Written Testimony of
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Mr. Chairman and members of the Subcommittee, I am Rick Stanley, Vice President of GE Energy's Engineering Division. I appreciate the opportunity to testify today on the link between energy and water and technologies that can enable us to better manage these interrelated resources. GE has long recognized the connection between energy and water, and commends the Committee for its efforts to explore and make progress on this critically important topic. In my testimony today, I will address 3 major points: the depth of the challenges surrounding the use of water in power generation, the role of current technology in addressing these challenges, and the need for targeted research and development through public-private partnerships.

Background

GE is a global leader in power generation technology and products with more than 100 years of industry experience. In 2008, GE's water and power generation businesses were integrated to better meet customer needs and address significant global challenges. Our team of more than 30,000 employees operates in 140 countries around the world, and had 2008 revenues of $23 billion. GE Power & Water offers a diverse portfolio of products and services, including renewable energy technologies such as wind, solar, and biomass, and fossil power generation, gasification, nuclear, oil & gas, transmission, and smart meters. GE Power & Water likewise has technologies for water treatment and use, including process chemicals, water chemicals, equipment and membranes.

At GE, we see the importance of achieving water and energy efficiencies across our own portfolio of businesses. In 2005**,** GE launched a global environmental initiative called ecomagination. We have committed to reduce our greenhouse gas emissions by 30% on a normalized basis (allowing for projected growth of GE's businesses), or 1% in absolute terms from 2006 to 2012. In addition, we have committed to reducing our water consumption by an absolute 20% during the same time frame. At the same time, we're working with our customers around the world to help them achieve similar efficiencies.

In addition, GE is doubling its level of investment in clean research and development from $700 million in 2005 to more than $1.5 billion by the year 2010. This research effort is focused on helping our customers meet pressing energy and water challenges.

The Energy-Water Nexus

It could be said our economy runs on water. Unfortunately, water demand already exceeds supply in many parts of the world. And, as the world's population continues to grow at an unprecedented rate, many more areas are expected to experience this imbalance in the near future.[1] The situation is no different here in the United States, where most states expect water shortages during the next decade.

[1] Greenfacts.org

Energy and water are co-dependent. In simplest terms, energy is required for producing water and water is required in the production of energy. Globally, the demand for both of these crucial resources is projected to grow at an alarming pace, with energy demand doubling[2] and water demand tripling[3] in the next 20 years.

As we prepare to meet the future electricity demands here in the U.S., corresponding demands for water related to electricity production are expected nearly to triple from 1995 consumption levels. In addition, the deployment of technologies to meet expected carbon emission requirements will increase water consumption by an additional 1-2 billion gallons per day.[4]

Water reuse represents a significant opportunity to achieve reductions in water consumption for power generation. It is estimated that 45% of freshwater withdrawals in the United States is used for industrial purposes.[5] And nearly 90% of all industrial water – or 39% of all freshwater withdrawals -- is used for the generation of power.[6] Although power generation facilities in the United States today withdraw 136 billion gallons per day (GPD), they only consume 4 billion GPD through evaporation and other means. The vast majority of the water is used for once-through cooling water applications, and then returned to the receiving stream. Once-through cooling, however, consumes large amounts of energy to pump the water, and it also elevates the temperature of the receiving stream.[7] It is often less expensive to pull water from a river or the ground than it is to reuse it.[8] In addition, many power plants in the United States use potable water from municipal systems to meet their cooling and other

[2] DOE / EIA-0384 (2004)
[3] NETL 2006
[4] NETL 2006
[5] USGS. Estimated Use of Water in the United States in 2000, USGS Circular 1268, March 2004
[6] USGS. Estimated Use of Water in the United States in 2000, USGS Circular 1268, March 2004
[7] USGS, Estimated Use of Water in the United States in 2000, USGS Circular 1268, March 2004
[8] USGS, Estimated Use of Water in the United States in 2000, USGS Circular 1268, March 2004

needs.[9] This places strains on community systems. If the cooling water needs could be met with reused wastewater, significant benefits would result.

Another opportunity for reductions in water consumption for power generation is in selection of less water-intensive power generation technologies and in improving the efficiencies of those technologies. For example, the use of advanced gas turbines in power generation applications contributes to water savings. Key applications include the use of natural gas combined cycle (NGCC) power plants and integrated gasification combined cycle (IGCC).

NGCC plants currently account for about 20% of total electric generation in the United States. They are a highly efficient, flexible source of clean and reliable electric power, and can be constructed and installed in relatively short periods of time in comparison with other forms of electric generation. On a per megawatt basis, NGCC plants utilize less than 50% of the water used by pulverized coal power plants – which comprise the largest percentage of US power generation capability today. Wider deployment of natural gas combined cycle plants – and technology advances to make those plants more efficient – will have a dramatic impact on water usage for power generation in the United States.

IGCC is a power generation technology that gasifies coal to remove pollutants and capture carbon prior to combustion. IGCC technology is commercially ready to utilize the abundant coal resources here in the US, with both lower emissions and reduced water consumption. GE is building the first fully commercial IGCC plant at Duke's Edwardsport, Indiana facilities. This new GE IGCC generation plant will utilize 30% less water and offer significant emissions reduction benefits in comparison with a traditional pulverized coal facility. GE also is working with the University of Wyoming to develop advanced coal gasification technology, including a unique dry feed injection process.

[9] Wade Miller, Executive Director, WateReuse Association (2009)

The development of this dry feed process will deliver IGCC's environmental benefits utilizing lower rank coals from Wyoming, Colorado, Montana, Utah, and South and North Dakota, while capturing the 30% reduction in water consumption.

Beyond the fact that NGCC and IGCC have less intensive water consumption, continued advancements in gas turbine technology to achieve greater fuel efficiency will also reduce water consumption per megawatt of power produced.

The following sections discuss the challenges and research being performed to enable cost-effective water reuse and improved gas turbine efficiency.

Water Reuse Challenges

Throughout the cycle of power generation, significant quantities of waters are used in boilers, cooling towers, and gas fuel and emission treatments. Throughout this process the temperature, pH and contaminant levels of the water change significantly, bringing tremendous challenges to any water treatment scheme. The waters can contain a significant amount of oils, dissolved solids, minerals, and potentially ammonia, heavy metals and selenium. In order to reuse the waters in the process systems without damaging equipment, the waters must be cleaned to appropriate levels. This typically involves chemical treatments, water filtration, biological processes to purify the water, and often a thermal treatment to clean the waters. GE is investing in technologies throughout this cycle to make water treatment more cost-effective and robust, encouraging reuse and/or ecologically-friendly discharge. These treatments must be able to handle wide variability in water conditions, and be reliable and easily maintained.

During fuel preparation and emission cleaning, waters utilized undergo significant change in temperature and pH, and pick up contaminants that may include mercury, nitrates, salts, metal compounds, and selenium. Broad portfolios of technologies must be developed to allow customers to find the appropriate solution for their process in order to effectively reuse the water.

Water Reuse Technology

Technology used to treat water includes filtration products to remove particulate and organic matter, and membranes to remove dissolved minerals and organic matter that are present in essentially all natural water sources. State-of-the-art filtration products include hollow fiber microfiltration (MF) and ultrafiltration (UF) as well as spiral-wound nanofiltration (NF) and reverse osmosis (RO) membranes. In order to drive cost and energy efficiencies, investment in technology development will be required to meet future demands on water resources to meet growing needs in industrial and energy applications. In the near term, significant focus is being applied to higher-flux membrane systems that will enable larger water production for each unit area of membrane. This will result in lower energy consumption per unit volume of water treated. The integration of advanced filtration systems for pretreatment for RO systems will further enable reductions in plant footprint, while simultaneously allowing for higher-throughput due to an improved ability to remove contaminants that are harmful to RO systems and currently require more conservative designs.

Water scarcity requires high-recovery of product water in the removal of dissolved minerals from stressed, saline aquifers, such as in the Southwest USA, or for water reuse applications. GE is developing advanced technologies in electrically-driven processes for the removal of dissolved ions from these water sources that will allow for recovery of greater than 85-90% of feed water as product water. Not only will these systems enable improved efficiencies in water-management, they will also accomplish this at significantly reduced energy consumption as compared to current electrically-driven systems. This is being accomplished through advances in power electronics and novel energy-conversion systems. Furthermore, integration of renewable energy sources and advanced energy recovery devices will further reduce environmental impact and overall cost of operation by significantly lowering energy requirements.

Anticipated increased water needs, coupled with projected shortages, require innovations that enable substantially higher efficacy in wastewater recovery and reuse. GE intends to address these needs through the development of high-efficiency membrane materials that will allow for throughputs that increase water-flux by a factor of 10+, and further reduce energy costs and system footprint requirements. These innovations will be achieved through advances in manufacturing technologies and processes, as well as materials of composition, including advances in nano-materials. A major barrier to continuous operation and maintenance of water flux is membrane surface fouling by organic matter and mineral deposits. These effectively blind the surface and prevent flow through the membranes, which also leads to increased energy consumption. Advances in nano-materials can increase membrane capabilities in fouling control and increased flux with reduced energy consumption for water produced. Through novel incorporation of nano-materials into a membrane matrix, it is anticipated that biological growth can be mitigated. It is also expected that significant increases in membrane surface areas can be achieved with no increase in device size. Specifically designed and tailored nano-materials that can prevent mineral deposits from forming could also be envisioned. There are currently joint industry/university research programs in this highly-specialized technical area in Europe and other parts of the world. It is imperative that these capabilities be developed here to ensure that the United States remains at the technical forefront of this vital high-technology industry.

Investments in the technologies and establishment of facilities to pilot new technologies will be needed to advance the state-of-the art. The complexity of the waters and resulting complexity of the treatment systems will continue to be a barrier to broad adoption of water reuse. Joint government-industry-university initiatives will allow the power generation community to advance the knowledge of solution effectiveness, cost and reliability, allowing adoption to be more rapid and widespread.

Advanced Gas Turbine Technologies

As the world leader in industrial gas turbines, GE has always been at the forefront of technology advancement that improves gas turbine efficiency. As efficiency is improved, more output is achieved for the same fuel consumption and water usage. Therefore, improvements in gas turbine efficiency yield reduced water consumption per MW of power output. To improve gas turbine efficiency, GE conducts research in technologies such as aerodynamics, aeromechanics, compressor, high-temperature materials and coatings, heat transfer, combustion, controls, and manufacturing. In a current cost share program with the US Department of Energy, GE is working on technology advancements for hydrogen fueled gas turbines that will be used when carbon capture is used on IGCC coal power plants.

Current NGCC power plants are capable of reaching up to 60% efficiency. That means 60% of the thermal energy contained in the fuel is converted to useful power output. Aggressive Gas Turbine technology advancement can lead to 62% efficiency and define future technologies needed to get to 65% efficiency. The efficiency gain would not just apply to future power plants, but many pieces of the new technologies could be retrofitted into the existing gas turbine power generation fleet. General Electric's E and F class turbines are two of the backbones of the installed US fleet, with about 450 E class and 560 F class units deployed throughout the country. A one-percentage point improvement in efficiency applied to GE's existing F Class fleet would result in CO2 emissions reductions of 4.4 million tons per year while providing savings of more than a billion dollars per year in fuel costs.

Today, GE Energy is making significant investments to advance technology and develop new products and capabilities. Over the last 3 years, GE Energy has invested over $1 billion into gas turbine products and technology. However, much more is needed to develop the new technologies to reach the game changing level of 62% efficiency. There is a distinct role for government, specifically the Department of Energy, to partner with US private industry to reduce the inherent risk in the research and development efforts required to reach such an aggressive target. Besides the national benefits that will be realized for the US in terms of water usage and emissions reductions, a public-private partnership on gas turbine efficiency will likewise have substantial economic and employment benefits, as well as benefits for our national competitiveness in the global market for new technologies. The fact that GE's foreign competitors receive funding from their governments poses a significant challenge to the United States' traditional preeminence and leadership in gas turbine technology development.

H.R. 3029, introduced by Representative Paul Tonko and referred to this Subcommittee, provides the basis for a future partnership between industry and government to make the next big leap in gas turbine efficiency. GE commends Rep. Tonko for his efforts, and also applauds the House of Representatives for including this proposal in the recently-passed American Clean Energy and Security Act of 2009, H.R. 2454. Because of the magnitude of the technological risks, a government-industry partnership is needed to address challenges inherent in moving the efficiency benchmark to 65%, in areas including development of high temperature materials, improvements in combustion technology, advanced controls, and high performance compressor technology.

Highly skilled engineers located at GE's Global Research Center and GE Energy facilities in Schenectady, NY, Greenville, SC, Houston, TX, and Cincinnati, OH will remain at the forefront of GE's efforts to advance gas turbine technology. GE Energy has had an outstanding collaboration with the US DOE Fossil Energy team, including the National Energy Technology Laboratory. Our recommendation in the area of gas turbine technology is that the DOE, in addition to its current coal/IGCC gas turbine focus, be authorized and funded to also pursue advances in natural gas fueled gas turbine technologies.

The remainder of the testimony will focus on specific technologies identified by the Committee as areas of interest.

<u>Production of Clean Water – Desalination</u>

Desalination refers to any process that removes excess salt and minerals from water. Water desalination and its integration with power plants is an economically attractive approach to improving overall system efficiency. There are, in general, two approaches to desalination – Reverse Osmosis (RO) and Multi-effect Distillation (MED). Both processes can utilize waste heat from power plants to operate more efficiently in producing clean water.

GE is taking leadership role in integrating desalination with power generation equipment. GE is working with external partners to promote use of gas turbines for use in desalination applications for both MED and RO processes. For example, GE's LMS100 aeroderivative gas turbine has heat rejection that can be ideally integrated with a desalination process to produce clean water as well as power. GE's Global Research Center has also developed low cost approaches to desalination that can be utilized in next-generation desalination applications.

The main short-term technical challenges are in optimizing the overall system efficiency to produce power and water at the lowest cost. The MED process requires significant heat input, and proper integration with gas turbines can mean substantial savings in total power usage.

GE would support research in system integration of desalination and power generation processes and development of the next generation technologies required to achieve this integration at low cost.

Organic Rankine Cycle – Power From Waste Heat Without Water Usage

Organic Rankine cycle technology utilizes an organic solvent as a working fluid in a Rankine thermodynamic cycle to extract power from low-grade waste heat. This is similar to a steam cycle, but can recover lower grade heat since the organic solvent has a lower boiling point. There are several organic Rankine cycle applications for heat recovery in geothermal and gas turbine applications. The key advantage is that it is a closed cycle, and it does not utilize water.

GE is working with external industry leaders in evaluating this technology for gas turbine applications. Internally, GE is trying to develop next-generation organic Rankine cycle technology that can be more efficient and also less expensive. This technology is already being used in the Oil and Gas industry for power generation in pipeline applications. For simple cycle gas turbines used in peaking applications, this technology can potentially recover heat to produce electricity without using incremental water.

The key technology hurdle is reducing the capital cost of the equipment. Currently, the capital cost is 20-30% higher than a steam cycle. Current technology utilizes one fluid to recover waste heat from gas turbines and a second fluid to serve as the working fluid.

Future systems may utilize a single organic solvent to recover waste heat and serve directly as the working fluid. Technology also needs to be demonstrated in a bigger scale for gas turbine applications.

Use of GE Jenbacher Gas Engines In Wastewater Treatment Systems

The process of treating municipal and industrial wastewaters from homes and facilities across the United States is a tremendous undertaking, involving complex operations and processes to treat flows and return treated water to the environment. During these processes, chemical and biological constituents are removed and separated from wastewater, producing treated effluent that often is cleaner than the bodies of water into which it is discharged. The removed constituents, energy-rich biosolids, are then subsequently treated, in some cases anaerobically (without oxygen) to be used in various manners. The by-product is a methane-rich biogas that can be used to produce electricity and heat.

There are over 16,000 municipal wastewater treatment plants (WWTPs) in the United States, and approximately 540 of these plants anaerobically treat their biosolids.[10] The biogas produced by this treatment process is most often flared at the facility. The United States Environmental Protection Agency published a report in April 2007 that stated that less than 20% of the facilities with anaerobic digestion used their biogas for electricity or heat production.[11] The USEPA estimated that if each of these plants were to convert the biogas to electricity, it would produce 340 MW of renewable energy and remove 2.3 million metric tons of carbon dioxide – the equivalent of emissions from 430,000 automobiles – from the atmosphere.[12]

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[10] United States Environmental Protection Agency Combined Heat and Power Partnership, "Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities" at page 1 (April 2007). This report is available at: http://www.epa.gov/CHP/documents/wwtf_opportunities.pdf.

[11] *Id.*
[12] *Id.* at pages 7-8.

General Electric's Jenbacher gas reciprocating engines provide an effective solution for wastewater professionals looking to optimize efficiency through the production of renewable energy. With more than 50 years' experience, GE Jenbacher has an extensive installed base of over 460 units running at WWTPs, primarily in Europe where this technology application has been used for years. The GE Jenbacher gas engine product portfolio includes a wide variety of engine sizes ranging from an electrical production of 0.33 MW to 2.70 MW on anaerobic, digester gases. Additionally, the GE Jenbacher gas engines present some of highest electrical and thermal efficiencies along with lowest emissions available. Combined with the use of waste heat from the engines, the total electrical and thermal efficiencies from GE Jenbacher gas engines can exceed 85%.

Depending on a wastewater treatment plant's processes and operations, the conversion of biogas to electricity and heat can amount to a reduction of 30% - 70% of a plant's energy costs – the second leading cost (after personnel) facing wastewater treatment operators today. By way of example, the Strass Plant in Austria, located approximately 4-miles from the GE Jenbacher factory, is the shining star for energy efficiency at WWTPs – currently producing 120% of the energy demand at the plant. The Strass Plant produces electricity to power all of its processes, and returns 20% of its demand to the grid from electricity produced by one GE Jenbacher J208 engine.

As this technology continues to gain interest in the United States, GE Jenbacher gas engines will continue to be a leader in technology and research improvements. Future research will be dedicated to increasing electrical efficiencies, improving engine heat rates, and reducing emissions, such as Nitrogen Oxides (NO_x) and CO_2. A commitment to these endeavors will allow wastewater professionals to continue to protect their citizens by focusing on meeting their wastewater treatment requirements while saving millions of dollars on energy costs.

Conclusion

In summary, Mr. Chairman, the nexus between power generation and water usage is one of the world's most complex and critical public policy challenges. GE commends you and your colleagues for your leadership in exploring the issues, and for your particular emphasis on the role of technology solutions. GE is proud of its work in this area, and we believe that the Congress and this Committee can do a great deal to promote progress by bringing focus and facilitating partnerships between the US DoE and the private sector. Our specific recommendations are:

- Greater investments in water reuse technologies and establishment of facilities to pilot new technologies to advance the state-of-the-art in membrane capabilities.

- Additional research, development and demonstration of high efficiency natural gas turbine technology, as envisioned in H.R. 3029.

- Increased research in system integration of desalination and power generation processes and development of the next generation technologies required to achieve this integration at low cost.

- Additional research on and larger scale integration and demonstration of organic Rankine cycle technology for gas turbine applications.

Thank you, and I look forward to your questions.