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Opportunities for Elevator Energy Efficiency Improvements

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Abstract

Elevator energy consumption in North American office buildings with central air conditioning systems is generally considered to be about 5% of building electricity use. Although the amount is relatively small for an individual building, the aggregate is large. In general, hydraulic elevators used in relatively low-rise buildings are much less efficient than the traction elevators used in mid- to high-rise buildings. New technologies, including software, promise efficiency gains of about 30–40% within elevator classes. Powell (2004) suggested the potential for several hundred GWh/yr in savings from adopting high efficiency technologies.

Interestingly, this is *unregulated* energy use—that is, it is not covered in building codes based on approaches like ASHARE 90.1, which focus on envelope, HVAC, lighting, and service water heating. In practice, elevator energy use is additional, unpredicted electricity use that shows up on demand and energy portions of utility bills.

There are approximately 700,000 elevators in the United States. We estimate fewer than 100,000 new installations and extensive retrofits annually, with major retrofits occurring on a 20- to 30-year cycle.

Elevators are generally *engineered systems* rather than simple manufactured products, tailored to each installation. Adequate energy simulation software packages are only becoming available now, and we have not found efficiency metrics that are both useful and simple. For this reason and the relatively small energy savings potential, we recommend against developing an ENERGY STAR program for elevators. Instead, it may be helpful if, as part of its Commercial Buildings thrust, EPA posted potential energy savings from elevator options on its Web site. This would be something like "best practices" for new installations and recommendations for retrofits (capturing energy benefits when modernizing for other reasons).

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Introduction

Actual energy cost is a key performance metric for building owners. Before construction, building energy simulation software may be used to model building designs and thus predict energy consumption. These programs appropriately focus on the major building loads, which include lighting, ventilation, people, and the direct losses and gains through the building envelope (including the solar gains through windows). Incidental loads thought to be smaller may be ignored by simulations, partly because they are not under the control of the mechanical designer. However, if these "incidental" loads cumulatively are more than a few percent of total building energy use, ignoring them leads to simulation reports that systematically underestimate actual energy consumption. This leads to unpleasant surprises after the building is in use.

The energy use of elevators is often in this category of unpredicted energy uses. Literature on this subject includes reports that are not completely consistent, because the area is not well studied. By one source, elevators typically use 3–5% of the electricity in modern buildings[1] (Al-Sharif 2004a). Simulations suggest that a lightly loaded low-rise hydraulic elevator doing 100,000 starts (door openings) per year would use 1,900 kWh/yr. In contrast, a heavily used (500,000 starts/yr) non-regenerative elevator in a high-rise commercial building would use about 15,000 kWh/yr (Enermodal 2004). For context, a typical 1,900 square foot electrically heated house in the West North Central Census Division would use about 7,100 kWh/yr for space heating (RECS 2001,[2] Table CE2-10c, 5200 HDD). On the other hand, standby power can be as great as 2 kW/lift (Al-Sharif 2004a), which would translate into about 10,000 kWh/yr by itself for an elevator that was on for 5,000 hr/yr.

Elevator technology choices (hydraulic vs. traction) can yield 3:1 differences in energy consumption (Al-Sharif 2004b, Figure 1, which cites Doolard 1992). Within a drive class, the best performers will use about 30–40% less electricity than the least efficient (Al-Sharif 2004a). At least two-thirds of all elevator installations are hydraulic, limited to no more than 7-story lift. The rest are *traction* elevators that use wire ropes (or belts) pulled over sheaves driven by a motor. In general, traction elevators have counterweights, while hydraulics do not. A counterweight is connected to the cab by a pulley, so it descends when the elevator rises, and vice versa. Counterweights decrease the weight to be lifted.

Hydraulic elevators dominate the low-rise market, because they cost substantially less to purchase. Mid-rise markets traditionally use geared traction motors, while gearless (direct motor-to-sheave) predominates in high-rise buildings. The oldest and least efficient traction elevators used motor-generators as DC power sources for the drive motor, and electro-mechanical relays for control. Current, more efficient units use solid-state variable-voltage, variable-frequency drives, often with permanent magnet motors instead of induction units. The most efficient equipment uses regenerative braking to feed electric energy back into the building instead of dissipating it as heat.

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[1] The dominant electricity uses in modern commercial buildings are lighting and HVAC, specifically air-conditioning.

[2] http://www.eia.doe.gov/emeu/recs/recs2001/detail_tables.html

There are about 700,000 to 800,000 elevators in the United States.[3] With reasonable extrapolation from a recent Canadian study, these would use in the range of 3,000 GWh/yr (Enermodal 2004). There is also indirect or induced energy use: virtually all the electricity used by elevators is dissipated as heat within the building.[4] This offsets heating that otherwise would be required, but adds to the air conditioning load. For a large, cooling-dominated building, this will add perhaps 20–40% to the direct energy use of the elevators: lower for a very efficient HVAC system and elevator resistors located outside the thermal envelope; more for HVAC with high parasitics and low system EER.

Industry experts interviewed suggest that the cycle between major renovations is on the order of 20–30 years, which would correspond to 25,000–40,000 renovations/yr. We believe that total new and renovation opportunities are less than 100,000 units/yr.[5] Both activities are opportunities for market intervention for energy efficiency. Elevator vintage matters, with new or upgraded traction elevators using 30–40% less energy than older units.[6]

The U.S. market has four principal manufacturers—Kone, Otis, Schindler, and ThyssenKrupp, all internationally active, plus numerous specialist firms. Sales generally seem to be through manufacturers' local sales offices. There are also specialized design consultants who help architects and engineers develop bid specifications.

If the goal is to recognize energy-efficient building elevators, the most important consideration is that elevators are not products. They are best considered as engineered systems. Once installed, the core elements (cabs, hoistways) will be used for the life of the building in many cases, whether 50 or 100 years. However, during this service life, many components that affect energy use will be changed out, typically on a 20–30 year renovation cycle. Thus, elevator systems are analogous to chiller-based "built-up" air conditioning systems rather than systems built around packaged unitary equipment. Although it is feasible to specify attributes of an efficient system (such as regeneration), actual energy consumption will depend on a myriad of details, such as software trade-offs between minimum energy consumption and minimum total trip time.[7] Further, because of occupancy details such as people per square foot by floor, usage schedules, and even build-out rates for tenant occupancy in new structures, it is difficult to forecast actual energy consumption by elevators in a specific building.

A second important consideration is that factors other than energy efficiency are the key market drivers today. Particularly for new construction, one important driver is the value to owners of less space allocated to elevators and their support systems, whether in penthouses or within the thermal envelope. This has led to the emergence of broad categories of "machine room-less" (MRL) elevator systems with much more compact drive systems and controls hardware. Other important considerations include reliability (expected time between failures, or frequency of required service). Smooth starts and stops and flexible operating systems that yield both efficiency and short wait times are also valued.

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[3] This is a rough consensus number from several industry sources.

[4] This may not be strictly true for regenerative elevators, if they ever feed electricity back to the grid. These are not common yet.

[5] One manufacturer estimates 225,000 installations/yr, but this seems high. It includes all classes, and presumably includes both installations in new buildings and major upgrades.

[6] Our estimate is conservative and based on personal communications with Al-Sharif and representatives of two major manufacturers. Individual cases can be more striking: Al-Sharif (2004) cites 1:2 energy consumption ratio for traction elevators with and without VVVF drives.

[7] At least one manufacturer offers this trade-off capability explicitly.

Because elevators are systems rather than mass-produced products, ACEEE recommends against developing an ENERGY STAR elevator qualification form. However, there are many actions that ENERGY STAR could take that would help motivate owners and their agents to adopt hardware and software features that lead to energy efficiency and pollution prevention. These might include populating the "Tools and Resources" page[8] with a "+ Elevators" heading, either at the same level as "+ Lighting" and "+ Fan Systems," or within "+ Other Load Reductions." Content suggestions are developed in the Discussion section, below.

Methods

This report is based on a literature review[9] and interviews with experts in the industry. The best single source extant for our concerns with energy and pollution prevention is Enermodal (2004), a report prepared for NRCan as the agency considered options for an ENERGY STAR-like program in Canada. The public elevator engineering literature is slim. Codes and standards are the concern of ASME Committee A17.[10] In addition, we found one trade association, the National Elevator Industry, Inc. (NEII).[11] We found one trade magazine, *Elevator World.*[12] This magazine recently published two helpful articles on elevator energy use based on simulations (Al-Sharif 2004b; Al-Sharif, Peters, and Smith 2004). The same source has recently published a primer, *Elevators 101* (McCain 2004) for facility managers and others who want introductory material for working with specialists. Over the years, a few textbooks and reference manuals have also been published (Al-Sharif 2004b).

Elevator Technologies

All elevators have elements in common, including cabs, doors (usually powered), lights (typically less than about 200 watts), ventilating fans, and safety devices. Guide rails to locate the elevator within the hoistway are essentially universal. Most importantly, virtually all passenger elevators in service in the United States have automatic controls. These controls assure that cabs go where they are dispatched, that doors don't close on passengers, etc.

Hydraulic elevators are by far the most common type, probably about 75% of all units. On the other hand, they are limited to no more than six or seven-story service. The simplest hydraulic elevator uses a single-stage hydraulic cylinder under the cab. An electric motor powers a hydraulic pump. The pump forces fluid into the cylinder, below the piston, forcing the piston to rise. When the elevator is descending, its potential energy is converted to heat that must be dissipated. In these systems, the hydraulic cylinder is housed in a well bored in the ground; the well has an impermeable liner to prevent hydraulic fluid from leaking into the ground and contaminating ground water. The hole is essentially as deep as the elevator lift height.

One way to avoid drilling is to use a telescoping hydraulic cylinder, which has become more common. These systems can be installed entirely within the building structure, by having the cylinder located behind the cab and bearing on a structural element at the top of the elevator cab.

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[8] http://www.energystar.gov/index.cfm?c=tools_resources.bus_energy_management_tools_resources

[9] Literature is defined broadly and specifically includes manufacturers' Web sites.

[10] http://www.cstools.asme.org/csconnect/CommitteePages.cfm?Committee=L01030000

[11] http://www.neii.org

[12] http://www.elevator-world.com

Hydraulic elevators have been the lowest-cost option for service up to six or seven stories. In addition, since the fluid reservoir and pump apparatus are preferentially located at the lowest level of the building, no penthouse is required. In addition, lift forces are transferred directly to the foundation, so structural reinforcement is minimized.

As height increases, *traction elevators*, the other major category, become more cost-effective. In these, the elevator cab is suspended from wire ropes (or coated wire belts in some designs). The ropes wrap around a sheave ("pulley") that is driven by a motor, either directly ("gearless") or through a reduction gear. Traction elevators can be divided into several categories. The first distinction is between geared and gearless. In general, gearless are used for taller buildings and have faster travel speeds (2–4 m/sec). Geared units are more prevalent in mid-rise buildings, from perhaps seven to twenty stories. With conventional systems, gearing allows use of smaller, less expensive motors. They produce enough torque by working at higher speeds. However, most worm gear systems are themselves only about 70% efficient (Enermodal 2004).

A second categorization would be by motor type. The oldest units use DC motors (very high starting torque and excellent speed control). In these older units, "mains" (building) power drives an AC motor linked on a common shaft to a DC generator whose output feeds the traction motor. For energy conservation, the motor-generators generally turn off after 2 minutes if there is no call for service. The first generation of upgrades for these units replaced the motor-generator with an SCR (silicon-controlled rectifier) bank, starting several decades ago. Unfortunately, these units required large isolation transformers and generally showed 1.5–2.5 kW of standby power use to energize the transformers, etc.[13] Most modern systems convert line power to "VVVF" (variable speed, variable frequency) AC, with voltage and frequency dependent on load and desired speed. The VVVF power drives fairly conventional 3-phase induction motors. In contrast, other advanced systems synthesize power for permanent magnet motors that do not have rotor windings.

Regeneration[14] offers savings with many motor systems, but requires some explanation. A "perfect" elevator system with energy storage would use no net energy over a suitable time period: The energy needed to lift people to upper floors would be regained when they return to the ground floor. Indeed, traction elevators do trip-level energy storage by using counterweights. The counterweights typically weigh about as much as the cab plus about half its maximum load. So, a full elevator needs help from the motor to carry people to upper floors, but an empty elevator needs energy to descend instead, because it takes energy to lift the difference in weight between the empty elevator and its counterweights. Conversely, the full elevator descending and the empty one rising yield potential energy that must dissipated as heat if it cannot be recovered as electricity. Older systems, both AC and DC, dissipated this energy as heat, either in the motor windings or in resistor banks (Enermodal 2004).[15] Contemporary systems, which have advanced power conditioning systems, can effectively use the motor as a generator. As an option, the power electronics can condition the power so it can be fed into the building's electricity distribution system, offsetting some of the power otherwise purchased from the grid. The direct (but intermittent) power generated is likely to be in the range of 10 kW per hoistway. The

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[13] 2 kW * 5000 hr/yr operating = 10,000 kWh/yr, with an economic value of perhaps $1000/yr including modest demand charges.

[14] Regeneration is sometimes referred to as "four-quadrant motor operation."

[15] Elevators may have mechanical brakes as safety measures or to hold the car in place at a landing, but modern drives no longer use brakes for stopping the cab (McCain 2004).

incremental cost of regeneration with a contemporary drive system is roughly $10,000/elevator. For a 15-floor commercial mid-rise building simulation and a 25-story residential high-rise simulation, regeneration reduced electricity use by 30% relative to the base case geared traction motor systems (Enermodal 2004).

The Elevator Market

Elevators are not mass-produced commodities. Although manufacturers offer "models" with familial characteristics, each installation is individually engineered for a specific application as characterized by the owner. Typically, the owner's representative (architect) provides specifications in terms of number of stops (stories), expected traffic, and his/her willingness to pay for premium features (which range from marble floors to advanced controls). These conversations generally are held between the owner's representative and the metropolitan area factory representative or sales engineer. All major manufacturers provide "bare-bones" systems for competitive bid situations that look exclusively for lowest first cost. Each also has upgrades for interiors, drives, and controls.

For complex or very large buildings, specialized elevator consultants may be brought in to provide specification services, evaluate bids, etc. Following bid acceptance, the elevator system is designed and installed on a schedule determined by the larger needs of the construction or renovation project. In the case of an occupied building, when no more than one elevator can be taken out of service at any given time, a modernization project may take years, with months spent on each lift in turn.

Paths to Higher Efficiency

From the discussion above and other information we were able to find, it is fairly obvious that energy efficiency has not been the highest priority in the industry. Before the Al-Sharif, Peters, and Smith (2004) model development and simulations studies, rules of thumb for lift energy disagreed by a factor of two or more (Al-Sharif 2004b). One manufacturer has licensed the new simulation model and adapted it for use with its products; the model will be made available to its sales engineers and consulting engineers.[16]

Motors and Drives[17]

Two converging trends have fostered innovation in motors and drive systems. First, customers want systems that require less space, such as machine room-less systems, and they are willing to pay for avoided construction costs and reduced non-leasable space. Second, rapid evolution of solid-state motor controls has opened the door to innovative motor and drive designs. The Otis "Gen2™" system illustrates systems that exploit these trends. The motor

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[16] Providing proprietary models to consulting engineers is common in the HVAC industry. In addition to load and equipment modeling environments like Carrier's HAP and Trane's TRACE, there are also pump selection and fan selection models, for example. It is interesting that energy efficiency has been so far down on priorities for elevator specifiers that the first simulation models of traffic, dispatch, and energy are rather recent.

[17] In motor applications, the term "drive" seems to be reserved for the power conditioning systems that convert main power to variable voltage variable frequency or other systems that allow motor speed and torque to be varied to better match application requirements. "Drive" is not conventionally used for the components that convert motor shaft power.

innovation is the use of a very compact and inherently variable-speed permanent-magnet motor. To provide the necessary torque with conventional wire ropes ("cables") would require a geared system, since ropes cannot be bent around a sheave (pulley) smaller than about a 30" diameter. Instead, the Gen2™ system replaces conventional round-section wire ropes with multiple flat polyethylene-coated steel belts. These work well when wrapping around a 4" sheave. For a given hoist speed, the smaller sheave rotates 7.5 times as quickly as a 30" sheave, so the smaller motor can deliver more torque and does not need a reduction gear system.

There are downstream synergies, too: The compact motor and sheave system can be built into the "bedplate" (elevator suspension assembly at the top of the hoistway) and mounted as a unit at the top of the hoistway, eliminating the machine room. The power conversion and control cabinet(s) are placed almost anywhere "near" the hoistways. The belts require no lubrication, so no toxic waste is generated. The system vibrates less and is quieter. According to the manufacturer, the integrated system uses about 35% less energy than a conventional geared traction system (Powell 2004).

Across the board, the same solid-state power systems make *regeneration* technically feasible for all traction elevators. It is frequently available as a premium feature, but may not have a particularly attractive economic payback for some customers. Current market share is not known.

Controls

Early elevators were controlled by operators who manually opened and closed doors and directed the cab to the appropriate floor. These were succeeded by self-service systems based on electro-mechanical relays.[18] Modern systems use software executed on the ubiquitous personal computer. Simple systems allow establishing fixed routines, such as turning off some lifts at night and on weekends. At increasing cost, additional features can be added that increase operating flexibility, response to power curtailment, and energy efficiency. For example, some systems "learn" where to position cabs at specific times, such as having all lifts return to the lobby in the early morning (when people are going up to their offices). This reduces waiting time. Some will automatically save energy by matching the number of active elevators to the load in that interval, and some advanced systems can respond to utility peak demand signals by reducing power consumed. This can be quite sophisticated, employing advanced algorithms that track where each elevator is located, to consider the potential energy available from its cab and counterweight locations. We estimate that advanced elevator control systems may save 5% more than the same technologies (motor/drive systems) with basic software.

Hydraulic Elevator Possibilities

Energy efficiency opportunities are limited, even though these elevators use substantially more energy than traction elevators for equivalent passenger movement. First, hydraulic elevators do not have counterweights, so there is no compensation for the energy required to lift the cab deadweight and the passenger load. Adding counterweights would increase cost substantially and somewhat increase the size of the hoistway, reducing rentable space (and making retrofits very difficult or impossible in many cases). The potential energy of the cab (and

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[18] These are still seen. They are characterized by push-pull knobs to select destination floors. Pushing the knob selects the floor, but the selection can be cancelled by pulling the knob back out. This feature is not found in electronic controls.

piston) lifted to the top is not recovered when the elevator moves back down, but dissipated as heat. Because the elevator machinery room for hydraulic elevators is typically in the cooled space (adjacent to the lowest elevator stop), this heat must be removed by the air conditioning system. The characteristic hydraulic elevator may use 3,500 kWh/yr.[19] If we value electricity at $0.15/kWh (including demand charges), this is $525/yr. It is technically possible to include advanced features such as permanent magnet motors with regeneration. However, more efficient motor, drive, and pump systems would have to cost less than $1.500 to meet a three-year payback criterion for business investment. As noted above, regeneration alone may be priced at $10,000/lift. However, as better drives and software diffuse and become features at lower price points, we expect some improvements to be offered for hydraulic elevators as well.

Parenthetically, there are said to be environmental concerns about actual or possible hydraulic fluid leaks into the ground. This concern can be addressed with two technical options: (1) using “holeless” telescoping hydraulic elevators; or (2) adopting use of vegetable oil-based biodegradable hydraulic fluids that are becoming commonly available for applications where temperatures are not extreme.

Lighting

The default value for cab lighting is generally taken as 200 watts. For a typical 40 ft^2 cab (5 ft x 8 ft), that is 5 watt/ft^2. If this load is never turned off, that would be 1,750 kWh/cab/year. Although this level is moderate for tall-building elevators, it could be about a third of the sum of lighting and hoist energy of the very common low-rise hydraulic elevator. The lighting load can be reduced two ways. The first is to enable the elevator controls to turn off the lights (and ventilating fan) when the cab is not in active service. This is thought to be relatively common now. The second approach is to choose more efficient lighting. Because elevators are small and have low ceilings, they may not routinely achieve the 1 watt/ ft^2 performance level of many contemporary office spaces, but several technologies are scalable to give high efficiency lighting for small spaces.

One example would be various types of compact fluorescent lamps. According to Rea (2000), elevators cabs require about the same illumination as (office) corridors and that can be as little as one-fifth the level of adjacent spaces (such as offices). This naively suggests that a 20 watt “circlite” compact fluorescent (assume 25 watts with ballast) would be adequate: It produces around 1,200 mean lumens, 30 lumens generated per square foot of cab. Assume a very high efficiency office lighting system that uses lamps that produce 100 lumens/watt and requires 1 watt/ft^2 of illuminated area. In this example, the cab would receive 50% more lumens/ft^2 than the IESNA recommendation for corridors (30 vs. 20).[20] The challenge is to interest the cab designer in a lighting solution including a light, high-albedo interior instead of dark wood paneling. This can give good illumination throughout the cab, with low power consumption. From this example, we consider 1.5 watts/ ft^2 to be readily attainable and even 1.0 watts/ ft^2 achievable.

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[19] Source = unpublished simulations by one major manufacturer.

[20] Of course, proper lighting design would be done in illuminance units (lux) instead of luminous flux (lumens).

Estimating Elevator Energy Efficiency

The state of the art has been summarized by Al-Sharif (2004b). Approaches that have been used include:

1. Calculation from first principles.
2. Direct measurements of elevator energy use under varying conditions, with different mechanical and electrical components. This can be done as research, or to look for ways to reduce energy consumption of existing units through retrofits.
3. Calculations from formulas and tables, which can be based on measurements, first principles, or a combination.
4. Simulations, typically based on first principles, traffic models, and engineering data from empirical studies.

Unfortunately, results have varied by as much as a factor of two between estimates based on Doolard's empirical measurements and those based on Schroeder's formulas, which are based on inputs such as starts/day, number of floors in the building, etc. (Doolard 1992; Al-Sharif, Peters, and Smith 2004). Best practice increasingly seems to be based on simulation models driven by traffic models, such as Al-Sharif, Peters, and Smith (2004) describe. This approach is being offered as a service by one manufacturer. We have also been shown spreadsheet-based models by another source.

One context in which this matters is the potential for regulating energy efficiency. As a particular example, Hong Kong has issued a "Code of Practice for Energy Efficiency in Lift and Escalator Installations." It is voluntary, but includes upper limits on motor power, total harmonic distortion, and power factor, and includes guidelines on elevator management (cited in Al-Sharif, Peters, and Smith 2004). This guide seems to require onsite measurements, so it is relatively expensive to implement.

Results

ACEEE has learned that elevators are almost always engineered systems, not products. In addition, elevator technology options are changing, and most of the changes (such as new motors, drives, and software) will offer greater energy efficiency. In addition, the emergence of decent elevator energy simulation software will allow manufacturers and their agents to establish the value (rate of economic return) of investments in better efficiency. On the other hand, many options available to customers are not particularly cost-effective, but are offered as premium features offering other services valued by customers (such as short waiting times or reduced noise and vibration).

ACEEE has not found a simple and cost-effective way to regulate elevator efficiency (as is being attempted in Hong Kong, a very high density urban environment). In addition, we have not found a simple way to predict energy efficiency of specific features relative to a given baseline.

However, it is possible to specify features for new and retrofitted elevators that will lead to greater efficiency and less power plant pollution.

Discussion and Recommendations

It may be helpful if, as part of its Commercial Buildings thrust, EPA posted potential energy savings from elevator options at "Tools and Resources"[21] on potential energy savings from elevator options. This would be something like "best practices" for new installations and recommendations for retrofits (capturing energy benefits when modernizing for other reasons). On the ENERGY STAR page cited, this could be positioned (for example) under "Other Load Reductions" or as a parallel to that, similar to others such as "Fan Systems."

Conversely, at this time, the potential savings are unlikely to be large enough to justify developing an ENERGY STAR label for efficient elevator systems. Most importantly, because technologies are still evolving, with different manufacturers seeming to stress different paths, a *prescriptive* approach is likely to be challenging to develop and still might leave room for some rather inefficient designs. A *performance*-based system would have its own challenges. The simplest case would be a ratio of energy use (kWh) to a measure of utilization demand. That, in turn, would be determined by the number of floors and the number of people using the system (floor area can be a proxy for users).

The state-of-the-art uses traffic models to drive the energy simulation. Our sense is that use of these new tools is far less common than using DOE-2 or equivalent for overall energy use in buildings—and that seems far from pervasive. However, at least two manufacturers (ThyssenKrupp and Otis) have expressed interest in developing several specific "prototype building" cases for publication on the ENERGY STAR site. For example, this might contain simulations for 4-, 10-, and 20-story office buildings. These would allow visitors to the ENERGY STAR site to estimate the effects of adopting efficiency options.

Finally, we offer several miscellaneous recommendations:

1. It will be advantageous to ENERGY STAR to open or continue conversations with Mark Shewfelt at NRCan. NRCan has done excellent work in this areas, but the U.S. program has much greater leverage because the amount of buildings work is about ten times larger.
2. Hydraulic elevators offer some additional challenges. Although much less expensive than traction elevators, they use roughly three times as much energy for the same lift and traffic. They offer few opportunities for regeneration, because the absolute energy consumption is relatively small.
3. Ignore escalators. First, there are rather few of them, roughly 10% of the population of elevators. Second, there are few technical options for improving efficiency. One option, apparently in common use in Europe, is to have the escalator stop when its sensors have noted no traffic for some interval such as five minutes.

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