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ENG Z GEN
Engine/Generator

Why You Should Be Excited About the Russell Engine/Generators

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A White Paper on: The Environmental, and Economic Benefits associated with the Engine/Generator Technologies for Current and Future Generations

The Problem

Electricity is the cleanest and most efficient form of energy humanity has ever known. Unfortunately, many of the methods used for producing electricity are inefficient, wasteful and even harmful to the environment. These methods drive up the cost of electricity, waste our natural resources, and do not address the environmental concerns of current or future generations.

Although we consider electricity essential to our modern way of life, approximately 16% of the current world's population (1.2 billion people) have little or no access to electricity (The Rockefeller Foundation, 2017). Growing demands for expanded electrical service worldwide, brings with it, ever-increasing environmental concerns.

We must develop new methods of producing electrical energy. Solar panels and windmills are cleaner methods, but they cannot provide all the energy that a modern, thriving society requires.

Also, for underdeveloped communities the infrastructure cost of solar and/or wind energy is far beyond their means. What is needed are smaller, expandable distributed-power-generation systems that are affordable, and capable of growing with society's needs. These systems must be highly efficient (requiring less fuel), environmentally friendly, dependable and readily available. Systems with these attributes, do not exist at this time.

These questions, and the problems they represent must be addressed:

- Can we conserve more fuel, for our current and future generations without reducing the amount of electricity that we use now?
- Is there anything we can do that will help protect our environment from the harmful atmospheric effects caused by;
    1. CO2 emissions
    2. NOx emissions
    3. and Heat emissions?
- Are there cleaner, and less expensive fuels that can be used for producing electricity?

The answer to all the above questions is yes, with development of new and better technologies.

Background

Before we talk about what we can do to fix our energy problems, we must understand that these problems have been developing for a very long time. Scientists and engineers have been very effective over the years in developing products and technologies that make our lives safer, simpler and more productive.

In 1879, Thomas Edison filed for a U.S. patent on an electric lamp using a carbon filament. Since then, his invention has been refined and improved, and the incandescent bulb is still widely used throughout the world today. Clearly, this invention was, and still is extremely effective for producing light. Although effective, today's incandescent light bulb is not efficient.

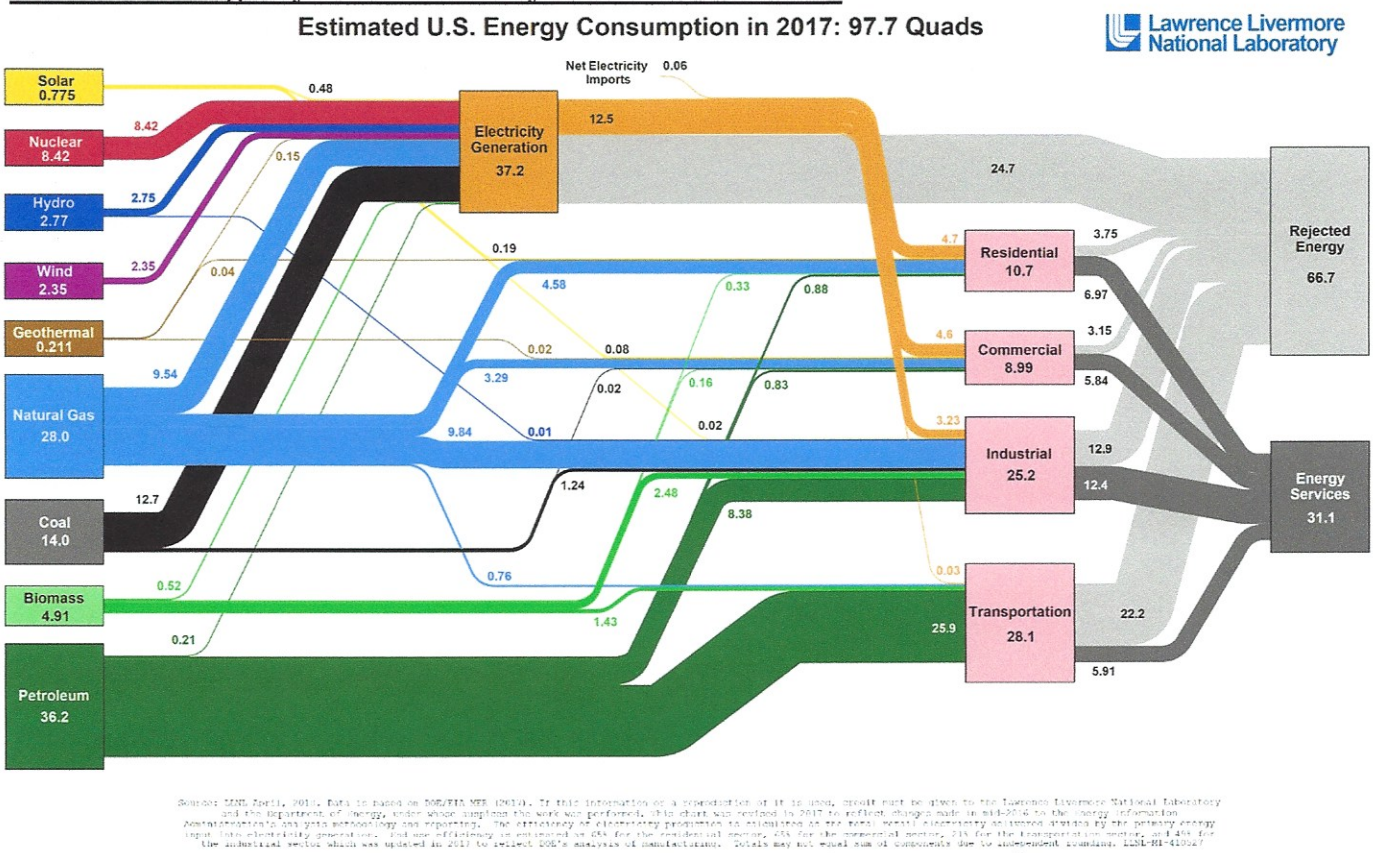
Efficiency is the ability to avoid wasting energy while producing a desired result. A typical 120 Volt incandescent bulb produces only 16 lumens (lm) of visible-light per-watt, compared to 60 lm/watt for a compact fluorescent bulb or 150 lm/watt for some white LED lamps. The white LED lamps are 89.3% more efficient than incandescent bulbs. Why? Because incandescent bulbs do not just produce light, they also produce unnecessary and unwanted waste heat.

Replacing all incandescent lightbulbs with highly efficient white LED lamps would:

- conserve our natural energy resources (i.e. natural gas, oil, coal, etc.),
- reduce atmospheric CO2, NOx and heat emissions, and
- reduce the size of your electric bill.

However, addressing the efficiency of incandescent lighting is not a fix for our long-term energy problems, it is only a minuscule part of a much larger issue. As evidenced in the graph (below), it can be seen that the greatest issue for future generations is the enormous amount of energy in the form of **unused heat energy** (Rejected Energy) that is wasted. Most of this unused heat energy ultimately ends up in our atmosphere.

Global Warming may not be caused by CO2 emissions alone.



Thanks to the Lawrence Livermore National Laboratory and the U.S. Department of Energy
https://www.visualcapitalist.com/visualizing-u-s-energy-consumption-one-chart/

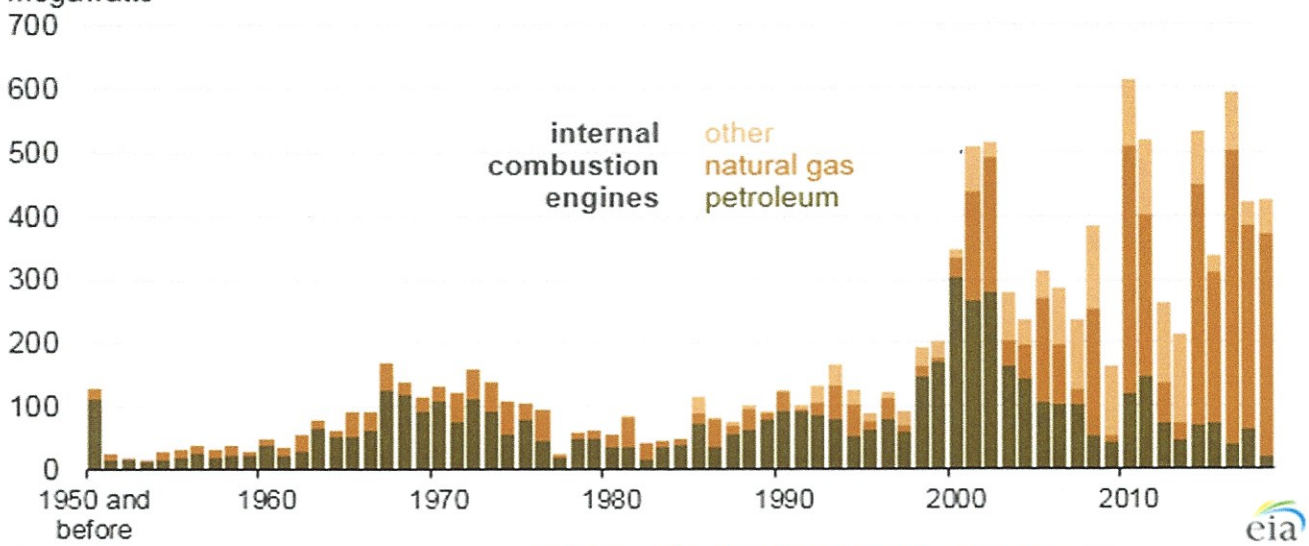
We can see from the graph above that in 2017, the U.S. consumed **97.7 Quads** of energy. One quad is a quadrillion BTUs of heat energy, or the same amount of heat that can be produced by 8 billion,7 million (8,007,000,000) (U.S.) gallons of gasoline.

The most glaring issue shown in the above graph is the enormous amount (66.7 quads) of Rejected Energy (shown in gray, right side), that is wasted. That means a whopping **68%** of all energy is actually rejected energy, or energy that gets wasted through various inefficiencies, leaving only 31.1 quads, or **32%** of the total energy consumed to do productive work (Energy Services).

On the left side of the graph is a list of our sources of energy. In 2017, solar provided 0.775 of a quad, while wind provided 2.35 quads (0.775+2.35= 3.125 quads). Their combined total of 3.125 quads represents only **3.19%** of the total energy used in 2017. Although wind and solar are cleaner sources of energy, they both have problems. As we all know, the sun doesn't always shine, and the wind doesn't always blow. As a result, higher polluting reciprocating internal combustion engines, typically used for backup, standby, or emergency power, are now becoming increasingly popular for larger utility-scale power generation applications with high levels of electricity generation from intermittent sources such as wind and solar. Does this mean we justify high polluting electrical-generation techniques, just to use wind and solar?

Natural gas-fired reciprocating engines are being deployed more to balance renewables

Annual utility-scale additions of selected electricity generators (through November 2018)



Source: U.S. Energy Information Administration, *Preliminary Monthly Electric Generator Inventory*, January 2019
Note: Other includes landfill gas, biomass, and other gas.

It is clearly shown in the above graph that the use of internal combustion engines, especially those fueled by natural gas and renewables, have seen a dramatic rise in deployment since the year 2000. One of the main advantages of reciprocating engines is their ability to provide incremental electricity quickly. Because these units can start and stop quickly and operate at partial loads, they have become increasingly important in applications with high shares of renewable electricity generation from wind and solar.

Power plants with large reciprocating engines are often located in states with significant renewable energy generation, specifically wind generation. Texas, which has the most wind electricity generation capacity in the country, has 910 MW (megawatts) of natural gas-driven reciprocating engines, or 20% of the national total (4,642 MW). Kansas and California also have large amounts of renewable generation, and the next highest capacities of reciprocating engines.

As both wind and solar generation increases, the need for flexible, highly responsive, and dependable backup-support systems will continue to grow also.

The above graphs show, what most of us already know. We use an enormous amount of energy. What most of us don't know, is just **how much energy we waste**. We believe that someday technology will resolve these problems. Yet we still use the Otto cycle engine (designed in 1876), to power our cars. After 143 years of development, the engine in your car is still only 18 to 20% efficient. Why do we still use it? Of every dollar you spend on fuel $0.80 is wasted, with the majority of it escaping into the atmosphere as unused heat energy. However, all (100%) of the fuel used in the combustion process produced pollutants, which include CO2, NOx and an enormous amount of heat emissions.

See graph, "Energy Consumption in 2017". Of all the 28.1 quads of fuel energy used in the entire **Transportation** sector (planes, trains, buses, trucks, and cars, etc.), 22.2 quads, or **79%** of it was Rejected Energy, with the majority of that energy escaping into the atmosphere as wasted heat.

In **Electricity Generation**, we can see that 37.2 quads of energy were used in 2017. If we subtract the Solar, Hydro, Wind, and Geothermal sources of electricity generation (totaling 6.10 quads), (because they do not use man-made heat energy), we are left with 31.1 quads of electricity generation that is provided as a result of man-made heat producing techniques. When we divide the 24.7 quads of Rejected Energy attributed to Electricity Generation, by the remaining 31.1 quads of man-made heat energy provided for electricity generation we again end up with **79.4% waste**.

Addressing conservation and the preservation of our atmosphere, where are the technological improvements? What about plans for our future energy needs? Solar and wind are only a small part of the answer. If we tripled the amount of solar and wind energy produced in 2017, it would still only represent **9.57%** of our total annual energy needs. We need a big change, and we need it now!
We must have some hope for a long and lasting clean-energy future.

The Solution

Technology is the solution and our hope for the future.

When Bob Russell started development of his new engine, he didn't know how inefficient conventional internal-combustion engines really were. His primary concerns were, "what can we do to make an engine more powerful, efficient and cleaner? It must use less fuel, by using the fuel it consumes more completely and productively".

Throughout several major design changes, it became clear what the new engine could and could not do. It could maximize the efficiency of any liquid or gaseous fuels, although the efficiency will not be the same for all fuels. It could produce incredibly high rotational forces from a very small package (this is called power density, and the new engine has a lot of it). It does not have a broad speed range. The optimal use for this new engine is to take advantage of the fixed-speed engine design by combining it with an electric-generator to make the first single-purpose, one-piece, integrated **Engine/Generator** unit. The **Russell Engine/Generator**.

Because large electric motors and generators are typically 94 to 98% efficient, the integration of a highly efficient engine with a highly efficient generator is the perfect match. Bob Russell has applied for and received multiple U.S. and foreign patents for the Engine/Generator technology. "How can we make this Engine/Generator run cleaner, while reducing heat emissions? If we can control heat emissions, can't we control combustion temperatures also? If we can control combustion temperatures, maybe we can reduce or even eliminate NOx emissions." This is the line of thinking that has, after years of development, brought us to where we are today.

The Russell **Eng/Gen + Boost** is the most efficient, and environmentally friendly design of the Russell Energy Corporation. This patent-pending design is the first, one-piece, **combined-cycle**, Engine/Generator unit ever. So, what is a combined-cycle unit, and why is it better?

The combined-cycle process typically used by large utility-scale power plants today, uses natural-gas fueled jet engines to turn generators and produce electricity. Exhaust heat from these jet engines is captured and used to produce steam, which is supplied to a separate steam turbine, attached to a separate generator that also produces electricity. Combining the electrical output from both of the different generating technologies together (natural gas and steam) increases the operating efficiency of this type of powerplant. On the plus side, because of its efficiency, it reduces the amount of fuel typically consumed per kilowatt produced (compared to non combined-cycle processes). On the negative side, these generating facilities are very large, very expensive, and the jet engines produce a variety of pollutants, including NOx emissions.

Why is the **Eng/Gen + Boost** better? One of the most exciting features of the Engine/Generator technologies is their ability to optimize every facet of the combustion event, and the subsequent power conversion process for maximum efficiency. In the Eng/Gen + Boost we exploit these advantages to control and limit combustion temperatures, while we produce additional steam-pressure within the cylinders to increase efficiency by converting more of the combustion heat energy to do usable work.
The results of these efforts are:

- reduced fuel consumption,
- increased output power,
- the reduction or elimination of NOx emissions,
- the reduction or elimination (with CHP), of external cooling system requirements,
- and the reduction of exhaust gas temperatures into the atmosphere.

The Eng/Gen + Boost is designed to use gaseous fuels such as natural gas, renewable methane, propane, hydrogen, etc., CO2 emissions with these fuels will be minimal. When using renewable methane and hydrogen, CO2 emissions will be rated at 0.

The Eng/Gen + Boost technology is designed to be dependable, durable, and affordable, to purchase, operate, and maintain. It offers an easily expandable, modular, plug-and-play system that is ideally suited to support future growth, while providing consistent electrical service in all stationary applications. Distributed generation will allow the production of clean, affordable, electric energy everywhere, including in third-world countries where conventional transmission technologies are impractical, or unaffordable.

As mentioned before, solar and wind have a long way to go before they can provide for the needs of our country. If that day ever comes, we will still need clean, affordable backup generation systems to ensure a smooth, consistent flow of electricity when using these variable-output generation devices. The Engine/Generator technologies are ideally suited for this application.

The current global genset (an engine connected to a separate generator) market is about $20 billion annually. By 2026, the global market is expected to expand to over $100 billion per-year (2017; Global Market Insights, Inc). In light of all the positive features and predictions: highly efficient, less polluting, cooler emissions, extremely power dense, smaller, lighter, quieter, fewer parts, lower initial cost, lower operational costs, long life, plug-and-play convenience in smaller and lighter modular mounting racks, etc., it is conceivable that once proven, the family of **Russell Engine/Generator** designs could command a large portion of the current and future genset market.

Because of their great size and weight, traditional power-generation technologies (an engine connected to a separate generator) are unsuitable for all but the largest onboard transportation applications (i.e. ships and trains). The **Eng/Gen + Boost** is designed to be the smallest, lightest and most power dense, one-piece, electric power-generation system ever. It is therefore, ideally suited for virtually all transportation applications as well (i.e. electric cars, buses, trucks, aircraft, etc.). It has been estimated that the **Engine/Generator** technologies will produce efficiencies between >45% and 60%, depending on the fuel being used. With the knowledge that the engine in your car is only 18 to 20% efficient today, the **Engine/Generator** technologies represent an impressive, earth friendly improvement. This market segment alone (transportation), could bring on a paradigm shift in the way we do things today.

The **Engine/Generator** family of designs is the technology of the future. It is ideally suited for all stationary or portable power-generation applications. Future developments and improvements are anticipated to provide the Russell Energy Corporation (REC) with increased patent protection and long-term growth.

REC is looking for interested parties, whether they be, investors, manufacturing businesses, energy users, or people who just want to live on and leave our planet in the most responsible and environmentally friendly manner possible. People who recognize the value, and opportunities offered by the worldwide development of disruptive technologies such as the **Engine/Generator** family of designs, and want to be part of that development, and all the good it will do. REC is currently considering funding options for the development, building, and testing of the prototype engine to be used in the first series of **Eng/Gen + Boost**, field test units.

If you want to make a positive difference in the health of our planet, and the future for our children, send us a note at: comments@russellenergy.com . Get on our mailing list and stay informed about our progress. Tell your friends, and ask them to tell their friends. If you are an investor, or if you represent a business interested in manufacturing or licensing rights, we would love to hear from you. REC is open to strategic alliances, particularly in power conditioning, and electronic control.

We look forward to hearing from you,
Russell Energy Corporation