Elevator Energy Consumption

Background

This technical topic expands on the **P4P New Construction Program Guidelines v4.1 Section 4.5.18** that describes modeling savings from elevators. Additions and changes to the section are shown in blue font below. A similar calculation procedure may be used by P4P Existing Buildings (EB) projects to document savings from elevator replacement, except design parameters of the existing elevators must be used instead of the baseline parameters.

Elevators may account for 4% - 10% of project energy cost, and present significant opportunity for energy savings. The example included in the Technical Topic is based on an actual project, and shows ~35% savings in the proposed elevator energy use compared to the baseline elevator.

There is a companion "***Elevator Energy Consumption Calculator***" spreadsheet that implements the described methodology.

Elevators *(from P4P New Construction Program Guidelines v4.1 Section 4.5.18)*

Elevators are a regulated load in ASHRAE 90.1-2013 and have mandatory requirements. Performance credit may be claimed for any component that exceeds mandatory or baseline requirements such as fan power, lighting power density, elevator motor efficiency, and elevator mechanical efficiency.

The baseline shall be modeled as follows:

- ≤ 4 stories: hydraulic motor, 58% mechanical efficiency
- > 4 stories: traction motor, 64% mechanical efficiency
- 0.33 W/CFM for ventilation fans
- 3.14 W/SqFt lighting power density
- Cab motor power shall be calculated using the following equations

$$bhp = (Weight\ of\ Car + Rated\ Load - Counterweight)\ x\ Speed\ of\ Car/(33{,}000\ x\ h_{mechanical})$$

$$P_m = bhp * 746/h_{motor}$$

Where:

- *Weight of Car* = proposed design elevator car weight, lb
- *Rated Load* = proposed design elevator load at which to operate, lb
- *Counterweight of Car* = elevator counterweight,
  - *hydraulic elevators:* no counterweight
  - *traction elevators*: same as in proposed design; if not specified, weight of car + 40% of rated load
- *Speed of Car* = speed of the proposed elevator, ft/min
- *Pm* = peak cab motor power
- $h_{mechanical}$ = mechanical efficiency of the elevator
- h_{motor} = motor efficiency
  - Cab motor efficiency (h_{motor}) shall be determined using the following tables
    - Table G3.9.3 for hydraulic baseline elevators
    - Table G3.9.1 for traction baseline elevators

Table G3.9.3 ***Performance Rating Method*** **Hydraulic Elevator Motor *Efficiency***

Horsepower	Full-Load *Efficiency*
10	72%
20	75%
30	78%
40	78%
100	80%

Table G3.9.1 ***Performance Rating Method*** **Motor *Efficiency* Requirements**

Motor Horsepower	Minimum Nominal Full-Load *Efficiency*, %
1.0	82.5
1.5	84.0
2.0	84.0
3.0	87.5
5.0	87.5
7.5	89.5
10.0	89.5
15.0	91.0
20.0	91.0
25.0	92.4
30.0	92.4
40.0	93.0
50.0	93.0
60.0	93.6
75.0	94.1
100.0	94.5
125.0	94.5
150.0	95.0
200.0	95.0

Elevator full load hours must be calculated as follows:

$$EFLH_{elev} = DH * 365$$

Where:

- $EFLH_{elev}$ – elevator effective full load hours
- *DH* – average travel time from Table 1 below, based on building type and size, and the elevator application type. Alterative elevator run hours may be considered with prior program approval.

Table 1: Usage Categories

Usage Intensity/ Frequency	Very Low Very Seldom	Low Seldom	Medium Occasionally	High Frequently	Very High Very Frequently
Average Travel Time (hours per day)	0.2	0.5	1.5	3	6
Typical Type of Buildings and Use	Residential building with up to 6 dwellings. Small office or administrative building with few operations.	Residential building with up to 20 dwellings. Small Office or Administrative Building with 2 to 5 floors. Small Hotels Goods lift with few operations.	Residential building with up to 50 dwellings. Small office or administrative building with up to 10 floors. Medium Sized Hotels Goods lift with medium operations	Residential building with more than 50 dwellings. Tall office or administrative building with more than 10 floors. Large Hotel Small to Medium Sized Hospitals Good lift in production process with a single shaft.	Office or administration building over 100 meters in height. Large Hospital Goods lift in production process with several shafts.

Baseline elevator fans shall operate continuously, 24/7.

Baseline elevator lighting shall operate continuously, 24/7.

The proposed design shall be modeled as follows:

Design elevator cab motor power [Watt] must be calculated as follows:

$$P_{m,prop} = bhp_{prop} * \ 746/h_{motor,prop}$$

Where:

- bhp_{prop} and $H_{motor,prop}$ is the brake horse power and electrical efficiency of the proposed elevator motor. Tables G3.9.3 & G3.9.1 above must be used as applicable if proposed elevator motor efficiency is unavailable.

Design fan and lighting power shall be based on design documents.

The same effective full load hours ($EFLH_{elev}$) must be modeled for the proposed design as for the baseline.

If elevator cab lighting has occupancy sensor controls, the annual lighting runtime must be equal to $EFLH_{elev}$.

Elevator usage may be included in the baseline and proposed simulation models in lieu of using the Elevator Energy Consumption Calculator. However, elevators are not expected to interact with other building systems and components, thus either methods should result in the same energy savings.

Example

Proposed design of a 10-floor office building includes 4 passenger elevators (Car 1) and 1 service elevator (Car 2). Parameters of both elevators are shown in Figure 1.

Figure 1: Elevator Calculator - Description of the Proposed Equipment

	Elevator ID	1	2
Application	Elevator Name	Car 1	Car 2
	Quantity	4	1
	Passanger or service elevator?	Passenger	Service
	Buildings and elevator type	Office or administrative building 6 - 10 floors	Goods lift with few operations
	Average Travel Time (hours per day)	1.5	0.5
	Usage Type: Intensity/ Frequency	Medium/ Occasionally	Low/ Seldom
	Number of Stories Served (including below grade floors)	10	10
Proposed Design	Counterweight of Car (lbs) (if unknown, leave blank)		
	Weight of Car (lb.)	8,098	8,824
	Rated Load (lb.)	3,500	4,000
	Speed of Car (ft./min)	1,200	1,200
	bhp	81.94	53.43
	Motor efficiency (%)	94.5%	93.6%
	Cabin Fan Power (Watt)	90	90
	Cabin Airflow (CFM)	325	325
	Cabin Lighting Power (Watt)	100	100
	Cabin Occupancy Sensor Lighting Controls (Y/N)	Yes	Yes
	Cab Area (Square Feet)	56	56

The total baseline elevator annual electric consumption is calculated as follows:

$$bhp_1 = (8{,}098\ lbs + 3{,}500\ lbs - (8{,}098\ lbs + 0.4 * 3{,}500\ lbs)) *\ 1{,}200\ ft/min/(33{,}000 *\ 0.64) = 119.3\ bhp$$

$$P_{m,1} = 119.3 * \frac{746}{0.945} = 94{,}177\ W\ = 94.2\ kW$$

$$bhp_2 = (8{,}824\ lbs + 4{,}000\ lbs - (8{,}824\ lbs + 0.4 * 4{,}000\ lbs)) *\ 1{,}200\ ft/min/(33{,}000 *\ 0.64) = \\ = 136.4\ bhp$$

$$P_{m,2} = 136.4 * \frac{746}{0.95} = 107{,}109\ W\ = 107.1\ kW$$

$$Elevator_{Baseline} \frac{kWh}{yr} = \left(94.2\ kW * 1.5 \frac{hours}{day} * 365 \frac{days}{year}\right) * 4 + \left(107.1\ kW * 0.5 \frac{hours}{day} * 365 \frac{days}{year}\right) * 1 \\ = 225{,}843.8\ kWh/yr$$

$$Lighting\ Load_1 = 3.14\frac{W}{sf} * 56\ sf * 24\frac{hours}{day} * 365\frac{days}{year} * 4 * \frac{1kW}{1000W} = 6{,}161.4\ kWh/yr$$

$$Lighting\ Load_2 = 3.14\frac{W}{sf} * 56\ sf * 24\frac{hours}{day} * 365\frac{days}{year} * 1 * \frac{1kW}{1000W} = 1{,}540.4\ kWh/yr$$

$$Lighting\ Load_{1+2} = 7{,}701.8\frac{kWh}{yr}$$

$$Ventilation\ Load_1 = 0.33\frac{W}{CFM} * 325\ CFM * 24\frac{hours}{day} * 365\frac{days}{year} * 4 * \frac{1kW}{1000W} = 3{,}758.0\ kWh/yr$$

$$Ventilation\ Load_2 = 0.33\frac{W}{CFM} * 325\ CFM * 24\frac{hours}{day} * 365\frac{days}{year} * 1 * \frac{1kW}{1000W} = 939.5\ kWh/yr$$

$$Ventilation\ Load_{1+2} = 4{,}697.5\ kWh/yr$$

$$Total\ Elevator_{Baseline}\frac{kWh}{yr} = 225{,}843.8\frac{kWh}{yr} + 7{,}701.8\frac{kWh}{yr} + 4{,}697.5\frac{kWh}{yr} = 238{,}243.1\ kWh/yr$$

The total proposed elevator annual electric consumption is calculated as follows:

$$P_{m,1} = 81.94\ HP * \frac{746}{0.945} = 64{,}685\ W = 64.7\ kW$$

$$P_{m,2} = 53.43\ HP * \frac{746}{0.936} = 42{,}584\ W = 42.6\ kW$$

$$Elevator_{Design}\frac{kWh}{yr} = \left(64.7\ kW * 1.5\frac{hours}{day} * 365\frac{days}{year}\right) * 4 + \left(42.6\ kW * 0.5\frac{hours}{day} * 365\frac{days}{year}\right) * 1 = 149{,}467.5\ kWh/yr$$

$$Lighting\ Load_1 = 100\ W * 1.5\frac{hours}{day} * 365\frac{days}{year} * 4 * \frac{1kW}{1000W} = 219.0\ kWh/yr$$

$$Lighting\ Load_2 = 100\ W * 0.5\frac{hours}{day} * 365\frac{days}{year} * 1 * \frac{1kW}{1000W} = 18.3\ kWh/yr$$

$$Lighting\ Load_{1+2} = 237.3\ kWh/yr$$

$$Ventilation\ Load_1 = 90\ W * 24\frac{hours}{day} * 365\frac{days}{year} * 4 * \frac{1kW}{1000W} = 3{,}153.6\ kWh/yr$$

$$Ventilation\ Load_2 = 90\ W * 24\frac{hours}{day} * 365\frac{days}{year} * 1 * \frac{1kW}{1000W} = 788.4\ kWh/yr$$

$$Ventilation\ Load_{1+2} = 3{,}942.0\ kWh/yr$$

$$Total\ Elevator_{Design} = 149{,}467.5\frac{kWh}{yr} + 237.3\frac{kWh}{yr} + 3{,}942.0\frac{kWh}{yr} = 153{,}646.8\frac{kWh}{yr}$$

The total elevator savings are calculated as follows:

$$Total\ Elevator\ Savings = 238{,}243.1\ \frac{kWh}{yr} - 153{,}646.8\frac{kWh}{yr} = 84{,}596.3\frac{kWh}{yr}$$

Figure 2: Elevator Calculator – Baseline and Proposed Energy Use and Savings

	Elevator ID	1	2	3
Proposed kWh	Peak Motor Power per Motor, Pm (kW)	64.7	42.6	
	Annual Motor Energy Use (kWh/yr)	141,693	7,775	
	Annual Cabin Fan Energy Use (kWh/Yr)	3,154	788	-
	Annual Cabin Lighting Energy Use (kWh/Yr)	219	18	-
Baseline kWh	Baseline Parameters			
	Cab Lighting Power Allowance (W/SF)	3.14	3.14	-
	Cab Fan Power Allowance (W/CFM)	0.33	0.33	-
	Baseline Elevator Type	Traction	Traction	-
	Counterweight [weight of car + 40% of rated load] (lb.)	9,498	10,424	-
	Cab Mechanical Efficiency [h mechanical] (%) ASHRAE 90.1-2016 Table G3.9.2	64.0%	64.0%	-
	bhp	119.3	136.4	
	Cab Motor Efficiency [h motor] (%) ASHRAE 90.1-2016 Tables G3.9.3 & G3.9.1	94.5%	95.0%	
	Peak Motor Power per Motor, Pm (kW)	94.2	107.1	
	Annual Motor kWh/yr	206,298	19,546	
	Annual Fan kWh/Yr	3,758	940	
	Annual Light kWh/Yr	6,161	1,540	

Savings Summary			
Building	Annual Electric Consumption (kWh)		
	Baseline	Proposed	Savings
Motor	225,844	149,468	76,376
Fans	4,698	3,942	756
Lights	7,702	237	7,465
Total	238,243	153,647	84,596

References

1. Goel, S, M Rosenburg, and C Eley. “ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.” Pacific Northwest National Laboratory, Sept. 2017.
2. “Lifts Energy Efficiency” VDI-4707 Part 1, March 2009.
3. Pacific Northwest National Laboratory, “PNNL 2013EndUseTables”, June 20 2014.