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Turbine Efficiency Improvements for Existing Power Plants

"How Technology Can Revolutionize Efficiency"

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Testimony before the Select Committee on Energy Independence and Global Warming
US House of Representatives

February 25, 2009

Summary:

- Natural gas-fired turbines currently account for over 40% of the US electrical generation capacity. Existing turbines can be made more efficient by the incorporation of known and new technologies. Increasing turbine efficiency benefits consumers by reducing the amount of CO2 emissions, by reducing the fuel required to generate the same amount of electricity, and by providing additional capacity beyond that caused by the efficiency improvement.

- FTT has invented technologies that can be retrofit into natural gas-fired turbine power plants worldwide to create up to 15% more power from the same plants. Much of that power is completely carbon-free and requires no additional fuel. Application of this technology to existing US gas turbine power plants can generate an additional 9GW of power replacing the equivalent of 13 coal plants.

- The incorporation of Spar-Shell Blade into gas turbine plants account for two-thirds of the 15% total capacity improvement and will help put our nation at the forefront of a technology that will have world-wide implications. Efficiency improvements such as these can have a world-wide impact in CO2 emissions and fuel usage and so should be included in our nation's renewable energy policy and plans.

Testimony:

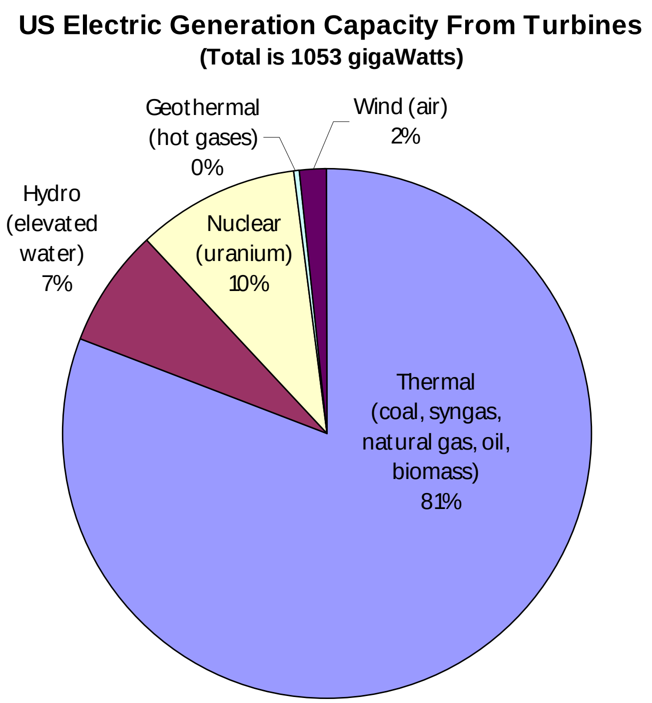
Mr. Chairman and Members of the Committee, thank you for this opportunity to address you today. I am Shirley Brostmeyer, Chief Executive Officer of Florida Turbine Technologies—a 185 person small business in Jupiter, Florida, specializing in turbine design and manufacturing. My company develops next-generation turbomachinery for the Air Force, Army, NASA, Department of Energy, and as a second-source supplier to aircraft and industrial turbine manufacturers. Florida Turbine Technologies, or FTT as it is often called, employs many of the world's foremost experts in turbine technology.

While FTT has been in business for only ten years, we have already made major contributions to our nation's environment. The turbine efficiency improvements of my small company have helped to eliminate 30 million tons of CO_2 from the atmosphere every year[1]. This is the equivalent of eliminating eight coal plants from US soil. Such dramatic improvements are possible because almost all of our power today is generated from turbines. Even a small improvement to the efficiency of these machines results in a huge reduction in the amount of fuel burned and in CO_2 emissions. For that reason, turbine efficiency improvement technologies offer the most near-term and cost effective means for energy independence. In my testimony today, I'd like to share the importance of a technology that FTT is developing, called the "Spar-Shell Blade", and other technologies that will increase turbine efficiency. I would like to show why turbine technology should be an integral part of the discussion regarding "*How Technology Can Revolutionize Efficiency*".

Why is Turbine Efficiency So Important?

A turbine is a machine that extracts energy from the flow of a fluid. The fluid could be air (in the case of wind turbines), steam (as in coal –powered turbines and turbines in nuclear plants), water (as in hydraulic turbines), or combustion products (as in natural gas turbines or aerospace jet engines).

Turbines provide 97% of the current US electric power and are used in almost all power plants: gas-turbine combined-cycle, coal-powered steam plants, nuclear plants, hydroelectric plants, and even solar-thermal plants. The breakdown by type of turbine,[2] shown in Figure 1, reveals that over 80% of the US electric power generation capacity is from thermal turbines, in which at least one form of fuel (for example: coal, natural gas, oil, syngas or biomass) is burned to create the hot gas or working fluid which rotate the turbines. Natural gas-fired turbines make up 53% of all thermal turbines, which means that approximately 41% of all US electrical generation capacity is by natural-gas fired turbines.



Ref: Electric Power Annual 2007, Energy Information Administration, Dept of Energy, 2008.

Figure 1: US Electric Generation Capacity from Turbines

According to the DOE's Energy Information Administration[3], the net generation of electricity from all energy cor
This means that nearly two-thirds of all power generation is lost in the energy conversion process (see Figure 2). In other words, today's electrical generation is, on the whole,

[1] Based on replacement of coal-burning power plants.

[2] Electric Power Annual 2007, Energy Information Administration, US Dept of Energy, 2008, page 25.

[3] Annual Energy Review 2001, Energy Information Administration, US Dept of Energy, 2002, page 219.

only 34.5% efficient. Because conversion losses are so large, relatively small reductions in losses (or improvements in efficiency) can yield substantial increases in the energy output. In other words, for every one per cent improvement in efficiency, the available energy is increased by 2.5%. Since turbines make up nearly all of the world's electric generation capacity, incremental turbine efficiency improvements can have extremely large impacts on the bottom line of energy production and fuel consumption.

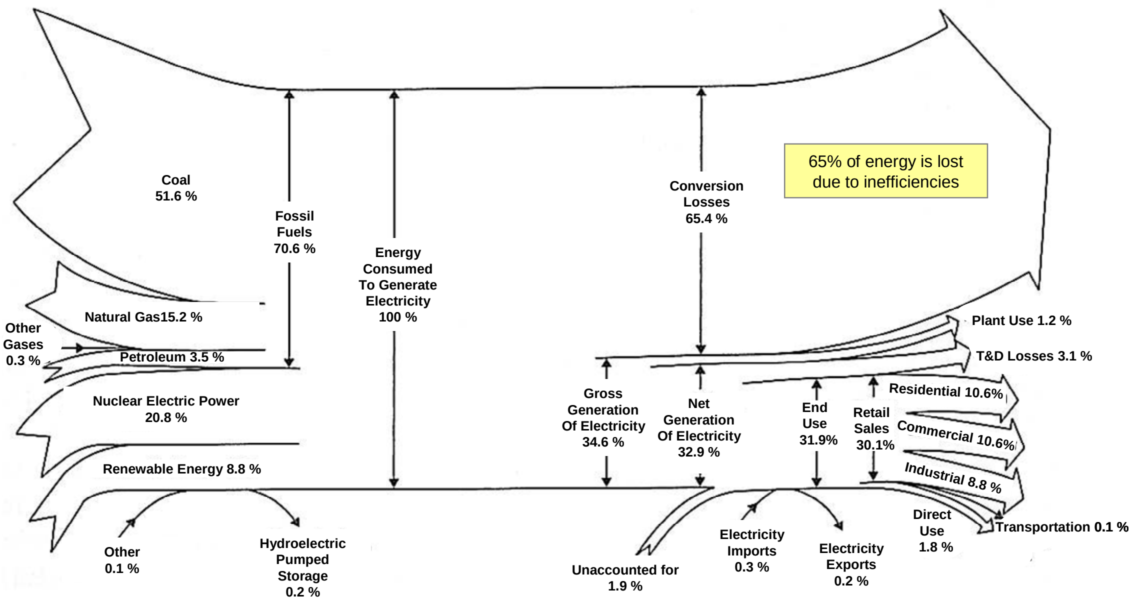


Figure 2: Conversion Losses Account for Two-Thirds of Energy Consumption (Ref: Annual Energy Review 2001, EIA, page 219, with percentage converted from absolute values by FTT).

The modern power-generating turbine has been undergoing efficiency improvements since its first production. Combined cycle plants, in which exhaust heat from a gas turbine is used to make steam to power a separate turbine also producing electricity, are the most efficient and have been in use since 1968. Many of today's operating power-generating turbines were designed based on technology that is 10 to 50 years old. The latest technologies would make them run cleaner and more efficiently. A typical large older gas turbine used in combined cycle applications produces 100 to 250 megawatts of power at 48-52% thermal efficiency; new combined-cycle power plants (designed within the last ten years) can see efficiencies as high as 59%.

The importance of turbine efficiency is rooted in the following points. When efficiency is increased:

1. Less fuel is required for the same amount of energy produced.

2. Less CO_2 emissions are generated for the same amount of energy produced because less fuel is used.

While combined cycle turbine plants are highly efficient, they are expensive to build and take many years from initial conception to completion. As our world energy requirements continue to increase at alarming rates, our society will need to keep older plants in use longer and longer in order to keep up with demand. For all of these reasons, the importance of near-term improvements to existing power plants can not be overemphasized.

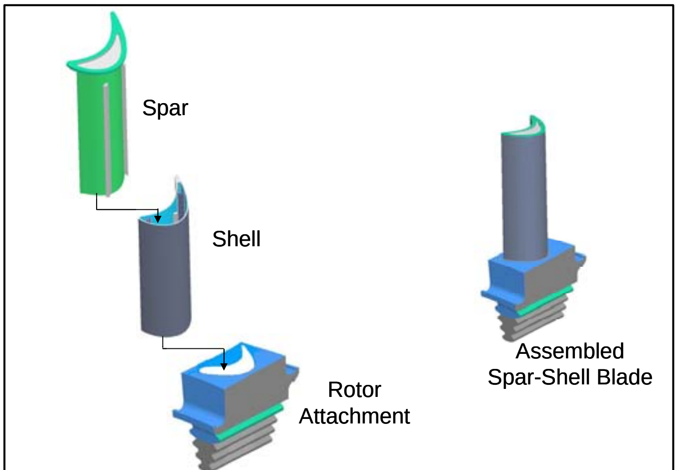
One very promising efficiency technology is called the "Spar-Shell Blade", currently being developed by FTT under a Small Business Innovative Research grant from the Department of Energy. The Spar-Shell Blade represents a promising leap in gas turbine technology that can be applied to over 60 GW of the US natural-gas generator nameplate capacity[4] (7% of total US power generation capacity). This program should be accelerated immediately to minimize CO2 emissions and reduce fuel consumption. In addition, other turbine efficiency programs should be an integral part of our energy independence strategy.

What is Spar-Shell Technology?

The simplest turbines have one rotor assembly which is a shaft with blades attached. The moving fluid acts on the blades so that they rotate and impart energy to the rotor. In the case of natural gas turbines, the hotter the working fluid (the gas), the more energy can be extracted from the turbine, and the more efficient the turbine is.

Currently, the efficiency of natural gas turbines is limited by the temperature that the turbine materials can withstand. Significant investment has already been made to achieve higher and higher turbine temperatures – through high temperature nickel superalloys, cooling air, thermal barrier coatings, film cooling, and other technologies developed in the last century. However, any further improvements in these technologies will serve only to incrementally increase the temperature above where standard operating temperatures are today.

The Spar-Shell technology allows the turbine operator to achieve significantly greater temperature increases because the turbine blade material is no longer the nickel alloy that is currently used, but a higher temperature metal of the refractory type. Refractory materials are a class of metals that are extraordinarily resistant to heat and wear. Examples of refractory metals include Niobium, Molybdenum, Tungsten, and Tantalum. Refractory materials have been in use in gas turbines for simple geometries, but not for complex blade shapes due to difficulties associated with their manufacture.



The Spar-Shell Blade is an assembly of three components, and can be a direct replacement for existing blades in natural gas turbines.

Figure 3: Spar-Shell Blade Assembly

[4] According to the Electric Power Annual 2007, EIA, the net generation of natural gas-fired turbines in 2007 was 102 GW (equivalent full-time operation). FTT assumes it is economically viable to apply this Spar-Shell Blade to 50% of this net generation on capacity operating at 85% of the time, or 60 GW of the US installed capacity.

FTT's Spar-Shell technology leverages the excellent heat resistance of the refractory metal and combines it with an advanced design approach – the Spar-Shell Blade – in which the external surface of the blade exposed to the turbine's hot gas, "the Shell", is composed of a refractory metal while an internal structure "the Spar" (composed of more conventional materials) provides support. The Shell protects the Spar's conventional materials from the hot working fluid of the operating engine, as illustrated in Figure 3.

The Spar-Shell Blade allows the metal temperature of the turbine blade to increase by 100 degrees F, saving 50 - 75% of the air required to keep the blades "cool". These changes allow for the overall turbine to operate 3.5% more efficiently. In other words, if all the industrial gas turbines in the US were retrofitted with Spar-Shell blades, we would reduce the fuel required by our power producing plants by 3.5% - essentially 12 days of energy consumption for free. The Department Of Energy has supported the Spar-Shell Blade with Small Business Innovative Research grants.

What Other Efficiency Technologies Does FTT Work On?

FTT is also actively developing other technologies for improving the efficiency of modern gas turbine power plants. While a wind turbine is open to the environment, gas, steam, and water turbines are constructed with cases around the blades to contain and control the working fluid. Every molecule of working fluid that the blade does not extract work from as it passes by, is called "leakage" which also reduces turbine efficiency. FTT is currently working on methods to control and limit the amount of leakages in turbines through advanced clearance control schemes and sealing technologies.

There are other ways to increase turbine efficiency. Improvements in the surface finish of blades and cases help to minimize losses in efficiency. FTT is working on methods to improve the surface finish such as better blade coatings, improved wear resistance, and other surface treatments.

The combination of all these technologies will help power producers get the most from their investments. Combined, these technologies contribute to a total of 5% efficiency improvements, with the Spar-Shell Blade making up 70% of the total, as shown in Figure 4

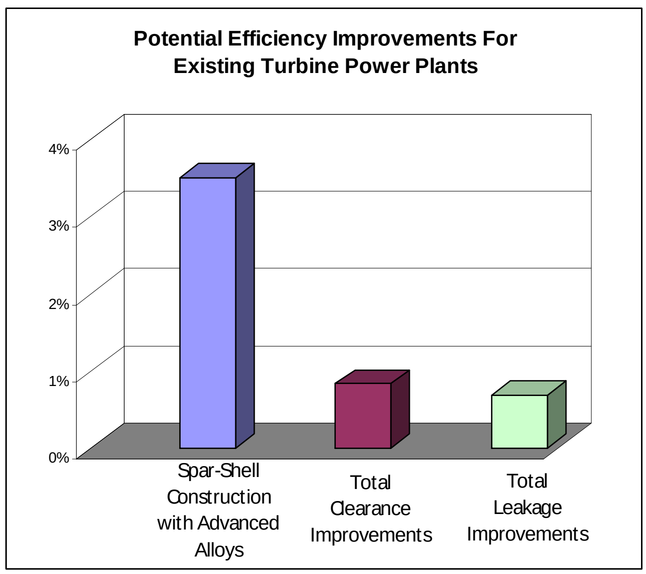


Figure 4: Efficiency Improvements Of Up To 5% Have Been Identified

How Do Technologies Lead to Natural Gas Savings, Higher Plant Capacity, and Lower Emissions?

The efficiency improvement technologies described above can be incorporated into existing combined cycle gas turbine power plants to generate additional electrical capacity. This capacity stems from two sources:

1. Air previously required for cooling the turbine blades is now combusted with fuel, to give additional power output ("upgraded power capability")

2. The ratio of conversion of electricity from fuel is higher ("turbine efficiency")

The Spar-Shell blade and associated efficiency improvements not only yield additional electricity for the same amount of fuel, these improvements allow the power plant to increase the rated generating capacity. For every 100 MW of electricity generated before the implementation of Spar-Shell and other efficient technologies, 5 MW of additional electricity is generated by the increase in efficiency (no additional fuel is required and no emissions are generated). Further, because of the increase in air through the combustion process, an additional 10 MW of clean natural gas combined cycle power is generated to result in a total of 15 MW additional power (or 15% increase).

This is illustrated in Figure 5. For the US natural gas installed capacity viable for Spar-Shell Blade, 60 GW of US turbine capacity becomes 69 GW of capacity. This additional capacity is enough to power 4.5 million homes and is equivalent to the production of 13 coal-fired plants. Further, the efficiency improvements can be applied on a world-wide basis, which translates 240 GW total world-wide natural gas electrical capacity[5] to 276 GW.

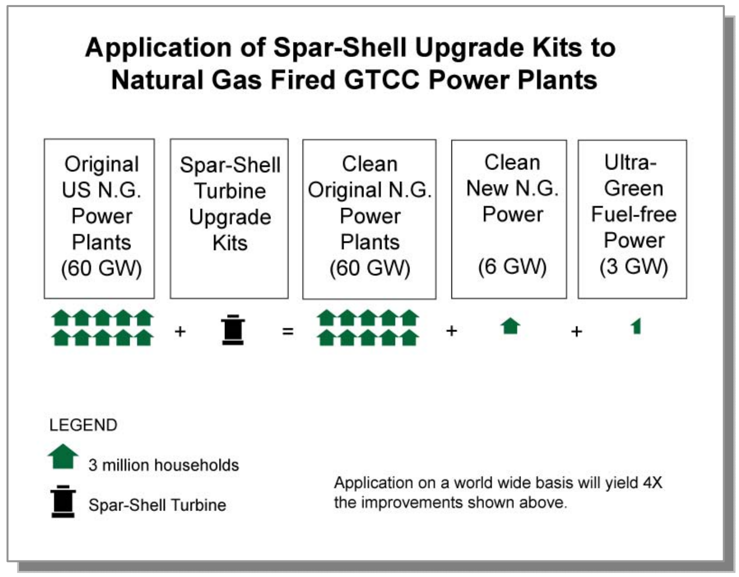


Figure 5: Efficiency Improvements Can Result in 15% Increase in Power

How does this efficiency improvement convert to reductions in CO2 emissions? As mentioned in the previous section, when the turbine is more efficient, less fuel is required to generate the same amount of energy, and less CO2 emissions are generated for the same amount of energy because less fuel is used. The calculated 5% plant efficiency improvement applied to the 60 GW of US turbine capacity saves 15 million tons in US CO2 production annually due to Spar-Shell and related technologies, relative to the original power plant (and 60 million tons of CO2 saved per year world-wide).

How does this efficiency improvement convert to savings in oil? Measured in millions of barrels of oil equivalent (mboe) per year, the natural gas savings due to efficiency improvements is 25 mboe on a US basis and 100 mboe world-wide.

When comparing these striking numbers to other recovery policy options, the importance of turbine efficiency truly stands out. Development rig and engine verification will cost an estimated $25 million. Implementation to generate 9GW of additional US power will cost $3-$5 billion which is a cost of $300-$500 per kilowatt. One-

[5] 2005: Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007).

third of this power (3 GW) is fuel-free and pollution free at a cost less than 20% of the cost of alternative fuel-free, pollution-free technologies.

Turbine efficiencies will continue to be important as electrical power generation from natural gas is not expected to decrease, but rather will increase with increases in electricity demand. Figure 6 shows the predicted world electricity generation by fuel to the year 2030[6]. These predictions show that natural gas turbine power generation will continue to be a predominant source of energy for many years to come.

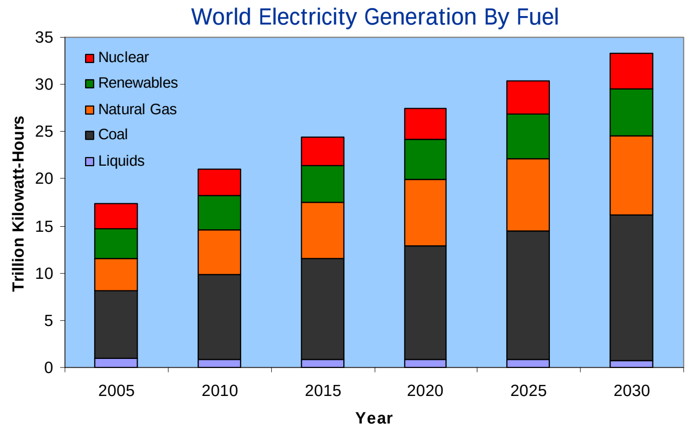


Figure 6: World Electricity Generation By Fuel By Year

What Hurdles Exist to Obtaining The Benefits of Spar-Shell Technologies?

"Renewable" should include "Efficiency":
The Spar Shell program and other technology programs that focus on efficiency need to be included as an integral part of our "renewable energy" plan. Since power outages can cost millions of dollars per day, utilities are extremely conservative with respect to the introduction of new technologies. They want to avoid a failure at all cost.

For that reason, efficiency technologies need to be tested on "turbine rigs" which simulate turbine conditions at a fraction of the cost of operating engines. Only after many hours of successful rig testing followed by engine testing, will a utility incorporate new energy-saving technologies. Engine testing is expensive for several reasons. New hardware must be secured and fuel costs incurred. But more importantly, the cost of insuring the testing due to the risk of potential outages and hardware replacement is high. Failures during the validation phase can cost a utility $5 to $10 million. Although the typical test program of these technologies is in the millions of dollars, such an investment is well worth the investment when considering our nation's energy security.

In summary, natural gas-fired turbines currently account for approximately 50% of the US electrical generation capacity. Existing turbines can be made more efficient by the incorporation of known and new technologies. Increasing turbine efficiency benefits consumers by reducing the amount of CO2 emissions, by reducing the fuel required to generate the same amount of electricity, and by providing additional capacity beyond that caused by the efficiency improvement.

FTT has invented technologies that can be retrofit into natural gas-fired turbine power plants worldwide to create essentially "free power"— or up to 15% more power from the same plants. Much of that "free power" is completely carbon-free and requires no additional fuel.

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[6] 2005: Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), Projections: EIA, System for the Analysis of Global Energy Markets/Global Energy Module (2008).

The incorporation of Spar-Shell Blade into gas turbine plants will help put our nation at the forefront of a technology that will have world-wide implications. Efficiency improvements such as these can have a world-wide impact in CO_2 emissions and fuel usage and so should be included in our nation's renewable energy policy and plans.