Portfolio Manager looks up the efficiency ratio in the lookup table

Starting at 100 and working down, Portfolio Manager searches the lookup table for K-12 School for the first ratio value that is larger than the computed ratio for the building. The lookup table is included in the technical methodology document for K-12 School.

- A ratio of 0.8070 is less than 0.8124 (requirement for 69) but greater than 0.8039 (requirement for 70)
- ***The rating is 69***

References

Jones, R., Smith, Charles, and Lof, George. 1994. Measurement and Analysis of Evaporation from an Inactive Outdoor Swimming Pool. Solar Energy: 53(1): 3-10.

ASHRAE 2005 ASHRAE Handbook of Fundamentals. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. 1791 Tullie Circle, NE.E., Atlanta GA 30329.

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Duffie, J. A and Beckman, W. A. “Solar Engineering of Thermal Processes”. 2nd edition. John Wiley & Sons, Inc. New York. 1993. Page: 158.

Appendix A
Pool Energy Calculations

Table 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/ft^2 h V = room air speed, mph P_{pw} = saturation pressure at pool water temperature, in. Hg[i] 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)*	$Energy_{evaporation} = \dot{q}''_{evap} \times t_o \times A_p \times \frac{1}{\eta_h} \times \frac{kBtu}{1000Btu} \times \frac{1.047SourcekBtu}{SitekBtu}$	t_o = hours pool is open, hrs/yr A_p = pool surface area, ft^2 η_h = efficiency of pool heater

Table A-2
Energy Contribution from Convection Loss

Contribution to Pool Energy	Equation	Input Parameters
Rate of Convection Loss *(Site Energy/ft²/hr)*	$\boldsymbol{\dot{q}''_{conv} = h_c(T_w - T_a)}$	q''_{conv} = heat loss by convection, Btu/ft^2·h h_c = convection coefficient, Btu/ft^2·h·°F[ii] T_w = pool water temperature, °F T_a = air temperature, °F
Total Annual Convection Loss *(Source Energy/yr)*	$Energy_{convection} = \dot{q}''_{conv} \times t_o \times A_p \times \frac{1}{\eta_h} \times \frac{kBtu}{1000Btu} \times \frac{1.047SourcekBtu}{SitekBtu}$	t_o = hours pool is open, hrs/yr A_p = pool surface area, ft^2 η_h = efficiency of pool heater

Table A-3
Energy Contribution from Radiation Loss

Contribution to Pool Energy	Equation	Input Parameters
Rate of Radiation Loss *(Site Energy/ft²/hr)*	$q''_{rad} = h_{rad}(T_w - T_s)$	q''_{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[iii]
Total Annual Radiation Loss *(Source Energy/yr)*	$Energy_{radiation} = \dot{q}''_{rad} \times t_o \times A_p \times \frac{1}{\eta_h} \times \frac{kBtu}{1000Btu} \times \frac{1.047SourcekBtu}{SitekBtu}$	t_o = hours pool is open, hrs/yr A_p = pool surface area, ft^2 η_h = efficiency of pool heater

Table A-4 Energy Contribution from Water Pumping		
Contribution to Pool Energy	**Equation**	**Input Parameters**
Hourly Pumping Energy *(Site Energy/hr)*	$P_P = \frac{1}{C}\frac{H_{Loss} \cdot \dot{m}}{\eta_p}$	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[iv] η_p = pump overall efficiency
Annual Pumping Energy *(Source Energy/yr)*	$Energy_{pump} = P_P \times t_P \times \frac{kBtu}{1000Btu} \times \frac{3.34SourcekBtu}{SitekBtu}$	t_P = pump run time, hrs/yr

[i] 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 (T_{dp}) 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: P_w 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

[ii] Convection coefficients from flat surfaces can be estimated using the following correlations:

$$h_c = 0.5 + 0.235V$$

Where: V is the air wind speed, mph.

[iii] 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:

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

Where σ is the Stefan Boltzmann constant and T_w = pool surface temperature. A value of 1.0 Btu/ft2·h·°F is used for h_{rad}.

[iv] The pool-water circulation rate is approximated by:

$$\dot{m} = \frac{\rho \cdot A_p \cdot L_D}{\tau}$$

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