Motors: Elevators

Although significant energy savings are possible with premium-efficiency elevator systems, when compared with conventional systems, the added costs remain too high to justify installing premium-efficiency systems for energy savings alone. Simple payback periods can range from 20 to more than 200 years. Nevertheless, premium-efficiency elevators offer many non-energy benefits that building owners may find compelling, such as high performance and improved reliability. The energy savings—which can run into the tens of thousands of kilowatt-hours per year relative to conventional elevators—may be a bonus to building owners.

What Are the Options?

Premium and conventional elevators may differ either by their type (hydraulic or traction), the presence or absence of gearing, the drive types they use, or their ability to regenerate power (**Table 1**).

Elevator Type

Traction elevators. Mid-rise (7 to 24 floors) and high-rise (25 and more floors) buildings conventionally use traction elevators, which have steel ropes that raise and lower cars from above. In a machine room above the elevator shaft, a control system operates a motor that turns a sheave. Cables roll over this deeply grooved pulley to pull a car up or lower it down. The cables are also attached to a counterweight that weighs about as much as the car on the other side of the sheave when it is at 40 percent of capacity (an average load). The purpose of the counterweight is to create a balance to conserve energy. With a counterweight, the elevator operates much like a see-saw—the motor can move the car by just overcoming friction between the ropes and sheave and the difference in weight between the elevator car and the counterweight.

Conventional elevators require a machine room to house elevator equipment, including the drive and elevator control system. A new type of traction elevator, called a machine room–less elevator, was introduced in the U.S. in 1999. It uses a high-efficiency variable speed motor drive that is so compact it can be mounted on the elevator cab, eliminating the need for an elevator machine room. This elevator is a premium-efficiency alternative for low-rise buildings.

Table 1: Characteristics of premium-efficiency elevators

Premium-efficiency elevators may be 21 to 45 percent more efficient than conventional elevators.

Building type	Conventional elevators	Conventional drive type	Premium-efficiency elevators	Premium-drive type	Energy savings possible (%)
Low-rise (6 or fewer floors)	Hydraulic	Any	Geared regenerative, gearless nonregenerative, gearless regenerative	AC VVVF	21–24
Mid-rise (7–24 floors)	Geared nonregenerative	AC VVVF	Geared regenerative, gearless nonregenerative, gearless regenerative	AC VVVF, DC SCR, DC PWM	31–45
High-rise (25 or more floors)	Geared nonregenerative	AC VVVF	Geared regenerative, gearless nonregenerative, gearless regenerative	AC VVVF, DC SCR, DC PWM	30–43

Notes: AC = alternating current; DC = direct current; PWM = pulse-width modulating; SCR = silicon-controlled rectifier; VVVF = variable voltage, variable frequency.

Source: E SOURCE

The major market barrier for efficient machine room–less elevators in low-rise buildings is cost. Machine room–less elevators improve efficiency, but at a high price premium—at least 25 to 30 percent more than hydraulic elevators. The key attraction of these elevators is that they eliminate the cost of designing and building a penthouse on the roof; building owners may be able to save as much as $30,000 by not incorporating an elevator machine room, which would reduce the simple payback period for new construction applications.

Hydraulic elevators. Low-rise buildings (six floors and fewer) conventionally install hydraulic elevators, which use a fluid to lift and lower the car. The car has a piston in a cylinder beneath it; the elevator lifts when an electric motor powers a hydraulic pump to push a fluid (typically oil) into the cylinder, which pushes the piston up. To lower the car, the control system opens a valve and the fluid flows back into the tank as the weight of the car pushes down on the piston. Hydraulic machines can effectively multiply the relatively weak force of the pump to generate the stronger force needed to lift the car.

Hydraulic elevators are simple and inexpensive, but they are comparatively inefficient because they lack the counterweight that traction elevators have. As the car descends, the potential energy that was stored in the car as it ascended is converted into heat; in a traction elevator, potential energy is transferred to the ascending counterweight as the car descends.

Gearing

Traction elevators can be either geared or gearless. In gearless elevators, the motor rotates the sheaves directly. In geared elevators, the motor turns a gear train that rotates the sheave. Although geared elevators cost less, they cannot travel as swiftly as gearless elevators, which gives them poorer performance in mid- and high-rise buildings. Geared elevators can travel up to 500 feet per minute (fpm), whereas gearless elevators can travel as fast as 1,200 fpm. Speeds of at least 700 fpm are often preferred for high-rises and some mid-rises.

Drives

The elevator motor drive adjusts motor torque output to achieve desired acceleration, deceleration, and travel speed independent of car loading. The drive's efficiency is an important component of overall elevator efficiency; just upgrading an old drive without changing its mechanical components can reduce energy consumption by up to 30 percent. Outdated, inefficient drives that may be part of existing elevator systems but are no longer on the market include alternating-current (AC) two-speed, AC variable-voltage, and direct-current (DC) motor-generator sets. Modern, efficient drives include AC variable-voltage/variable-frequency, DC silicon-controlled rectifier, and DC pulse-width modulation drives.

Regeneration

Premium-efficiency traction elevators often use regeneration to offer the greatest efficiency possible. Regenerative systems turn the motor backward during descent so that it acts as a generator, and the resulting power is sent to uses within the building. It can be used with either AC or DC motors. Regenerative drives on the market in North America include the ThyssenKrupp 10K DC Drive, Schindler Transitronic DC Drive, and Otis Elevonic Class elevators. However, regeneration is unlikely to be cost-effective, because it adds $6,000 to $10,000 to the cost of an elevator.

Other Components

Motors. The oldest traction elevators use DC motors, which offer excellent speed control. Today, DC motors are used only in mid- to high-rise buildings, where their high performance justifies their high price premium. The most common AC motor is an induction motor that requires a gearbox to reduce the motor speed and produce the required torque to start the elevator car moving. Inefficient (70 percent efficient) worm gears are typically used for this purpose. Advanced systems have permanent-magnet AC motors with no rotor windings. These systems are 1 to 3 percentage points more efficient than induction motors, and they do not require a gearbox, which further improves efficiency. They also have fewer moving parts and require a variable-frequency drive.

Controls. Newer controls provide more convenient, efficient operation for mid- to high-rise buildings. Old, outdated controls consist of electromechanical relays. All new elevator controls are microprocessor-based; elevators are controlled by software that may incorporate algorithms to save energy (typically, on the order of 5 percent savings relative to systems that operate without such algorithms). This software allows the elevator system to place cars where they are most needed—in the interest of smooth operation with minimal waiting times—and to shut down extra elevators when they are not needed. The algorithms used in such software are based on analyses of elevator usage patterns called "traffic studies." Traffic studies are conducted by professional elevator consultants who use specialized tools to determine the optimum size, speed, and number of elevators for a building based on its peak use periods.

Lighting. Energy-efficient car lighting uses efficient light sources, such as compact fluorescent lamps, and can be controlled by occupancy sensors. ThyssenKrupp offers a seismic occupancy sensor for retrofits to provide lighting controls. Opening the doors causes enough vibration to turn on the lights. Most modern control systems have the ability to disable the light and ventilation fan in a car when it is not in use.

How to Make the Best Choice

Although elevator systems on the market today vary greatly in terms of energy efficiency, the most efficient systems are simply too costly to warrant consideration for energy-saving reasons alone. The simple payback periods range from 21 to 207 years in the example cases in **Table 2**.

Table 2: Elevator payback period

These results of elevator energy consumption simulations compare different types of elevators that are market competitors for certain building types. They show that premium-efficiency elevators are not cost-effective due to energy savings alone.

Elevator type	Drive type	Energy savings	Cost ($)	Annual cost savings ($) at $0.10/kWh	Payback period (years)
4-floor medical arts low-rise, 60,000 starts					
Hydraulic	Hydraulic direct	0%	75,000	0	NA
Machine room–less	AC VVVF	24%	95,000	103	194
6-floor residential low-rise, 200,000 starts					
Hydraulic	Hydraulic direct	0%	85,000	0	NA
Machine room–less	AC VVVF	21%	95,000	121	83
15-floor commercial mid-rise, 400,000 starts					
Geared nonregenerative	AC VVVF	0%	225,000	0	NA
Geared regenerative	AC VVVF	31%	235,000	479	21
Gearless regenerative	DC PWM	45%	330,000	696	151
25-floor residential high-rise, 300,000 starts					
Geared nonregenerative	AC VVVF	0%	270,000	0	NA
Geared regenerative	AC VVVF	30%	279,000	369	24
Gearless regenerative	DC PWM	43%	380,000	532	207

Notes: AC = alternating current; DC = direct current; kWh = kilowatt-hour; NA = not applicable; PWM = pulse-width modulating; VVVF = variable voltage, variable frequency.

Source: E SOURCE

One elevator company, ThyssenKrupp, has developed simulation software for estimating energy savings opportunities for customers. Other elevator companies, most of which currently use simplistic spreadsheet tools, will likely follow. To use the tool for projects involving new elevators from ThyssenKrupp, a ThyssenKrupp representative will enter the specifications of the elevators to be compared into the software to estimate the amount of energy each would consume.

Premium-efficiency elevators are likely to be least attractive to owners of low-rise buildings. Hydraulic elevators' low price continues to make them the undisputed leaders of the low-rise market. However, premium-efficiency elevators are likely to be very attractive to owners of mid- and high-rise buildings where speed and reliability are highly valued. These building owners may prefer premium-efficiency elevators because they provide the following benefits:

- *Improved reliability.* To keep elevator users and building operators satisfied, elevators must be highly reliable; that is, they must have an acceptably long expected time between failures. Older, less-efficient elevators suffer from more-frequent reliability problems.

- *High performance.* Passengers prefer to ride in elevators that start and stop smoothly and provide a quiet ride. Speed is important in mid- to high-rise buildings. In low-rise buildings, acceleration and deceleration are more important than maximum travel speed.

- *Compactness.* Machine room–less elevators use a high-efficiency drive that is so compact it eliminates the need to build an elevator machine room in new construction.

- *Reduced size of electrical service.* Elevators that have lower power requirements may reduce installation costs if the required capacity of the electrical service is reduced.

What's on the Horizon?

Recent elevator technology advances have included more-efficient drives and motors, better cabling, and advanced speed controls, all of which improve the efficiency of new traction elevator systems. The future of elevator technology may be elevators that use magnetic levitation instead of cables and are powered by linear induction motors. This technology would result in reduced friction, which could improve system efficiency as well as performance by producing a smoother ride. It would also mean that more than one car could use one shaft and the system would operate using switches, like a vertical railroad.