STATE OF NEW YORK
PUBLIC SERVICE COMMISSION

JOINT PETITION OF ENERGY INVESTMENT SYSTEMS, INC. AND THE C.V. STARR RESEARCH FOUNDATION AT THE COOPER UNION FOR THE ADVANCEMENT OF SCIENCE AND ART	**CASE 03-E-0188**

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Petition to the Public Service Commission:
To Establish an Approval Pathway for Regenerative Drive Technology in the Renewable Portfolio Standard Proceeding

Submitted to the New York State
Public Service Commission

Submitted by Energy Investment Systems, Inc.
and the C.V. Starr Research Foundation
at The Cooper Union for the Advancement of Science and Art

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BACKGROUND

On March 22, 2010, Energy Investment Systems (EIS) submitted comments through a State Administrative Procedure Act procedure for the Renewable Portfolio Standard (RPS) proceeding recommending approval of a technology for the customer-sited tier. The technology is that of regenerative elevator drives, which are known colloquially in the industry as "regen." Regen allows mechanical energy generated through the gravitational pull of elevators to be transformed into electricity for use within a building.

The Commission's Order of April 2, 2010, which authorizes customer-sited tier programs through 2015 and resolves geographic balance and other issues pertaining to the RPS program, responded to the EIS proposal as follows:

> Energy Investment Systems, Inc. submitted comments urging the inclusion of new technologies to capture useful energy from the gravitational force of downward traveling elevators. We do not have enough information on this proposal to address it at this time, but will not preclude future consideration.

The CV Starr Research Foundation at the Cooper Union for the Advancement of Science and Art (Cooper) joins with EIS in this petition to address technology approval criteria cited within the RPS of the Public Service Commission (PSC) and discuss concerns over geographic balancing between upstate and downstate renewable technology implementation. New York City has the largest number of high-rise buildings that could benefit from a proliferation of this technology, although other New York State cities with high-rise structures would similarly benefit.

Pursuant to subsequent communications with Department of Public Service staff, EIS and Cooper have prepared this petition for Commission consideration of regenerative drive technology within the customer-sited tier of RPS.

INTRODUCTION

While there are numerous accepted definitions of renewable resources or renewable energy, they all suggest two major concepts. First, the energy should be generated from a natural source existing in nature, such as wind, sunlight, water and geothermal heat. The second concept is that the energy source is naturally replenished, and is not depleted when used. The force of gravity, which easily satisfies these definitions as well as sustainability concerns with respect to generating power without combustion, is non-polluting and has a zero carbon footprint.

The benefits of regen to meet New York State energy objectives and reduce carbon footprints are recognized as technologically valid. Opinions may differ, however, over its proper classification as a renewable resource, an energy efficiency measure, or an energy storage technology. Such interpretations may be obscured by semantics and underlying assumptions. Resolution of this issue affects the availability and extent of technology incentives.

An analysis of these arguments is submitted to support the Commission's acceptance of regen as an approved technology under the Renewable Portfolio Standard:

1. Regen does not function as an energy efficiency measure. Energy efficiency means that less energy is needed to perform the same work. For example, an energy efficient compact fluorescent light consumes less electricity to provide the same amount of light or lumens as a less efficient incandescent bulb.

   Regen power emanates from the energy consumed to propel the elevator. It does not offset or reduce the amount of electricity used as the elevator works, such as when a heavy elevator car ascends or a light car descends. Regen power is created when the elevator motor is not consuming power.

2. Regen is not an energy storage technology. A pumped storage hydroelectric facility "pumps" potential energy in the form of water to a higher level where it is stored only to be released and gravity fed to create electricity when it is economically advantageous to do so.

A regen-equipped elevator also uses gravity to generate electricity. It does not, however, consume energy for the purpose of storing it; it consumes electricity to perform work, i.e., transporting people or goods, in the same manner as any other energy-consuming transportation system. As an added advantage, the system continues to perform work while generating electricity, whether transporting a heavy load down or a light load up.

3. The location of the elevator or counterweight is a pre-existing condition with respect to regen, established by the elevator system as it performs its regular work. Gravity gives life to the adage "what goes up must come down." The force to propel either a heavy car or the counterweight upwards when it is heavier is electricity. The electricity resulting from a descending and heavier cab or counterweight is captured by regen technology for use in the building to offset the use of grid power. Power is generated in a traction elevator, first, by the gravitational pull on descending cabs that are heavier than the ascending counterweight and, second, by the gravitational pull on descending counterweights when they are heavier than ascending elevator cars.

Terms such as storage, generation, and efficiency are often blurred when used in a policy framework. Load controls and load controlling equipment used for demand response have been variously characterized as both efficiency measures and renewable resources. Peter Smith, a former president of the New York State Energy Research and Development Authority (NYSERDA), characterized load controls and curtailment practices as the cleanest form of power available. The general understanding of energy conservation has also evolved over the past 35 years. A sense of sacrifice was the prevailing theme in the 1970's; it has given way to a focus on energy efficiency and now encompasses combined heat and power, which was formerly called cogeneration, and before that, total energy systems. Solar thermal, for example, was recently approved by the Commission and demonstrates its ability to establish pragmatic approaches outside of a rigid and traditional policy framework. This innovative approach to technology approval can prove instructive in considering regen under the Renewable Portfolio Standard.

This petition offers specific arguments and evidence to support the ability of regenerative drive technology to satisfy the Commission's customer-sited tier criteria for eligibility as an approved

RPS technology. It is beyond the purview of this petition to discuss how regen might eventually be incentivized by NYSERDA, if the Commission were to approve it.

The Study Design section describes a joint project of EIS and Cooper Union to quantify ways to calculate prospective incentive needs and estimate implementation costs under various conditions. Findings will be shared with the Commission and DPS Staff as they emerge, should the project come to fruition.

SUMMARY OF REGENERATIVE TECHNOLOGY

Regenerative drive technology is applicable in traction elevators, which make up the vast majority of elevators in New York City today. New York City was also the birthplace of the traction elevator more than a century ago. A cable connects an elevator car over a pulley to a counterweight. The elevator and counterweight operate like a seesaw where the amount of force needed to go up is offset by the side that comes down. Electric motors rotate grooved drums with deep sheaves (pulleys) that help grip the cables due to the enhanced area of surface contact (hence, the name "traction" elevators).

Energy is required to push or pull upwards; gravity is the moving force when a cab or counterweight falls. The counterweight generally weighs 40-50 percent of the elevator car at full load. The car frequently travels at less than full load; sometimes the car is heavier than the counterweight and sometimes it is lighter.

The elevator consumes electricity in two states. The first pushes the car up when it is heavier than the counterweight; the second pushes the counterweight up so that a lighter weight car can come down. They are illustrated in **Figure 1** (below left).

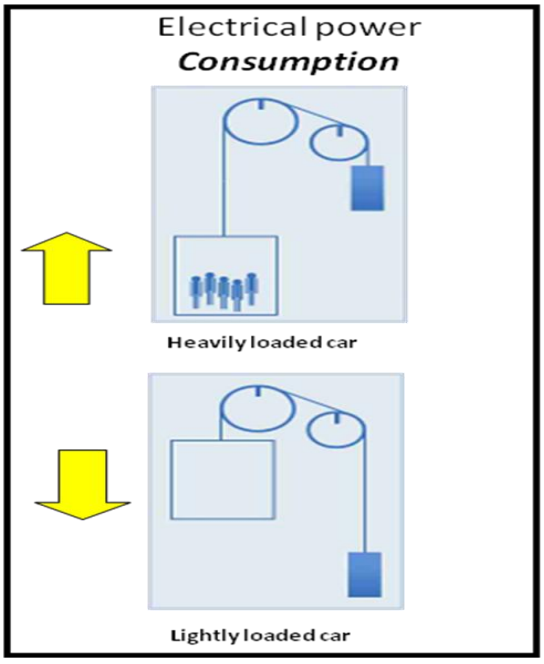

Figure 1. States of Electricity Consumption

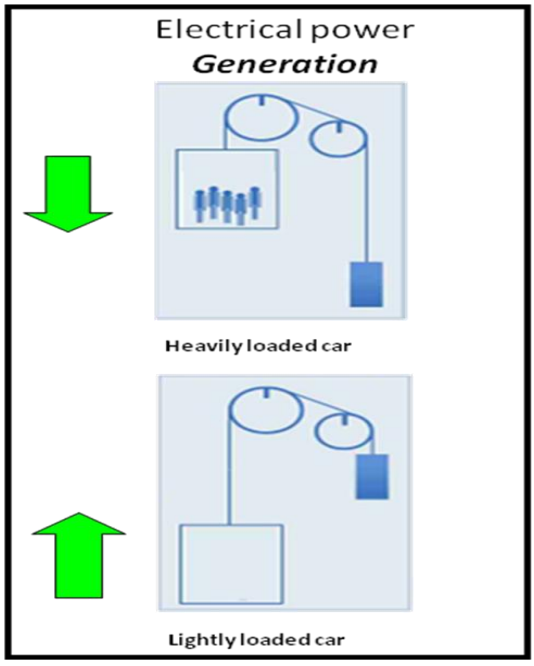

Figure 2. States of Electricity Generation

An elevator equipped with regenerative drives generates power when the gravitational pull (the force going down) is greater than the weight going up, and gravity must be held in check. As illustrated in **Figure 2** (above right), this happens first when a downward moving elevator weighs more than the counterweight and, second, when an elevator car weighing less than the counterweight goes up. In these cases, the mechanical energy of the moving car or counterweight causes the elevator motor to rotate in the opposite direction, functioning as a generator (or *re*-generator) of electricity. The elevator can also produce electricity as it slows down, or decelerates, before it stops when the motor/generator works as a braking system. Conventional elevator systems dissipate this untapped electricity as waste heat, routing it through electrical resistors in the elevator shaft or machine room, on essentially the same principle as an electric toaster.

We emphasize the intrinsic sophistication of the cab and counterweight system. It is incorrect to assume that when the elevator goes up it consumes power and when it comes down it generates power. At any specific time, the elevator could be in either a continuous consumption or generation mode, based on trip patterns in a building. This property allows regen to satisfy RPS criteria to reduce demand during peak load periods.

Consider a typical office tower whose elevators are outfitted with regen capacity. In the morning, empty elevators descend to pick up passengers and crowded elevators ascend to take them to their offices. The crowded elevator going up is heavier than its descending counterweight; when the elevator comes down empty, it is lighter than the ascending counterweight. Both ascending and descending trips consume power, and there is no need to check the force of gravity.

The potential of regen accelerates during peak usage at the end of the workday. From the late afternoon to early evening, an elevator outfitted with regen will generate power continuously as lightly loaded and often empty elevators ascend to pick up office workers and crowded elevators descend as workers stream out of the building.

Government support for implementation would spur research and development to further reduce the gap between electricity consumed and electricity generated. Even if regen generated less

power than anticipated, it offers a number of environmental benefits that boost its potential beyond a mere generation-to-consumption ratio.

CRITERIA UNDER COMMISSION ORDER IN CASE 03-E-0188

New York State recognition of regeneration as an approved energy technology in accordance with the PSC Renewable Portfolio Standard would significantly advance the enhancement and application of the technology. According to our research, regen meets and surpasses the RPS criteria identified in PSC orders of April 14, 2005, and April 2, 2010, in Case 03-E-0188.

1. Technologies that play a role in diversifying the State's energy mix

   Regen is currently an uncommon method to generate electricity in New York State. Traction elevators are already an efficient form of transportation, consuming far less energy than other forms of vertical or horizontal transportation. Traction elevators are far more efficient than hydraulic elevators, which do not have counterweights and use electric pumps to raise and lower the cars. Regenerative elevator drives, which use the gravitational pull of the elevator cab or counterweight to generate energy, replenish energy supplies consumed, thus reducing building electricity needs from the grid.

   If approved for RPS, regen technology would significantly diversify and enhance the State's renewable portfolio, especially in New York City, where solar and wind applications are limited. The City does, however, have 65,000 elevators that the City Department of Buildings estimates make approximately 30 million trips a day. To date, however, most building owners are unaware of this potential savings, as evidenced by the very small percentage of City buildings taking advantage of this technology. Naturally, the estimated 10,000 elevators statewide outside of the City could benefit in a similar fashion.

   Throughout the petition, we refer to the capacity of regen, especially in the City's large commercial buildings, to help offset demand when the grid peaks and the least efficient and most costly power plants must be brought on line. Once the connection between regen power production and the ISO Day Ahead Market is demonstrated (and documented), we believe that additional ways to accentuate regen for demand response will evolve. This will further enhance regen as a source of non-polluting energy supplies when the grid is strained and diversification of energy supply is most needed.

New York City, which comprises NYISO Zone J, is a recognized load pocket. An estimated 80 percent of peak power is generated within the City's borders; a good deal of the remainder is provided by the Indian Point 2 and 3 nuclear power plants, whose Nuclear Regulatory Commission (NRC) licenses are up for renewal in September 2013 and December 2015, respectively. The plants are continually threatened with closure, most recently because of safety concerns in case of earthquakes such as in Japan as well as NYS DEC concerns over aquatic effects in the Hudson River. On March 22, 2011, Governor Cuomo urged that Indian Point be shut down "now," saying that "the plant is risky and should not operate." Were the NRC not to renew the Indian Point licenses, it would greatly increase the City's dependence on fossil fuels. Regen could replace a portion of today's high carbon footprint power supply with a stable and more diverse power mix. Although institutional and multifamily buildings do not have the same generating patterns as commercial buildings, they too offer potential opportunities to reduce grid dependence with regen-produced electricity.

2. Technologies that improve the environment

Regen has the potential to improve the environment in several tangible ways. Unfortunately, the relative efficiency of modern elevator systems has to date caused energy practitioners to overlook the potential advantage of regen and related technologies when seeking savings.

- Power generated without combustion or nuclear, through solar, wind or regen, replaces the need for additional fossil fuel combustion or nuclear-generated power. Furthermore, commercial skyscrapers have the greatest capacity to capture regen power during peak demand when grid power can be scarce, especially in hot weather when the most polluting power plants must be called into service.
- Regen can reduce the current practice whereby typical traction elevators dissipate the electricity they produce as heat in elevator shafts or elevator machine rooms. Additional grid-generated electricity is then required to cool the rooms so that equipment does not malfunction, and the building maintains a desirable comfort level.
- Regen supports a switch from conventional DC motors to less polluting AC elevator motors. A new permanent magnet motor (PMAC) with regen is projected to save a net 75 percent in electricity over a conventional DC elevator that uses a motor generator

(motor gen) set to convert incoming AC power to usable DC power partially because the electricity needed to power electromagnets is no longer needed. The motor gen set continues to consume AC power even when the motor is not running.

- DC motors generally use carbon brushes to supply power to rotors to produce mechanical energy. These brushes continually emit carbon dust, coating all surfaces in an elevator machine room. AC motors, which do not emit this dust, directly improve indoor air quality.

There is no pollution from gravity-captured electricity through regen. Any electricity produced in this manner protects the environment by offsetting the use of polluting fossil fuels to generate electricity. Furthermore, power is no longer dissipated as waste heat that must be cooled to protect the equipment, thus reducing air-conditioning loads and overall energy usage.

3. <u>The technology's ability to reduce demand during peak load times</u>

The capacity of regen technology to reduce peak demand is a fundamental driver behind its commercial viability. By approving regen as a customer-tier RPS technology, New York would encourage the adoption of this feasible new technology and enhance the state's capacity to reduce systemwide demand during times of peak consumption.

As illustrated in the technology summary, it is possible that long runs of several hours could exist during which the elevator either consumes or generates power. In a conventional office building, it is anticipated that consumption will occur primarily during the morning and generation will be prolonged at the end of the workday.

The example cited of an office tower whose elevators are outfitted with regen drives demonstrates how they would most reduce demand at times of peak usage. At the end of the workday, regen drives harness electricity as empty elevators ascend to pick up workers and brakes must be applied to the heavier counterweight. On the return trip, regen drives again produce electricity as they hold gravity in check as crowded elevators descend.

This is especially important downstate where the evening peak is substantially higher than the morning peak and, during hot New York City summers, air-conditioning use can increase demand 35-50 percent. Not only is the carbon footprint per kilowatt hour of consumption significantly greater at these times, but prices on the Day Ahead Market (DAM) administered by the New York Independent System Operator (NYISO) are generally higher in the late afternoon through early evening than earlier in the day. Regen in office towers would help offset the use of grid power at these times when it is most polluting, most expensive, and in shortest supply. It is of small consequence that the generating capacity of commercial elevators is limited earlier in the day when grid power is more abundant, lower priced and less polluting.

At times, NYISO deems electricity supplies to be severely strained and launches special actions to prevent a power emergency. Con Edison has developed similar programs to avert a power emergency if the electricity delivery infrastructure approaches overload. These curtailment events usually occur during summer heat waves and extend through rush hour. Frequently, some elevators are taken out of service when the events are called. However, it may prove beneficial, especially at the end of the workday to place all elevators with regen capacity in service. If our hypothesis that office building elevators are in a prolonged generation state in late afternoon through early evening is correct, regen can indeed be a powerful tool to advance the Commission's goals.

Furthermore, regen offers a consistent non-polluting opportunity to produce power that, unlike other RPS technologies, is far less affected by outside weather conditions. Although regen capacity is inherently intermittent like other renewable sources, we postulate that elevator trip patterns are a far more reliable source of power for commercial skyscrapers from 4:30 p.m. to 7 p.m., every day of the work week.

4. <u>The technology's ability to stimulate economic development opportunities in the state</u>
Should regen be recognized as an approved RPS technology, its rapid commercialization would be assured. The many business organizations, real estate owners and developers of commercial and multifamily buildings, and cooperative and condominium apartment

buildings that have declared an interest in becoming "green" comprise a potentially large market for the elevator industry that would support new manufacturing, installation and service jobs in sustainable technologies statewide. Training elevator mechanics for regen-related work would be a valuable course to include among the new green jobs programs being planned.

The market spreads beyond Manhattan to other urban areas across the state and beyond. According to Joe Schiavone, supervisor of elevator inspections in Buffalo, the upstate city has some 3,000 elevators, of which 1,800 are passenger elevators, 500 are freight elevators, with the balance in government and institutional buildings. Less than one percent have regen capability. Twenty-five percent of the existing elevators were installed prior to 1929. Retrofitting 10 percent or 300 of the elevators with regen at $25,000 per installation would gain the city $7.5 million in new business each year. Retrofitting 10 percent of New York City's 65,000 elevators at the same price would stimulate $162.5 million in new business activity.

Elevator codes continue to grow more stringent to assure passenger safety and elevator reliability. Some minimal compliance is now required, which focuses attention on elevator upgrading. An application to change motors and add regenerative drive technology would typically trigger additional code compliance upgrades. Satisfying the code could increase the cost of each elevator conversion by $100,000, adding a cumulative $6.5 billion to the city's economy.

Although we have not attempted to estimate the number of green jobs that this activity would create, we have discussed regen's impact on the City economy with academics, developers, labor leaders, environmentalists and the elevator industry. Each group emphasizes that regen's approval as a bona fide renewable technology would create jobs. Further jobs are anticipated through a complementary increase in research and applications to augment regen as a green building and demand response technology.

Documentation of the economic advantages of regen, combined with RPS approval, greater safety and reliability, and a general economic recovery, would catalyze growth throughout

the elevator industry. This is the kind of innovative thinking needed to return New York State to greater economic prosperity.

5. The technology should be innovative and appropriate for commercialization

Today's emphasis on sustainability is making the elevator industry greener, just as it has with appliances and automobiles. Over the past 15 years, the elevator industry has embraced the need to be more energy efficient; today it is undertaking energy efficiency with a vengeance.

There are four companies with a major presence in the United States that manufacture complete elevator systems for new construction: Otis, Schindler, Kone and ThyssenKrupp. They have all developed green machines that utilize PM motors, feature built-in regen technologies, and use lighter-weight materials and smaller equipment. GAL Manufacturing, a NYC-based entity, is introducing a new PMAC that can be packaged with regen for new construction and elevator retrofits for existing buildings.

In the past year, several compact regen products have emerged for retrofit of existing machines coincident with the economic recession. Products include Yaskawa's RC5, which is being marketed by Otis; Hitachi's RCU 2011, which is currently being tested in the New York City Housing Authority's Wald Houses on Manhattan's Lower East Side; Magnatek's digital Quattro drive system; and GAL's new PMAC motor, which will be paired with Yaskawa's RC5 as a green package for elevator retrofits in existing buildings. GAL, a manufacturer of elevator controllers and rope grippers to enhance elevator safety, is the largest manufacturing employer in the Bronx with 338 full-time employees. For elevators in new buildings, the most advanced application of the energy-saving and generating components is the machine room-less elevator, or MRL, where elevator motors are installed inside the shaftway.

The April 2010 issue of *Elevator World* magazine, which is devoted to environmental issues, discusses energy savings through technologies such as permanent magnets and regen. The cover story discusses Beijing's Gold LEED-certified Linked Hybrid Tower as a "sustainable look for the future."

> In order to maintain significant sustainability, the developer contracted Otis Elevator Co. to provide the vertical transportation for the project. Otis supplied 42 units, including 40 elevators and two Otis Link escalators for the complex. Thirty-two of the elevators were Gen2© elevator systems, which incorporate patented flat polyurethane-coated steel belts, which, when combined with a compact permanent magnet machine, deliver significant energy savings, design flexibility and quiet operation. In addition to the Gen2© system, ReGen™ drive technology provides energy savings of up to 75 percent compared to that of conventional systems. ReGen is designed to capture the energy usually lost by the elevator system from heat during the braking of the elevator.

Elevator retrofits, which the industry calls "modernizations," are down 75 percent in today's economy in New York City. The new compliance codes now going into effect are, however, sure to refocus attention on modernization. Adding regen and PMAC would mean an incremental cost increase of only 5-10 percent beyond a conventional upgrade. If regen were eligible for RPS incentives, building owners would be encouraged to undertake the work. The confluence of mandates and incentives could cause a significant proliferation in regen technology. As the economy grows, regen could further jump-start the industry.

Additional commercial applications of regen have great promise for major ports and transportation hubs like New York City. Innovative flywheel technology that regenerates power for mobile cranes in shipyards and for railway systems is described further below.

ADDITIONAL CRITERIA CITED IN CASE 03-E-0188

In addition to the primary criteria, the Commission Order of April 2, 2010, requires that a petition for consideration as an approved RPS technology address several additional points. Because gravity is not thought of as a traditional fuel (yet neither are wind and solar), the responses may seem somewhat strained, however, to be comprehensive, we address these additional considerations in support of our petition.

6. The technology's ability to promote fuel diversity

A proliferation of regenerative applications can help reduce New York's dependency on fossil fuels and other expensive and polluting sources of power in New York. Regen utilizes gravitational pull to reverse kinetic movement in a motor; "running it backwards" is how industry people express the concept. More expensive renewable technologies such as wind turbines and hydroelectric plants similarly transform kinetic energy into electrical energy, but must expend energy solely for that purpose. Regen makes use of a free and abundant energy source that you do not have to mine, refine or grow. It transforms mechanical energy into electricity simply as a by-product of its essential work cycle of delivering people to their vertical destination.

Regen is especially promising in new construction, where LEED certification is becoming commonplace and a LEED platinum designation represents a real marketing coup. Regen is one of the technologies being applied to create high performing structures with a heightened sustainability consciousness.

Another sustainable elevator technology that is often paired with regen is the use of permanent magnet AC motors, which require grid power to produce only one magnetic field in order to induce the motor to spin. The other magnetic field is created by the installation of neodymium iron boron rare earth magnets that form lightweight and compact super magnets with a pulling force of more than 120 pounds per cubic inch of magnet.[1] Although rare earth elements are mined materials and therefore generally not considered a renewable resource, their magnetic force is a natural, non-polluting energy source. In the quest for net zero

[1] Rare earth includes 17 various minerals. Neodymium combined with iron and boron comprises the cheapest and strongest of these super magnets.

energy consumption in elevators, PMAC and regen combine to lessen dependence on grid power and contribute natural, non-polluting diversity to the State's overall energy mix.

A growing number of new buildings such as the Platinum LEED-certified Bank of America building, also known as One Bryant Park, generate power through cogeneration systems. Regen, which offsets the most power during peak system usage, combined with cogeneration can significantly reduce a building's electric needs when grid power is most polluting and allow the City to meet a growing portion of its load through cleaner power. Using regen upstate during peaks similarly maximizes the potential of wind power to satisfy grid demand at other times.

At the same time, recognizing regen as a renewable technology eligible for research and development incentives would help stimulate the growth of similar technologies that have debuted recently.

- A new regenerative flywheel system for mobile cranes in shipyards and rail yards offers substantial savings over traditional fuel-guzzling models. Conventional cranes get their power from highly polluting on-board diesel generators, which provide intense bursts of voltage and frequency to variable-speed AC motors by way of an inverter. During lift cycles, peak power draws from the generator; the electric energy generated during lowering and braking is dissipated as heat through a resistor bank, just as with elevator systems. The California company VYCON has developed a system that uses a maintenance-free PM motor gen design that produces high-power short-duration discharges and regen charges for countless cycles.

- A gravity-powered floor lamp won the 2008 Greener Gadget Design Competition. Gravity pulls brass weights placed at the top of the lamp down a screw shaft to spin a generator that converts rotational motion into electricity to power ten LED lights (see http://science.howstuffworks.com/environmental/green-tech/sustainable/gravity-powered-lamp.htm).

- Electric vehicles use regenerative brakes to recover kinetic energy and convert it to electricity. Electric railways, including the newer New York Metropolitan Transportation

Authority subway cars, feed energy back into the supply system. NYSERDA has funded a NYPA study of ways to increase their use in the New York City subway system. Hybrid electric vehicles, such as the Toyota Prius, store the energy in a battery or bank of capacitors for later use.

- A personal vertical transportation device in development at London's Royal College of Art uses a gravity-driven counterweight system to send people up five stories in the time and effort required to climb one flight of stairs. The human-powered system requires no external energy input. Shifting weight from foot platform to seat, a person gently seesaws upwards; upon descent, as with regen, energy is fed back into the system to propel the next ascent. The compact system has great potential for the home, with special import for the elderly and disabled who cannot climb stairs but would benefit from the physical activity.

7. <u>The origin and composition of the generation fuel</u>

The actual fuel used to generate electricity is the gravitational pull of the earth. Much is known about the various properties of gravity. For example, regardless of their weight, objects large and small will fall at the same speed. The speed of the falling object increases exponentially as it falls, which could conceivably enhance regen capacity as scientists, engineers and physicists seek to expand its potential.

The study of the origins and properties of gravity continues globally to this day. Isaac Newton identified it as a universal force, Galileo conducted experiments to quantify its properties, and Einstein posited his own theory, "that gravity is nothing but the curvature of the four-dimensional space-time continuum."

8. <u>The extent to which the technology will result in new and incremental renewable resources</u>

The study of gravity at the theoretical level continues apace, as physicists worldwide carry on their search for the "ripples in spacetime" predicted by general relativity. Official recognition of regen and the applied application of gravity to generate electricity as an approved renewable technology would, however, help focus attention of pragmatic inventors

and engineers on new ways that gravity can be applied to propel objects, for example, by causing motors to spin and generate electricity.

It is our understanding that the intention of "the extent to which the technology will result in new and incremental renewable resources" refers to additional applications of the technology. As discussed above, regenerative drive technology is being applied in other situations, including hybrid and electric-powered vehicles, and in cranes that lift and transport heavy cargo from ship to shore, and vice versa. The broader uses of gravity as a renewable resource are seen in ever creative new ways, with examples including the gravity-powered lamp.

The increased focus on regen, combined with a general acceleration of renewable awareness, suggests two additional resource applications. First, a related energy-saving elevator technology is the PMAC motor, which uses rare earth metals to create one of the two magnetic fields needed to spin motors, thereby reducing electricity consumption. From an elevator retrofit perspective, PMAC will increase the ratio of generated electricity to power consumed. Rare earth metals are mined and, as such, not a renewable resource. A full 95 percent of the world's supply currently comes from China, which raises a host of international trade issues although the country controls less than 30 percent of the world's proven reserves. These issues are being addressed by the federal government and at the World Trade Organization. Permanent magnets do, however, help create electricity and mechanical energy naturally, without pollution or waste. The PMAC/regen combination will both reduce grid dependency and achieve significant economic savings.

The second way that regenerative technology can spur renewables is to set the stage for the additional benefits that electricity storage systems can provide. The flywheel is the storage technology used in the VICAM regen application in load-bearing mobile cranes described under criterion 6. The latest elevator technologies are most feasibly implemented in new construction. New buildings, especially the skyscrapers being erected throughout the world, deploy increasingly advanced systems that set examples for retrofit in existing buildings. The use of flywheels to store power regenerated from a bank of elevators might be especially beneficial in regions interested in methods to enhance grid reliability.

9. The nature of the process to turn the fuel into electricity

It is important to recognize that electricity can be either consumed or created in an elevator's electric motor. The motor is also the elevator system's brake.

Elevators can work in reverse by generating electricity in the same manner as wind turbines and hydroelectric power plants. In wind turbines, the force of the wind turns blades of varying designs to power a generator. In hydroelectric plants, the force of gravity creates water pressure to power a generator by turning a water turbine. These electric generators have an internal resistance to rotation that prevents the armature of the motor from freely turning due to the motor's magnetic field. This forced rotation transforms the kinetic energy of the system into electric energy. Elevators, in their regen braking mode, function similarly.

The force created by gravity on the heavy descending cars creates the need for braking. The force created by gravity on the heavier counterweight when an empty or near empty car ascends also creates the need for braking. The same is true when stopping the car at specified floors. The total mass of the elevator system that must be stopped includes the elevator cars, passengers, freight, counterweights, cables, the compensation system, etc. With all of the mentioned system components in motion, there is also frictional force that subtracts from the available kinetic energy.

In the braking mode, the motor is forced to turn without the input of electricity. As mentioned, there is an internal resistance to rotation that prevents the armature of the motor from freely turning due to the motor's magnetic field. In traditional electric motors, electricity is needed to power the motor's electromagnets and thereby create the necessary magnetic field when the motor is in the braking mode. In PMAC motors the rare earth magnets create a permanent magnetic field and are therefore a de facto renewable energy source.

Before regen, the electricity generated in the braking process was dissipated as heat in large resistors. A design that combines PMAC and regen eliminates the inefficiency of using additional electricity to power electromagnets and avoids wasting generated electricity. Regen's inherent energy savings, along with new energy technologies, have made the

harvesting of this braking energy a viable economic enterprise. The new regenerative drive system allows this free electricity to be fed seamlessly into a building's electric infrastructure.

10. The totality of the environmental impact in the generation process (air emissions, waste products, etc.)

In traditional terms, regen has no environmental impact with respect to air emission; without combustion, it contributes no sulfur dioxide or particulates to the atmosphere and has no carbon dioxide footprint whatsoever. There may be some residual waste heat since not all energy generated may be captured, however, research should lead to greater efficiency between the amount of electricity generated and captured.

To our knowledge, there is no data on the generation-to-capture ratio, just as there are no definitive statistics to determine an elevator's generation-to-consumption ratios. While generation to consumption is influenced by the trip patterns of a particular building, the percentage of electricity captured to that produced appears to be a technical issue that requires technological solutions. Advances in research and application will combine with data collected and measured in test facilities and onsite to increase the generated-to-captured efficiency.

It is important to note that regen has none of the deleterious environmental impact of other forms of traditional or renewable power production. There is no nuclear waste or other waste material requiring disposal; no excessive heat is emitted into rivers or the atmosphere. There is no danger to fish requiring mitigation as with nuclear and hydro-electric plants and no danger to birds from wind turbine blades.

11. The degree of development of the technology and the resource

The capacity of regen to satisfy commercial objectives was discussed under criterion 4 above. Two breakthroughs have occurred since we began to examine ways to save energy in existing elevator systems less than a year and a half ago. They are feasible and affordable for buildings that are considering elevator modernization. The first technology paves the way

for a broader application of regen in existing buildings; the second technological advance will profoundly affect net energy consumption in city buildings.

The first involves the retrofit of existing AC motors. As noted above, several leading technology firms are manufacturing products that install regen capability on existing systems without the need to purchase and install new motors, controls or other equipment. Easily implemented as part of standard modernization or retrofit, systems include Yaskawa's stand-alone add-on RC5 regenerative drive, which is now offered by Otis as part of its new green series; Hitachi's RCU Series for AC motors; Magnatek's Quattro DC drive; and the Go Green/Stay Green Modernization Package from Motor Control Engineering and Imperial Electric. Buildings that implement regen drives as they modernize elevator systems or replace motors and controls can achieve unparalleled efficiency gains.

The second development is the introduction of PMAC motors in buildings of fewer than 22 stories. Until relatively recently, only geared motors could operate at the slower speeds necessary for lower buildings. Since PM motors are not applicable with geared machines, PM and gearless technologies were not deemed appropriate in the lower rise buildings that comprise the vast majority of New York City's multifamily housing stock. EIS has learned, however, that gearless machines and PMAC motors with regenerative drives are to be implemented in some New York City Housing Authority (NYCHA) buildings as part of a complete elevator replacement program. Most NYCHA buildings are limited to 14 or fewer floors.

Both geared and gearless machines can be made more efficient through the addition of Variable Voltage Variable Frequency (VVVF) drives, which automatically change the electric voltage and frequency that feed into the motor to match the demand. When combined with VVVF drives, PMAC motors are now being manufactured to be much smaller and lighter than their predecessors. This results in a 50 percent reduction in the energy required to operate these motors, and removes the requirement of a separate machine room (hence the acronym MRL for machine room-less). The improved motor efficiency also extends to the braking mode where substantially more electricity can be created with the motor acting in reverse as a generator.

Although consuming or generating modes occur separately, the potential of both is best realized when used together as components of elevator modernization. The true economic benefits emerge when viewed from a net energy perspective. The more efficiently an elevator performs in the consumption mode, the greater the percentage of an elevator's power requirement that is offset by regen. Increasing efficiency in consumption while maximizing regen capacity brings the elevator ever closer to a zero net energy condition.

12. The probable cost of providing RPS program support for the technology or resource

A preliminary estimate has been made as to the amount of money that could be allocated to facilitate regenerative drive technology in the New York City area. According to industry sources, there are approximately 75,000 traction elevators in the New York City area that require modernization of controls and fixtures every 20 years. This does not include additional work to replace motors, gears, cabs, or other major components of an elevator system. It is conservatively anticipated that 3,750 modernization jobs are needed each year; however, it is acknowledged that the economic slump has delayed many jobs.

To spur implementation, it is proposed that incentives be granted for 500 regenerative drive systems in 2012, and that the number of units increases by 50 percent each year through 2016. In this discussion, regen capacity reflects the size of the motor rather than the yield. Generally, the taller the building the more regen capacity can be installed per elevator. The horsepower (hp) ranges from small elevators of 10 hp to motors of 40 hp for skyscrapers or those designed to carry heavy loads.

As a rule of thumb, smaller elevators can regenerate about 35 percent of capacity, while larger elevator motors can regenerate 50 percent. The percentage of regen to motor hp, however, can rise as motor efficiency increases and regen capacity is considered in car dispatching strategies. Regen capacity for a 10-hp motor is 2.61 kilowatt (kW), which regen reduces 25-35 percent; capacity for a 40-hp motor is 14.91 kW, with regen producing 50 percent of power consumed.

We recommend an incentive for 500 regenerative drives at an average of 8 kW of capacity for a total of 4,000 kW in 2012. We recommend an incentive of $750 per kW for each regenerative drive installed. This would provide an average incentive of $6,000 per regen installed, which would be 35-50 percent of the cost of an independent regenerative drive added to an AC motor, or about 15 percent of the cost of a silicon-controlled rectifier to replace a motor generator set for DC motors. The five-year incentive program is shown in **Table 1**.

Year	# Units	Total Installed Capacity (kW)	Incentive/ kW	Total Projected Incentives
2012	500	4,000	$750	$3,000,000
2013	750	6,000	$750	$4,500,000
2014	1,000	8,000	$650	$5,200,000
2015	1,500	12,000	$650	$7,800,000
2016	2,000	16,000	$650	$10,400,000

Table 1. Proposed Regen Incentives 2012-2016

It is anticipated that the program could be deployed in 2012, following a year to develop protocols to assure correct sizing and evaluation of equipment. There has been only limited research to quantify use and capacity; even less data is available to identify when elevators consume power and when it is generated. The five-year span should encompass applied research, as described in the Study Design below, to identify the actual number of kWh consumed and generated to assess value and cost effectiveness.

Research and demonstrations would help to assess the ability to price usage based on the ISO's Day-Ahead Market and price the value of generated power based on the DAM as well. If it is determined that the value of generated power (per kilowatt hour) is greater than the value of kilowatt hours consumed, a strong case can be made for introducing regen in buildings that purchase electricity based on Real-Time Pricing rate structures. The U.S. Environmental Protection Agency calculates electricity source emissions by the hour. It

would be interesting to see if the value of a reduced carbon footprint for regen is greater than the carbon footprint for usage.

STUDY DESIGN

EIS and Cooper have executed a letter of intent to undertake a joint study to assess the impact of regenerative power on New York City. The study aims to measure or extrapolate regen potential in commercial and residential buildings, determine its economic value with respect to the electric grid and overall economy, and build the framework for cost benefit analyses to determine its feasibility. Armed with this data, the study will recommend incentives to promote implementation and accelerate commercialization.

We propose to develop a methodology to project technology implementation costs and savings for buildings of diverse types, sizes and elevator trip patterns. We will recruit a portfolio of multistory New York City buildings, including apartment buildings, institutional buildings and premiere commercial skyscrapers to take part in the study. The proposed project envisions an advisory committee of elevator and energy experts, as well as professionals within the appropriate real estate sectors.

Steps will include:

- Sampling the electric consumption from diverse elevator systems and locations
- Developing a method to determine the amount of electricity used by traditional elevators
- Calculating the potential for regenerated power for existing elevators
- Determining the value of regeneration to offset electricity demand and costs in city buildings
- Determining the potential carbon footprint reduction in city buildings
- Reviewing and promoting public incentives for elevator modernizations
- Assessing the impact of regen on demand response objectives
- Developing a basic template for Cost Benefit Analysis (CBA) studies needed to determine the feasibility of regen upgrades
- Evaluating institutional issues including code compliance, and recommending solutions

The EIS/Cooper project will involve a coordinated research effort involving industry professionals, public agencies, owners and managers of New York City office buildings and multifamily dwellings, and other stakeholders in this issue. This larger group will help to

identify and sample elevator electric consumption patterns of old and new skyscrapers, as well as multifamily and mixed-use buildings.

This project will produce a new paradigm for research, development, testing of algorithms and dispatching methodologies. It will enable the creation of new designs that will maximize regeneration strategies while conserving energy during times of peak pricing.

NEW YORK: AN URBAN LABORATORY FOR ELEVATOR INNOVATION

New York has been a key source of elevator innovation since 1853 when Yonkers inventor Elisha Graves Otis stood on an elevator platform high above the crowd at New York City's Crystal Palace and severed the cable. Vertical hoisting devices dated back thousands of years, but the specter of snapping cables sending elevator platforms into free-fall had kept people from setting foot on them. Perceptions changed that fateful day nearly a century and a half ago as, onlookers agog, the new Otis ratchet safety mechanism brought the descending car to an abrupt stop.

With public confidence in hand, Otis installed the first passenger elevators in 1857, one of them in Peter Cooper's new Cooper Union and laid the groundwork for the vertical cities of today. Enthusiastically embraced by building owners and residents, elevators were installed in some 5,000 New York City apartment buildings by the end of the century. The impact on real estate values was immediate. Without elevators, the lowest floors had been the most valuable; the upper floors were worth less, the higher one had to climb. The advent of the elevator reversed this equation.

Continuing industry advances soon made possible the 1902 21-story Flatiron Building – one of New York City's first true "skyscrapers," to be followed by the 47-story Singer Building in 1908, the 50-story Met Life Building in 1909, the 57-story Woolworth Building in 1913, the 1930 77-story Chrysler Building, and the 102-story 1931 Empire State Building, each debuting as the world's tallest building. The Empire State Building with its 73 elevators that traveled 86 floors in just one minute reigned for four decades until the 110-story World Trade Center grabbed the skyscraper title. A feat of engineering in all respects, it unleashed a quarter century of feverish development in the New York elevator industry. It would redefine the skyline of New York City and seal its reputation for ingenuity, imagination and application in the eyes of the world.

This urban laboratory has produced countless innovations in the elevator industry, but a few bear special note.

- **Traction elevators**. New York City served as the incubator for the modern elevator from 1887 through the end of the century. Milestones include Otis' 1889 installation of the first DC-powered elevator motor, the 1891 introduction of electric motor speed controls by Westchester electrical engineer Harry Ward Leonard, and the hydraulic elevator system of the 1902 Flatiron Building. It was the traction elevator, however, a system of pulleys, cables and counterweight to lift cars from above, that enabled the continued growth of the City's towers – and it remains essentially unchanged today in many of the City's buildings.

- **The rope gripper.** Elevator safety concerns in today's megastructures led to the development of a new traction elevator device, the rope gripper, designed to prevent empty elevator cars from shooting upwards and to guard against a range of other electrical and mechanical malfunctions. Developed by Hollister-Whitney in 1999 and manufactured by GAL Manufacturing Corp. in the Bronx, it provides a new standard for safety and has been incorporated into current American Society of Mechanical Engineer elevator codes.

- **Sky lobbies**. The 1931 102-story Empire State Building signaled the end of the skyscraper race for four decades as financiers and investors grew reluctant to devote so much valuable space to the many elevators needed to service such a supersized structure. The race resumed in 1973 with the construction of the twin 110-story towers of the World Trade Center, for which Otis Elevators provided a groundbreaking solution for the location of their 95 elevators. Modeled after the city's subway system, express elevators carried people to "sky lobbies" on the 44th and 78th floors, where they could transfer to a bank of local elevators making stops on intervening floors. This allowed the local elevators to be stacked within the same elevator shafts and increased the amount of usable space on each floor from 62 to 75 percent. This New York inspiration has since made it possible to erect buildings of previously unimaginable heights in cities around the world.

- **Microprocessor controls**. Control systems to start, stop, accelerate regulate speed and decelerate elevators have been evolving since the 1850's, with many of these older systems still in operation. Today, as typified in the development of the Otis WTC system, sophisticated microprocessor circuit boards control every aspect of increasingly complex operations. Elevator dispatching systems based on computer algorithms improve traffic

control and reduce the number of elevators required in a given building. To track traffic flow, they compile information about time elapsed between stops at the same floor, the number of buttons pushed by people boarding a car, and the car's changing weight load. Using sophisticated algorithms, they estimate the number of people waiting for elevators at any given moment and determine which car to send, not necessarily the closest one. A number of elevator manufacturers currently compete to install their systems in city skyscrapers.

- **Destination Dispatch**. In 2006 Schindler Elevators installed its first hotel destination dispatch system in the Marriot Marquis in Midtown Manhattan. Passengers enter their desired destination on a keypad outside the elevator bank and are directed to the car that will deliver them to their floor in the shortest possible time. The Schindler system installed at Manhattan's 54-story Bank of America building, which was named Elevator World Magazine's 2010 Project of the Year, won the city's first Platinum LEED rating in part due to its destination dispatching system and the application of regenerative drives.

These are only a few examples of the technological talent and industry that have made New York City and its skyline what it is today. At the same time, dwindling corporate profits are squeezing many of our most ingenious technologists out of jobs, and the state's natural resources are growing scarcer by the day. Advances in elevator technology can help to restore the economic health of the industry and offer widespread ecological benefits. Regenerative drives, one of the most important technology developments in the elevator world in recent years, promise both financial and environmental benefits for the City and for urban areas statewide and around the globe.

CONCLUSION

Gravity itself is still a subject of wonder and mystery; the concept of the power of gravity as fuel is groundbreaking. In conventional elevator systems the energy created by the force of gravity on the system is transformed into electricity and fed into resister banks that simply dissipate the electricity as heat. Regenerative drive technology allows a traction elevator to capture the renewable gravity-generated force and transform it into useable electricity for use within the building's internal electrical infrastructure.

Although in use worldwide, regen is still a relatively new concept in the United States. In New York City, fewer than two percent of all elevators currently have regen capability. In greater New York State, it is estimated that regen has been applied in less than one percent of existing elevators. Previously seen only in new construction, the latest advances make regen widely available for a retrofit market. This important new industry product can help keep New York at the forefront of new energy technologies, and the application of such energy-saving technologies is clearly in the public interest.

For buildings and building owners, in a densely populated region that must strain to meet its electric needs and has been gravely affected by the current economic recession, regen offers our existing elevator buildings a compelling and affordable new renewable energy resource. The impact promises to be enormous.

For New York State, at a time when the economic climate is forcing coveted technology and manufacturing jobs out of state, regen and the elevator industry can provide important employment opportunities in manufacturing, installation, construction and service.

Market demand is the driver of production and commercialization. Designating regen a renewable technology would give it enormous cachet as a smart, economic and environmentally friendly technology that appears to be custom tailored not only to the City's skyscrapers but to the City's electric load patterns. Commission eligibility approval may be just what is needed to exemplify innovative thinking and establish a literally uplifting motif on the tenth anniversary of 9/11. PSC encouragement would position regen technology to realize full commercialization and contribute to the energy resources of New York State.

ABOUT THE PETITIONERS

This petition to the PSC is being submitted by Energy Investment Systems, Inc., in conjunction with the C.V. Starr Research Foundation at The Cooper Union for the Advancement of Science and Art. As part of their petition, the entities propose a study (see Study Design) to assess the prospective impact of regen technology in New York City and determine the feasibility and financial framework of potential RPS customer-sited tier incentives.

Energy Investment Systems

EIS provides its clients with information and solutions to navigate and succeed in today's challenging world of energy uncertainty. For over 25 years, building owners, property managers and developers have turned to EIS to increase energy efficiency and reduce their energy costs. EIS's residential real-time pricing work earned the company a 2004 NYSERDA 25th Anniversary Pioneer Award Winner for "excellence in energy innovation for the State of NY" on behalf of the city's multifamily buildings. That same year, EIS founder and president Lewis M. Kwit was selected as Energy Service Professional of the Year of the Association of Energy Engineers/NY Chapter. In 2007 EIS real-time pricing work was cited in New York City's 2007 long-range *PlaNYC for a Greener, Greater New York.* Mr. Kwit and the EIS consulting team regularly contribute their expertise to advance public policy discussions among public and private sectors.

The C.V. Starr Research Foundation at The Cooper Union for the Advancement of Science and Art

For a century and a half, The Cooper Union for the Advancement of Science and Art has been one of the nation's top-ranked institutions of higher education. Under the direction of Yashodhan C. Risbud, a Cooper Union alumnus and adjunct associate professor of electrical engineering at Cooper, the C.V. Starr Foundation serves as the primary research unit of Cooper Union's Albert Nerkin School of Engineering. Director Risbud oversees its participation in research activities that augment educational opportunities for students, enhance professional development of faculty and provide services to the community. Faculty serve as directors of these externally funded projects, assisted by other faculty members, outside consultants, and undergraduate and graduate students of The Cooper Union.