



# **ENERGY IS POWER: THE MILITARY APPLICATION OF REGENERATORS FOR POWER SURETY**

INTERNAL WHITE PAPER

ZEROBASE ENERGY, LLC  
1-4-10



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## Background

For generations, cheap and abundant energy has been available to American consumers and warfighters. Electricity is a part of who we are, powering nearly every item on which we base our western, modern, civilized life. In fact, the US National Academy of Engineering ranks “Electrification” as the #1 Engineering Achievement of the 20th Century.<sup>1</sup> In our digital society, stable, clean electricity—whether it is generated by oil or sunshine—is vital to maintaining our critical infrastructure at home and in theater.

It is common knowledge that the Department of Defense is the largest single consumer of energy in the United States and that energy is the key enabler of U.S. military power. In spite of that distinction, or perhaps because of it, vulnerabilities exist in the system: potential fossil fuel and electricity supply disruptions, and foreign policy and economic liabilities, combine to leave the American warfighter with the Achilles’ heel of energy dependence.

According to an August 2007 paper by the Brookings Institution, energy requirements are directly related to combat effectiveness; the infrastructure required to transport and distribute energy to the battlefield is extremely expensive and diverts resources from combat. Combat forces are limited by a “tether of fuel” that needs to be lengthened.<sup>2</sup>

Direct fuel costs, fuel cost volatility, vulnerability to the fuel logistics tail, and fragile power grids are all issues which the military must contend with on a daily basis, which is why it is also common knowledge that those inside the Pentagon are working to reduce risk to deployed forces due to availability and distribution demands of energy, reduce risk of loss of critical functions due to extended commercial grid power disruptions at fixed installations, and increase use of renewable energy sources and microgrids.

It is to the issue of renewable energy that this white paper was written. A catch-all term, Renewable Energy can mean many things in a growing industry, from grid-connected wind power to residential geothermal heat pumps; from biofuels to solar fields. One sector of renewable energy in particular is called ‘distributed generation’, or DG, the small-scale production of electricity at or near the point of use. DG has the potential to improve power supply reliability, reduce electricity costs, and lower harmful emissions. It also has the potential to aid in homeland security by reducing national exposure to vulnerable centralized power production and the thread of the grid system.

In fact, the DG revolution has begun. Consumers around the world are looking for reliable, on-site power solutions for disaster management, infrastructure hardening and business continuity as power outages become commonplace and energy prices increase. Fuel price volatility and climate change have made fossil-based power options increasingly unsustainable around the world.

Meantime, electrification in the developing world and the build-out of electrical infrastructure is pushing countries to leapfrog centralized power production and embrace distributed generation and micro-grid technology. This mirrors the trajectory of the mobile phone, which has offered nations the benefits of a reliable communications network without the heavy investment in fixed-line phone infrastructure.

The trend toward distributed independence and scalable solutions, with minimal infrastructure investment and lower total cost of ownership, has ushered in a large and growing market for deployable clean energy called ‘regeneration’. Regeneration is the application of distributed, renewable energy using sophisticated transportable appliances designed to generate, store and manage power from any source—solar, wind, fossil, the grid, and more—anywhere in the world. Regenerators offer easy use, independence and scalability heretofore unknown in the energy sector.

Regenerators are the next step in power generation technology, and their application by the U.S. military means the cost payoff of reduced fossil energy use for mobility, fixed and tactical installation and the operational payoff of less refueling and increased platform availability. This paper discusses the concept of regeneration, and details the attributes of ZeroBase Energy regenerator appliances, which have been shown to reduce in-theater generator running time by 85% and fossil fuel consumption by up to 65%.

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<sup>1</sup> <http://www.greatachievements.org>

<sup>2</sup> Gregory J. Lengyel, Colonel, USAF: Department of Defense Energy Strategy Teaching an Old Dog New Tricks, Brookings Institution, August 2007



## Portable Generators: A History of Fossil

Portable fossil fuel generators have historically been an acceptable solution when emergency or on-site power is needed to supply electricity. Portable generators found a place in the market because of their mobility, affordability, flexibility and simplicity. The world is changing, however, and because of volatile fuel prices, fuel distribution problems, and negative environmental impacts, the portable generator is not the solution that it once was.

While low fuel costs and product prices have historically made small generators inexpensive to buy and operate, fuel prices have seen severe price volatility in the early part of this century, making small, portable generators less ideal as backup or primary power sources. Plus, over the life of a generator, fuel costs add-up. Users looking for long term, reliable, back-up power are increasingly nervous about reliance on traditional fossil fuels.

Example: Several months after the invasion of Afghanistan, the U.S. Military was spending roughly \$3million per month to provide fuel to generators that powered mobile phone towers in Kabul.

When it comes to getting fuel, inconsistent fuel distribution has made small generators a far less appealing option. Conventional wisdom has often led to the deployment and support of small generators for emergency preparedness, but fuel distribution logistics have changed the global approach to disaster planning, forcing agencies to find power solutions that do not require liquid fossil fuels.

Example: After Hurricane Katrina, generators were either flooded to the point of uselessness, or inoperable due to lack of fuel availability. Similar issues arose in Southeast Asia during the 2005 Tsunami – fuel delivery systems broke down.

The importance of environmental sustainability cannot be understated. Around the world, federal, state, and municipal governments are working to reduce harmful emissions. Perhaps more than any other public policy priority, climate change will impact the market for small scale generators. Small two-stroke and four-stroke engines are among the most harmful to the earth's environment. In addition to greenhouse gas emissions, small generators negatively impact local air quality and lead to serious health conditions in children and the elderly.

Example: The American reconstruction team in Iraq recently reported that a new smog has formed around many neighborhoods in Baghdad, areas which only receive 4 hours of power from the national grid. The national government is thus subsidizing the purchase of portable generators by businesses and individuals, perpetuating mass pollution. Because of the severity of this new environmental problem, the reconstruction team is desperately looking for new approaches to distributed power production that are not dependent on small, fossil-fueled generators.

## Renewable Energy Installations: Systems of Complexity

Renewable Energy is a concept whose time has come. In every country around the globe, solar and wind installations are booming– from giant utility-based projects, to singular remote-power sites. Renewable Energy helps solve many of the power production problems we face, including fuel cost volatility, energy supply, centralized power production vulnerability, harmful emissions, and energy insecurity.

It is for these reasons that Renewable Energy sources will be at the forefront of energy policy for the foreseeable future. However, for all their positive contributions, distributed renewables currently have some difficulties when it comes to mainstream market adoption, including complexity, high initial cost, intermittent power production, non-mobility, and inconsistent installation and service.

Example: In the U.S., a standard residential solar installation can take as long as 7 months. Even the smallest of installation require multiple experts, including licensed solar installers, electrical engineers and other specialized technicians.

Renewable energy installations are complex projects. Sizing a renewable energy installation to the power load is a critical piece of any small-scale wind or solar project. Yet the general user never thinks about power consumption, and in fact finds the sizing exercise for renewable energy systems both complicated and daunting. In addition, integration of renewable energy into a business, home or government deployment is a large and often lengthy process. Users often feel that the process is just too much of a headache. While these attitudes are changing slowly, they remain a major barrier to wide adoption. Consumers see renewable energy as complicated, and a small portable generator (or flipping on the light switch for that matter) as simple.



The single largest barrier to mainstream adoption of building-integrated solar and wind is the start-up cost of the project. Though a small portable generator is initially affordable (with fuel costs incurred over the lifetime of the product, hence masking the true cost from the consumer), the cost of renewable energy installations are initially high. While renewables can be an affordable power solution over time, consumers are commonly scared of the initial overhead costs. With growing renewable energy installations comes an increase in unskilled installers who manage projects badly and deliver poor ongoing service. This is having a negative effect on consumer confidence in distributed renewable energy systems.

Another barrier for renewable power production is the intermittency of power production. Consumers are often concerned that they will have no solar power at night, or that wind energy production is variable. Whereas a small, fossil-fueled generator will run as long as fuel is supplied, renewables are impeded by the perception of insurmountable intermittency.

Lastly, by their very nature, renewable energy “installations” are long term, fixed items. Unlike the portable generator, solar or wind cannot be moved from location to location. Plus, it typically takes a long period of time to recoup the initial investment required to install solar or a stationary wind turbine.

## Renewable Energy and Military Energy Security

The United States Military has long understood the risks and costs of its fossil-fuel dependence. The Pentagon’s fuel bill rose from \$13 billion in 2007 to about \$20 billion in 2008<sup>3</sup>. Increasingly, the cost of war fighting is the cost of fuel. The Department of Defense measures the fully-burdened cost of fuel to its final destination as including the fuel required to deliver fuel, as well as the cost of operating convoys, support vehicles and airdrops.

The US Army Energy Security Task Force has outlined the core objectives of its energy policy: to make a consideration for all Army activities to reduce demand, increase efficiency, seek alternative sources, and create a culture of energy accountability while sustaining or enhancing operational capabilities<sup>4</sup>. The Army’s strategic energy goals are to reduce consumption, increase energy efficiency across platforms and facilities, increase the use of renewables, assure access to sufficient supplies and reduce adverse impacts on the environment.

The Department of Navy, as the largest fossil-fuel user in the military, has likewise committed to reducing petroleum use. The Navy directives call for a 50% reduction in petroleum consumption by 2020, with the first step being a 50% reduction in petroleum use by the commercial fleet by 2015<sup>5</sup>. Onshore, the Navy will look to Hybrid and Electric vehicles to reduce consumption, and produce 50% of its shore-based energy requirement from alternative resources.

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<sup>3</sup> “Greenery on the March”, The Economist December 10 2009

<sup>4</sup> “Army Energy Security”, Office of the Assistant Secretary of the Army (Installations and Environment), 2009

<sup>5</sup> “Navy Energy Task Force Update” December 2009



## Regenerators

### Regenerators Defined

Conceptually, regenerators are not unlike what we have come to expect from our laptop computers: mobile, expandable, reliable and powerful. The analogy is not coincidental: ‘productizing’, the transition of systems into products, has been a feature of modern industry for nearly 50 years. From telephones to computers and more, what used to be systems for delivering value to an elite few have transformed into products available to anyone.

Regenerators are the ‘productized’ version of what until now have been complex traditional and renewable energy systems in the area of Distributed Generation (DG). DG is the small-scale production of electricity at or near customers’ homes and businesses, and it has the potential to improve the reliability of the power supply, reduce the cost of electricity, and lower harmful greenhouse gas and particulate emissions.

Yet there is a vacuum in the DG industry in the areas of both traditional and more modern renewable energy: Traditional small-scale, fossil fuel generators that have dominated the market are failing to meet the challenges of a new energy world; unstable fuel costs, resource instability and environmental concerns have become a liability for small generator systems. In addition, renewable energy systems—solar, wind and other—are just that: systems, with inherent complexity in installation, maintenance and scalability. The market lacks innovative, clean-tech products that support growing demand for fuel-free, ‘Clean DG’: regeneration.

Regenerators are mobile, renewable energy-powered generators that at their core are solar energy production and storage *appliances*; simple to use and perfect for on-site, small scale industrial power production. Fundamental to a regenerator’s design is the concept of modularity and flexibility; they integrate off-the-shelf components modularly, including solar panels, inverters, charge controllers, and batteries. Additional modules can be added with ease to support wind turbines, fuel cells, even traditional generators. Custom modules can be designed that allow consumers to incorporate non-power components, such as communications, video equipment, and sensing & monitoring devices. Taken together, regenerators offer users a plug-and-play system in a wide range of configurations.

Because regenerators make primary power using renewable energy, the heat, noise and emissions signatures characteristic of fossil fuel generators are significantly reduced, making the products an important alternative for customers in varied markets including healthcare, security, tourism, the military and many others.

Regenerators sit at the junction of two worlds: Portable fossil fuel generators and renewable energy installations. But regenerators offer great advantages over both of these traditional technology types, each of which have inherent limitations.

### Regenerator Characteristics

We interact with the systems around us through products. An evolving combination of motor-drive-train-chassis-body became the modern car, and the combination of compressor-condenser-insulation-containers became the modern refrigerator. Likewise the wide-scale adoption of renewable energy will not be in the form of ‘hybrid-solar-energy-conversion-storage’; it will be in the form of regenerators. As portable renewable energy appliances,

Top: ZeroBase regenerator and wind turbine in theater (image courtesy of DoD)

Bottom: ZeroBase H-Series in-theater package with camo wrap and camo panels





regenerators remove much of the uncertainty associated with renewable energy and make distributed generation easy to understand, easy to purchase, and easy to install and operate.

A regenerator is characterized by five key attributes:

**Portable:** a regenerator is a self-contained, stand-alone device. It can produce and deliver power on its own or contribute to a grid or micro-grid. It can be easily moved from place to place, typically by light vehicle or trailer. It does not need expensive infrastructure modifications or repair to deploy, such as poured foundations or supporting structures. Just drop it off, set it up, and start producing power.

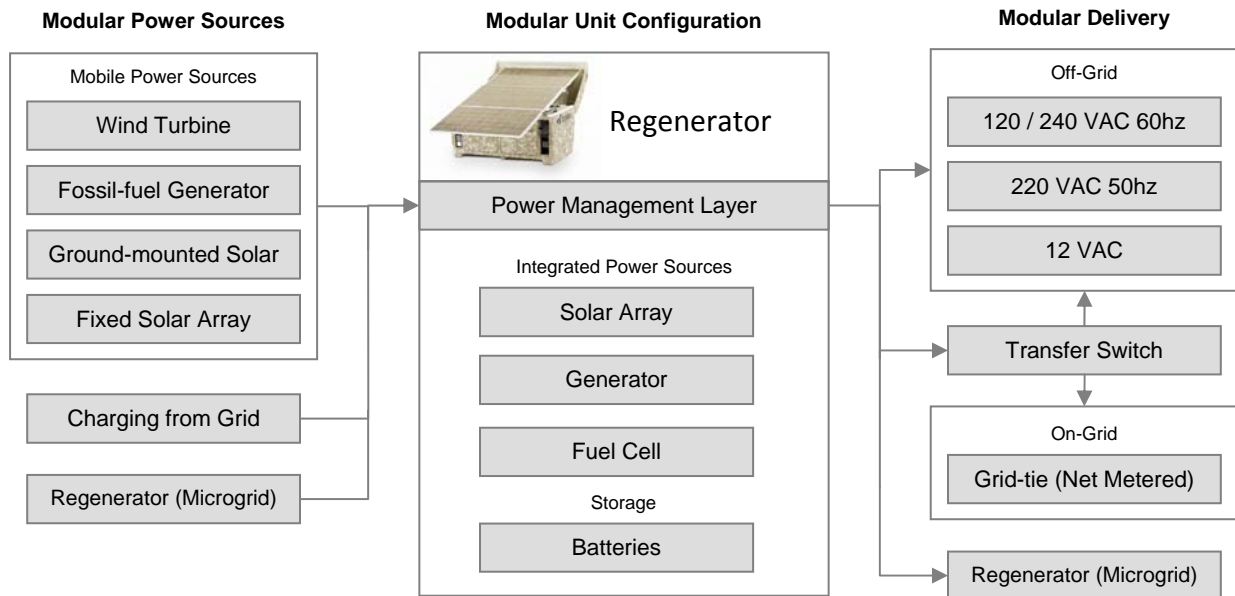
**Hybrid:** A regenerator manages delivery and storage of power from multiple resources. The power that flows through the system is stored in batteries and delivered on demand. Management systems are easy to use.

**Power Generation:** A regenerator generates power from renewable sources such as sun and wind, or from traditional fossil sources and the grid. The renewable sources can be integral to the product, mobile accessories, or fixed assets that are made operational off the grid, or ‘islanded’, by plugging them into a regenerator.

**Storage:** All the power generated by assets managed by a regenerator is stored or put to use. A regenerator can store power in a variety of batteries types, and a regenerator can manage the battery level to keep critical loads operational.

**Appliance:** A regenerator is simple to purchase, operate, and maintain. As a non-fossil-fuel-burning mobile device it is not subject to building codes. It requires no more knowledge of power technology to operate than a refrigerator requires knowledge of condenser technology. The regenerator does not need the frequent oil changes and coolant level checks that plague fossil-fuel generators.

### 1.1 Regenerator Operating Environment





## The Regenerator's Value to Energy Security

The British army calculates that it takes seven gallons of fuel to deliver one gallon to a location in Afghanistan. In the current deployments in Iraq and Afghanistan, 40% of the fuel consumed is used to run electric generators<sup>6</sup>. With the fuel supply lines to forward operating bases are under constant threat, every gallon of fuel saved means fewer convoys and airdrops to keep critical equipment in operation. Observers believe that saved fuel equals saved lives.

Additionally, the cost of warfare in remote locations is increasingly driven by the cost of fuel. In October, 2009 Marine Commandant General James Conway stated that the "average" price U.S. forces are truly paying --fully burdened--for operational fuel in the Afghan theater is \$400 per gallon. Some estimate that fuel at forward operating locations can cost \$1000 per gallon or more<sup>7</sup>.

Regenerators address several key Energy Security objectives:

- A regenerator reduces fossil fuel consumption by generating power from renewable sources and by reducing consumption by fossil-fuel generators.
- A regenerator contributes to energy surety (access to supply) by decentralizing power generation.
- A regenerator contributes to addressing Federal Mandates in the Federal Policy Act, Energy Independence Act, and Executive Directives to increase the use of renewable energy and reduce adverse effects on the environment.
- By reducing the fuel consumed by stationary generators, more fuel is conserved for tactical applications.

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<sup>6</sup> "Greenery on the March", The Economist December 10 2009

<sup>7</sup> "\$400 per gallon gas to drive debate over cost of war in Afghanistan", The Hill December 19, 2009



## Using Regenerators to Reduce Generator Operating Costs

### Fuel Conservation Factors

When managed by a regenerator the operating cost of a conventional fossil-fuel generator can be reduced by up to 80%. The regenerator achieves these savings by making four large gains: producing power from renewables, increasing generator efficiency, reducing generator running time and reducing generator size.

#### 1. Regenerators produce power from renewable sources

Regenerators offset more expensive fossil-fuel power generation by direct generation from renewable sources such as solar energy and wind power. The renewable assets may be integral to the regenerator, such as solar panels, or portable alongside the regenerator, such as a small wind turbine or light ground-mounted solar array. Renewable power generation offsets fossil-fuel consumption and where the complete power demand can be met with renewables, the fossil-fuel generator can be eliminated. A single ZeroBase regenerator can manage up to 10kW of renewable power generation assets.

#### 2. Regenerators increase generator operating efficiency

At a benchmark USMC location only 30% of the generator capacity deployed into the field was being used for power generation<sup>8</sup>. This is not because they are simply underutilized; generators are typically sized to support the maximum power requirement and run at rated capacity or only when equipment that uses AC motors - such as compressors or cooling units - are turned on. The remainder of the time the generator runs at idle speed or at a reduced capacity.

A typical diesel or JP8 generator operates most efficiently when producing power at 80-90% of prime-rated load. A generator idling or running at 20% capacity can use half the fuel required to run at full capacity. If the generator is frequently cycling between different speeds or turning on and off it consumes even more fuel than if producing power running at a steady rate.

A fossil-fuel generator being managed by a regenerator is always run at peak fuel efficiency. The regenerator automatically turns on the fossil fuel generator when the batteries need recharging or when power demand is high. By only running the generator at peak efficiency and storing any power not immediately put to use the regenerator maximizes the power produced for every gallon of fuel.

#### 3. Regenerators reduce generator running time

Commercial generators require frequent maintenance, including oil changes and coolant checks, with most manufacturers recommending maintenance every 100 hours. The regenerator extends the frequency of maintenance by significantly reducing running time.

A fossil-fuel generator needs to run or idle as long as power demands are present. The regenerator supplies power stored in its batteries, and automatically starts the generator only when the batteries need charging or when power demand is high. The remainder of the time the generator is offline.

In our benchmark USMC location where only 30% of the generator's capacity is used, the generator would normally run 24 hours a day producing 30% of its rated power. The regenerator will use direct generation to produce half the power from renewable sources and run the generator at full capacity for 3.5 hours to produce the rest. This 85% reduction in running time means less frequent maintenance costs and less frequent replacement costs.

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<sup>8</sup> USMC Experimental Forward Operating Base Executive IPT Meeting November 19, 2009



#### 4. Regenerators improve fuel efficiency by reducing the size of generator required

Generators are typically sized for their peak power requirement. A 5kW Tactical Quiet Generator would be used to support a steady load of less than 1.5 kW. Although 99% of the time only 1.5 kW is needed, a peak load of 5kW may be needed for a few minutes a day to support the starting load of an AC motor or compressor engaging. The generator is running most of its life at a low capacity where fuel consumption is inefficient and the generator life is reduced.

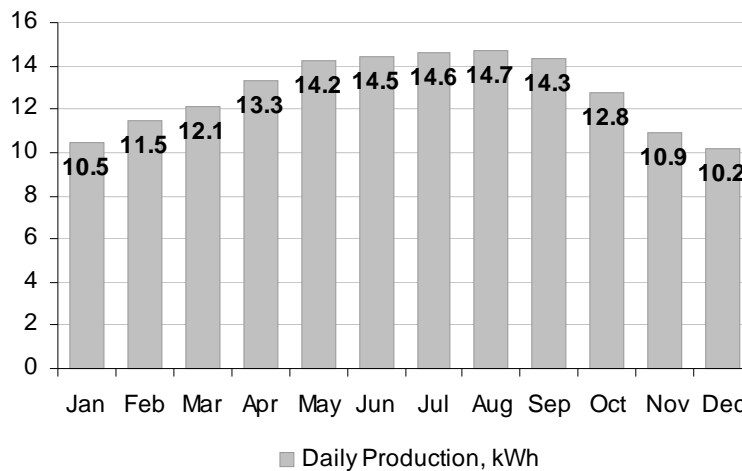
The regenerator supports a peak load above the generator’s rated power by drawing power from the batteries. A standard ZeroBase regenerator can support instant, continuous demand up to 6kW and a surge load of 9kW. The regenerator allows a smaller, more fuel efficient fossil-fuel generator to be used.

#### Example of Fuel Cost Savings

The following example shows the fuel savings using a regenerator with a 5 kW TQG (Tactical Quiet Generator burning diesel or JP8 fuel) at a location near Kandahar, Afghanistan. The generator is supporting a piece of telecom equipment which requires a steady supply of 1.5 kW, with an occasional millisecond-surge up to 6000 W. The generator is running for 99.9% of the time at 30% capacity, supplying 1.5 kW for twenty-four hours a day. The daily power output of this generator is 36 kWh, and it would normally consume 7.9 Gallons of fuel every day.

Like most renewable energy sources, the amount of power that a regenerator can produce is specific to the operating environment. The chart below shows how much power can be generated daily by a ZeroBase Z-series regenerator with 1.76 kW of internal solar panels and a mobile 350 W wind turbine under the environmental conditions in Kandahar, Afghanistan<sup>9</sup>:

**1.2 ZeroBase ‘Z-Series’ daily production from renewables, Kandahar Afghanistan**



The graph illustrates the seasonal effect of reduced sunlight in the winter months. To balance the reduced solar production, a lightweight mobile wind turbine is added. On average, one-third of the 1.5 kW continuous power requirement can be met using a combination of solar and wind production

<sup>9</sup> ZeroBase model using environmental data sourced from the National Renewable Energy Laboratory (NREL) seasonal latitude-tilt insolation maps, PVWATTS-1 model, and NOAA operational climatic data.



The chart below shows a comparison between the fuel used by the 5 kW TQG alone and the same generator managed by a ZeroBase Z-Series regenerator with 1.76 kW of integrated solar and a 350 W wind turbine.

**1.3 Fuel conservation supplying 1.5 kW (steady-state)**

Equipment	5 kW TQG	5 kW TQG + Z-Series regenerator	Savings
Running Time, Average	24.0 hr	4.9 hr	<b>19.1</b> hr
Fuel Consumed, Daily	7.9 Gal/day	2.8 Gal/day	<b>5.1</b> Gal/day
Fuel Consumed, Annually	2896 Gal	1027 Gal	<b>1246</b> Gal

The amount of fuel consumed is reduced 65% by using power generated from renewable resources and running the fossil-fuel generator as a hybrid system. The generator runs less than 5 hours instead of 24 hours per day to augment the distributed generation capability of the regenerator.

**1.4 Annual value of fuel conservation**

Equipment	5 kW TQG	5 kW TQG + Z-Series regenerator	Savings
Fuel Consumed, Daily	7.9 Gal/day	2.8 Gal/day	<b>5.1</b> Gal/day

Fully-burdened fuel price	Annual Cost	Annual Cost	Annual Savings
<b>\$10 / Gallon</b>	\$28,961	\$10,273	<b>\$18,688</b>
<b>\$50 / Gallon</b>	\$144,803	\$51,363	<b>\$93,440</b>
<b>\$100 / Gallon</b>	\$289,606	\$102,726	<b>\$186,880</b>
<b>\$400 / Gallon</b>	\$1,158,422	\$410,902	<b>\$747,520</b>

The fuel cost savings calculations do not account for the additional cost savings associated with the reduced frequency of generator maintenance, extended life and runtime of the generator or the fuel savings associated with reducing the size of the generator required.

Critical equipment, such as that used for communication and sensing, requires a steady uninterrupted 24-hour supply of power. The example above is for this type of steady-state application. Generators running variable loads, such as those supporting a work-site or encampment, burn even more fuel as they cycle between idling and running at high speeds. The additional cost savings using a regenerator to meet variable power demands can be up to 55% higher than those in the example above.



## Using Regenerators to Provide Power Surety

### Distributed Power Reserve

Planning for unfavorable weather is a requirement when relying on renewable sources for power. Solar production drops on cloudy days, and wind generation requires steady wind. The data collected on environmental conditions in a specific location allows us to calculate the average power generation, but for any given stretch of time the actual weather is rarely average. For this reason regenerators are fitted with a battery bank capable of sustaining power for days or weeks at a time. In tactical applications, a ZeroBase configures regenerators to provide 2.5 days of power using both stored power and distributed generation.

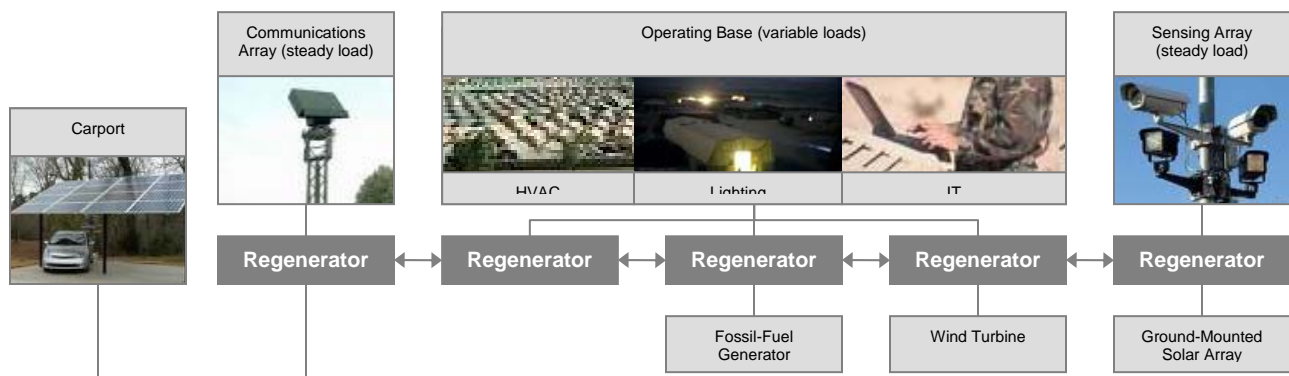
One of the core characteristics of U.S. Army Energy Security is Power Surety: preventing loss of access to power and fuel sources. There is a tactical advantage to having ready access to an ample supply of stored power. When the regenerator is used to hybridize a fossil-fuel generator, the power reserve protects against fuel supply interruptions or the generator requiring service. If the deployment is in a remote location, the power reserve can provide enough running time for a replacement generator to arrive.

If the regenerator is used in conjunction with a grid or micro-grid, the batteries will remain fully charged at all times. If the grid goes down, the power stored in each regenerator can be quickly deployed to run critical communications, medical, or infrastructure assets. The regenerator’s portability allows the stored power to be deployed where needed in the absence of the grid.

### Regenerator Microgrids

When large and variable power production is needed it is inefficient to have a single power source connected to a single load. All the power generation and storage assets should be available to be deployed as needed on demand. To harness the power of a number of regenerators, the units can be connected together to form a microgrid. On the power generation and storage side, a microgrid of renewables allows the power to be stored wherever there is excess battery capacity. On the power supply side, the microgrid allows the power of multiple units to be put to use wherever it is needed.

The microgrid is managed by slaving all units to one master control. This allows more precise management of all available assets, including the ability to keep a certain level of power in reserve for critical operations. An individual regenerator can be pulled off of the microgrid and be deployed elsewhere, including the master unit. Another core characteristic of U.S. Army Energy Policy is Survivability...ensuring resilience in energy systems. One tactical advantage of a regenerator microgrid is that disabling any single unit will not disrupt all power supply. The individual units will continue to provide power if the microgrid connection is lost. In the event that the master control unit is disabled, any other regenerator can become the new master unit. ZeroBase regenerators used in critical applications are fitted with redundant power control systems offering a second level of power security.





## Islanding Renewable Assets

Grid-tied renewable power assets have a critical weakness: When the grid goes down, the power generated has no means of distribution. The power systems of most renewable energy installations are designed only to feed power back to the grid. With a regenerator, however, when the grid goes down, a single regenerator can 'island' between 3kW and 10kW of power generation assets. If the renewable assets are tied to a building, the regenerator can be used to feed power to circuits that run critical loads. The regenerator is installed and functions in much the same way as a standby generator. If the renewable assets are not tied to a building, their power can be tapped by plugging directly into the regenerator. When the grid goes down the regenerators can be charged by a large solar array or wind turbine and then loaded on a truck or trailer so that the power can be used elsewhere.

## Using Regenerators for Silent Power Generation

### Reducing Generator Operating Time

Although the newest generation of quiet fossil-fuel generators are an improvement, at 70-90db they are still as loud as freeway traffic. OSHA permits only 8 hours daily exposure to a 90db sound level. Since a fossil-fuel generator needs to run or idle as long as power demands are present, the need for power comes at the cost of drowning out the environment. A regenerator operates silently by supplying power stored in its batteries, and automatically starts a generator only when the batteries need charging or when power demand is high. This can reduce a generator's running time by up to 85%.

### In-theater Deployment

In addition to reducing the number of hours fossil-fuel power generation is needed, a regenerator can be used to control when the conventional generators are run. ZeroBase regenerators in tactical deployments are fitted with sufficient power storage to run through the night on battery power alone. A regenerator can be set to fully charge its batteries from a fossil-fuel generator during daylight hours, eliminating the need to run the generator at night.

## ZeroBase Regenerator Products

### ZeroBase, LLC Company Overview

ZeroBase™ regenerator products are manufactured by ZeroBase Energy, LLC, a Pegasus Capital Advisors portfolio company. ZeroBase Energy is an American manufacturer of renewable energy products that deliver clean energy on site at the point-of-use.

ZeroBase began at Lyman Morse Technologies, the research and development arm of family-owned Lyman Morse Boatbuilding in Thomaston, Maine. Lyman Morse has built custom yachts for over a century, and today brings together old-world craftsmanship with state-of-the art technologies including: electronics, composite materials, complex engineering and marine-grade construction. Lyman Morse has over two decades of experience in developing renewable energy solutions and deploying them to the harshest marine environments.

Company founders created an energy device that combines the advantages of proven renewable energy components and composite construction in one easy-to-use product that's powered solely by the natural resources around us. The ZeroBase is a mobile, modular, multi-application renewable energy generation and management unit that can deliver electricity without or in conjunction with fossil fuel generators.



## ZeroBase Company Timeline

AUG 2006	PowerCube Energy formed by Reluminati, LLC at Lyman Morse Boatbuilding
AUG 2007	Intellectual Property filed
OCT 2007	First functional prototype – 600 W unit
JAN 2008	First functional prototype – 1200 W unit
MAR 2008	First commercial unit sold and operated
NOV 2008	First production unit sold to U.S. Department of Defense
AUG 2009	PowerCube purchased by Pegasus Capital Advisors, renamed ZeroBase Energy
OCT 2009	New power system that includes generator synchronization
NOV 2009	Catalog expanded to include mobility and remote monitoring products

## ZeroBase Regenerators

While there are many mobile power generation and storage products on the market, ZeroBase regenerators offer significant advantages:

**Environmentally Sealed Housing:** ZeroBase’s sealed composite housing is constructed like a boat’s hull, to withstand wind, rain, sand, corrosion and rising water. The power electronics are protected from the environment and the sealed AGM batteries require no venting. The integral solar panels fold up in minutes to protect against high wind or storms.

**Portability:** Each ZeroBase is a self-contained unit weighing between 1,800 and 3,200 lbs, depending on the model and the configuration. They are designed to be moved using a pallet jack or forklift and fit standard DOT and military specification trailers. Every ZeroBase product contains everything needed to set up and run. Minutes after the unit is delivered the solar panels are in place and generating power.

**Plug-and-play:** The power system in a ZeroBase is designed to be easily upgraded in the field. Every unit is pre-wired for additional solar panels, generator support, and grid connection. Power generation such as a wind turbine can be added by swapping out the appropriate board, and additional storage can be added at any time.

**Power Security:** For tactical applications each unit is equipped with two inverter / power management systems. As well as enabling each unit to be configured for 120V or 240V output, the redundant components provide each unit with a backup power delivery component should the primary fail.

**Remote Monitoring:** ZeroBase products can be equipped with a GPRS / GSM mobile phone or satellite phone to monitor power generation and use. Each unit’s performance can be tracked on a secure website and the unit can be powered on and off remotely.

**Proven Technology:** ZeroBase was developed by Lyman Morse Technologies, the research and development arm of family-owned Lyman Morse Boatbuilding in Thomaston, Maine. Lyman Morse has over thirty years experience in designing, outfitting, and servicing renewable power systems in marine craft. ZeroBase’s design and component selection benefits from Lyman Morse’s experience with a wide range of technologies and suppliers. Every ZeroBase product is engineered to rugged marine standards.

**Technology Services:** ZeroBase works with customers to understand their requirements and correctly size and configure a regenerator and other renewable energy products for application.

More information about ZeroBase regenerator products including complete product specifications can be found on at [www.thezerobase.com](http://www.thezerobase.com).



## Applications

**Off-Grid Residential:** The ZeroBase regenerator is perfectly sized to provide primary power for small to mid-size residences where power for lighting, water and small appliances is needed.

**Off-Grid Commercial:** Unlike fixed renewable systems, portable ZeroBase regenerators can be leased independent of the building they support. The system size can be scaled up from reserve power to provide for continuous power requirements

**Hybrid, Off-Grid Military:** When used to manage fossil-fuel generators, the ZeroBase regenerator reduces fossil-fuel consumption up to 65% and reduces generator running time by up to 85%.

**On/Off Grid Disaster Recovery:** During normal use, a ZeroBase regenerator can reduce power costs and provide emergency backup. When a disaster strikes, the units can be deployed where needed with charged banks of batteries ready to deliver power. Unlike fossil-fuel generators, ZeroBase regenerator do not need a continuous supply of fuel to generate and deliver power.

**On-grid Commercial and Residential:** In regions where grid power is unstable a ZeroBase regenerator provides battery backup that never needs refueling. Unlike fossil-fuel generators, a ZeroBase reduces energy costs year-round.

**Mobile Media Platform:** The ZeroBase regenerator is a highly-visible way of powering equipment at events using renewables. Units can be wrapped with graphics, power information kiosks and vending machines, or equipped with outlets to charge mobile phones and cameras.

**Electric Vehicle Charging:** In combination with a solar carport, the ZeroBase regenerator stores enough power to charge an electric vehicle. Additionally, power not used for vehicle charging can be fed back into the grid to reduce energy costs.

**Telecommunications:** The ZeroBase regenerator provides mobile emergency power and energy cost reduction for critical telecom equipment.

## Contact

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