Inventing the Future

How Technology Is Reshaping the Energy and Environmental Landscape

April 2015
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Inventing the Future

How Technology Is Reshaping the Energy and Environmental Landscape

April 2015
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Introduction

The United States is in the middle of an energy renaissance with such profound effects that energy self-sufficiency is increasingly within America’s reach. In 2005, the United States imported approximately 30 percent of its energy needs. By the end of 2014, that figure had fallen to just 13 percent. In short, the United States reduced its reliance on imported energy by roughly two-thirds in a little less than a decade.

This stunning turnaround in the U.S. energy equation has been driven by technology. On the demand side of the equation, energy efficiency technologies (along with structural shifts in the U.S. economy) have been steadily driving improvements in U.S. energy intensity — lowering the amount of energy used per dollar of economic output — over the past four decades. On the supply side of the equation, breakthroughs in technology are rapidly expanding the frontiers of energy production and unlocking resources that were considered technically and economically inaccessible just a generation ago. At the same time, U.S. emissions of greenhouse gases and criteria pollutants have been on the decline.

Business Roundtable companies are at the vanguard of this technology revolution. Our member companies invest $190 billion in research and development (R&D) each year (equivalent to roughly 70 percent of all private R&D spending in the United States), including tens of billions of dollars in R&D on energy and environmental technologies. They also spend hundreds of billions of dollars each year deploying these technologies to improve energy efficiency, enhance energy production and improve environmental performance throughout their operations.

As described in Taking Action on Energy (2013), Business Roundtable believes that America needs a comprehensive energy strategy that simultaneously advances the goals of economic growth, energy security and environmental stewardship. We believe that technology holds the keys to success and that public policy should capitalize on the private sector’s strengths in designing, developing, commercializing and applying cutting-edge energy and environmental technologies (see box on guiding principles for U.S. energy policy and regulations).

With these issues in mind, I invite you to read Inventing the Future: How Technology Is Reshaping the Energy and Environmental Landscape. The report highlights just a small sample of technologies that are actively contributing to a more efficient, secure and sustainable future. We have gathered a series of vignettes that tell the stories of how individual companies are putting technology to work for their customers and the public at large. It provides a unique snapshot of how the private sector is leveraging technology to solve real-world energy and environmental challenges here at home and across the globe.

Sincerely,
Nicholas K. Akins
Chairman, President and Chief Executive Officer
American Electric Power
Chair, Energy and Environment Committee
Business Roundtable
Business Roundtable Guiding Principles on Energy Policy

To advance the goals of economic growth, energy security and environmental stewardship, U.S. policies and regulations should be aligned with the following principles.

**Foster Innovation:** A long-term U.S. energy policy should foster innovation by improving education in science, technology, engineering and math (STEM) fields; sustaining public investments in a diverse portfolio of precommercial energy technology research and development (R&D); and focusing public investments on R&D for scalable energy sources that are likely to be commercially viable in the absence of government support.

**Encourage Competition and Energy Resource Diversity:** A long-term U.S. energy policy should encourage competition and energy source diversity by ensuring that the private sector has access to all energy sources, both foreign and domestic; avoiding measures that discourage any energy source or any form of energy investment; ensuring that policies and regulations are technology and fuel-source neutral; and ensuring that any policies supporting the commercialization of fuels or technologies are designed to overcome well-documented market inefficiencies, are applied only to fuels and technologies that have a credible pathway to unsubsidized competitiveness, and are finite in duration and eventually phased out in a predictable fashion.

**Empower Consumers:** A long-term U.S. energy policy should empower consumers by improving the quality, transparency and flow of information to energy consumers and by leveraging market-based solutions that use price signals and consumer choice among competitive fuel and technology options.

**Engage Internationally:** A long-term U.S. energy policy should engage the international community by supporting open, unbiased and rules-based trade and investment systems and by providing leadership and encouraging collective action to address global energy and environmental challenges, including climate change.

**Ensure Smarter Regulation:** A long-term U.S. energy policy should ensure smarter regulation by establishing clear, predictable “rules of the road” that encourage investments in long-lived energy assets; improving the quality, transparency and flow of information to policymakers; minimizing administrative and regulatory burden; requiring regulations to undergo a rigorous, consistent and transparent analysis of their cumulative costs and benefits; supporting the historic role of states as the primary regulators of energy production; incentivizing investment in energy efficiency; and avoiding regulatory policies that discourage investments in energy efficiency.

**Fortify Critical Infrastructure:** A long-term U.S. energy policy should support the fortification of critical infrastructure by maintaining and enhancing the security of key domestic energy infrastructure and by removing impediments to the alignment of market-driven infrastructure investments with future energy production and demand.
Azipod® Propulsion Systems

Improving the Fuel Efficiency and Flexibility of Shipping

Azipod propulsion systems feature an exterior electric motor that facilitates more efficient and flexible energy use aboard ships. While a typical ship propulsion system uses a mechanical process, with a diesel engine directly driving the main propeller shaft, the Azipod propulsion system uses an electric process, with the same generator that provides onboard electricity also powering the main propeller. An electrical control system between the generators and propellers provides stepless power to the propeller motors (allowing variable adjustment) and can adjust the speed of the propellers, which allows the generators to run at optimum efficiency levels regardless of the vessel’s speed.

The Technology

Azipod technology was originally patented in 1955, but the first commercial application of the Azipod system did not occur until 1990. The technology has evolved over the years through refinements to the original design such as simplified maintenance and enhanced controls. As of today, Azipod systems have logged more than 9 million hours of operation on 105 vessels of various types, particularly cruise ships, offshore and research vessels, and ice-going ships.

Azipod systems feature their electric motor housed in a submerged pod completely outside the hull of the ship. Power is fed to the pod via cables from diesel generators inside the ship, while a dedicated control system featuring circuit breakers, protective equipment and electrical drives (i.e., motor controls) is managed from the ship’s bridge. This streamlined propulsion system eliminates the need for rudders, stern transversal thrusters or long shaftlines inside the hull. It also gives the ship greater maneuverability with pods able to rotate a full 360 degrees.

The Benefits

- **Increased efficiency:** Azipod-equipped ships are more fuel efficient than conventional vessels of similar size and capability, typically realizing fuel consumption savings of 10–20 percent.

- **Greater fuel flexibility:** Since the Azipod relies on electric power, ships can use a combination of any number of conventional generation technologies (e.g., diesel and natural gas) or new energy sources (e.g., batteries, fuel cells and solar power).
Azipod® Propulsion
An External Electric Motor To Increase the Fuel Efficiency of Shipping
Alcoa 951™

Stronger Bonds for More Durable, Lightweight Vehicle Bodies

Alcoa 951 is a surface treatment used in vehicle manufacturing that enables aluminum auto body components to form an extremely durable, corrosion-resistant bond with structural adhesives. This aluminum bonding process facilitates the production of aluminum-intensive vehicle designs, which help lower emissions and improve fuel economy by reducing vehicle weight.

The Technology

Strong and long-lasting adhesively bonded joints are key enablers of the mass production of aluminum-intensive vehicles. At the request of a major automotive manufacturer, initial development of an alternative aluminum surface treatment to create durable aluminum bonds began in the 1990s, with the goal of reducing the environmental impact of then-standard processes while improving performance. However, full-scale development did not begin until 2011, when two market forces combined to increase demand for aluminum-intensive vehicles: customer demand for improved gas mileage and higher fuel standards for automakers by way of the Corporate Average Fuel Economy standard. After a final round of development and verification testing, Alcoa 951 was commercially released in 2013.

The Alcoa 951 surface pretreatment is applied to aluminum through an immersion or spray application. The aluminum oxide chemically binds with the adhesive, creating a strong link at the molecular level that produces lasting, durable joints. The technology delivers nine times the bond durability of currently used titanium zirconium and silicate-based systems while eliminating the environmental hazards of chrome-based bonding processes. The Alcoa 951 surface treatment is ultra-thin and essentially transparent to downstream processes such as forming, resistance spot welding and painting.

The Benefits

- **Increased efficiency:** Aluminum-intensive vehicle design can reduce vehicle mass by 25 percent, decreasing use-phase energy consumption by 20 percent and carbon dioxide emissions by 17 percent.

- **Improved environmental performance:** Alcoa 951 contains organic, environmentally friendly materials instead of the heavy metals that lead to environmental concerns and diminish performance in other manufacturing processes.
Alcoa 951™
A Surface Treatment that Enables More Durable Bonding between Aluminum Vehicle Components
Breakthrough Overhead Line Design™

Moving More Electric Power over Greater Distances with Fewer Losses

Breakthrough Overhead Line Design™ (BOLD™) is a new type of transmission line that features a more compact and efficient configuration and provides a high-capacity, reliable solution to many of the nation’s transmission challenges. BOLD™ can effectively deliver large blocks of power over long distances, connecting remote renewable generation projects to the power grid and load centers while boosting the load capacity of extra high-voltage lines by up to 60 percent* in the same right of way. It can also increase capacity in the same right of way when replacing existing old lines with BOLD™ technology.

The Technology

The development of BOLD™ technology has been driven by an increase in renewable generation and a heightened public interest in efficient transmission solutions. Although still a relatively new technology, BOLD™ has already been awarded seven patents and seven additional patents are pending. Debut of the technology is planned for mid-2016, when it will be used by AEP to replace an existing transmission line in Indiana.

BOLD™ features double-circuit lines with a novel arrangement of the three electrical phases. Whereas conventional lines are arranged in a stacked configuration with three cross arms, BOLD™ uses a more efficient configuration featuring a single, arch-shaped tubular cross arm assembly that supports both circuits and is up to 33 percent* shorter than the standard transmission pole. BOLD™’s three electrical phases are arranged in a more compact design using newly developed insulator assemblies. While conventional transmission lines require complex and costly terminal equipment for long-distance bulk power delivery, the configuration of the BOLD™ technology eliminates the need for this equipment by improving the intrinsic loading capacity of the line. Furthermore, BOLD™ offers lower magnetic field strengths, reduced energy losses and greater aesthetic appeal.

The Benefits

- **Increased capacity:** BOLD™ boosts the load capacity of extra high-voltage lines by up to 60 percent* relative to traditional alternatives.
- **Increased efficiency:** With up to four conductors per phase, BOLD™ can save up to 40 percent of the energy that is lost during power transmission using traditional lines. This improvement can also mitigate the need for additional power-generating capacity.

*For 345kV transmission lines.*
**Breakthrough Overhead Line Design™**

*A More Compact, Efficient Configuration for Electric Transmission Lines*

Conventional Line Design

- **BOLD™ transmission lines** effectively deliver renewable energy over long distances.

- A single, arch-shaped tubular cross arm assembly supports both circuits, reducing transmission pole height by up to 33 percent.*

- The compact configuration boosts the load capacity of high-voltage lines by up to 60 percent.*

Breakthrough Overhead Line Design™ (BOLD™)

*For 345kV transmission lines.*
Prepay Energy

Increasing Customer Flexibility and Control over Electricity Use

The Prepay Energy program is an integrated payment suite that allows consumers to track their energy usage in real time to obtain greater control over their utility expenditures. By combining smart grid technology with state-of-the-art communication networks, Prepay Energy allows utility customers to accurately monitor their energy usage, track their costs and manage their consumption.

The Technology

In recent years, utilities have made significant investments in “modernizing” the electricity grid by adding two-way digital communication technology devices such as smart meters. Such modernization is increasingly well received by customers, who continue to adopt and adapt to smart grid technologies where they see benefits. In fact, studies conducted in 2013 indicated that 41 percent of Americans were interested in a voluntary prepaid energy option, up nearly 10 percent from 2012.

Specifically, Prepay Energy programs leverage smart grid advancements by providing unique, network-driven software that delivers real-time customer account balance information. Prepay Energy also allows consumers to pay for energy in advance and to monitor their usage and account balance through daily communication with their supplier. The integrated payment suite offers a variety of options, including the ability to prepay in increments that correspond with individual budget cycles, choose a postpay option and pay from a mobile device, and it is offered as a cloud-based service that includes customer access and care portals and consumer messaging tools. In addition, the Prepay Energy model has been shown to improve customer satisfaction while reducing bad debt write-offs for utilities.

The Benefits

- **Reduced energy consumption**: Participation in prepaid energy services has been found to reduce energy consumption by roughly 11 percent, which translates to nearly $200 on average on customers’ energy bills. With the popularity of prepaid services growing rapidly, U.S. utilities expect to make Prepay Energy available to 9 million customers by 2015, which will drive further resource efficiency, environmental benefits and consumer satisfaction.
Prepay Energy Powered by PayGo
An Integrated Software Suite for Tracking Electricity Use in Real Time

Network-driven software delivers real-time customer balance information.

Multiple payment options include prepay, postpay and mobile phone payments.

Customers monitor usage through daily communication.
Dream Production

Transforming Carbon Dioxide into Commercial and Consumer Products

The Dream Production process turns carbon dioxide (CO₂) into a useful raw material and new building block for polyurethane foam, a material used as cushioning for a variety of commercial and consumer products. This scientific advancement has the potential to broaden the chemical industry’s raw material base — thereby reducing dependence on traditional fossil fuel inputs — while reducing overall manufacturing emissions.

The Technology

The Dream Production process allows manufacturers to use CO₂, formerly a waste product, as an alternative raw material for polyurethane production. Because the CO₂ released as a result of fossil fuel combustion is highly thermodynamically stable, finding a catalyst capable of activating it efficiently has been the key challenge to leveraging it as a manufacturing input. Scientists from Bayer and the research institute CAT Catalytic Center in Germany discovered a zinc-based catalyst that enables CO₂ to react efficiently with high-energy substances known as epoxides without complicating side reactions. This reaction results in a new kind of polyol that contains a large amount of CO₂ instead of fossil fuel. The combination of this new polyol and other additives makes a polyurethane foam.

Since this discovery, Bayer and other manufacturers have been working to chemically process CO₂ into polyols. A pilot plant in Leverkusen, Germany, is currently using the Dream Production process to produce polyols from CO₂ from a nearby coal-fired plant. The new CO₂-based foams have undergone thorough testing, and there are plans to introduce these materials into the process used to make mattresses in the near future.

The Benefits

- **Improved environmental performance:** The Dream Production process reduces the energy inputs required for polyurethane production while also reducing carbon emissions. Additionally, Dream Production transforms CO₂ waste into a useful raw material.

- **Enhanced energy security:** By helping to broaden the raw material base of the chemical industry, Dream Production can improve feedstock flexibility and diversity.
Dream Production
A Process for Converting Carbon Dioxide into a Useful Raw Material for Consumer Products

1. Separation and supply of carbon dioxide (CO₂)
2. Processing of CO₂
3. Production of consumer products

\[
\text{CO}_2 \xrightarrow{\text{Polyol}} \xrightarrow{\text{Isocyanate}} \text{Polyurethane}
\]
Combined Heat and Power (CHP) — also referred to as cogeneration — is the simultaneous production of electric power and heat from a single fuel source, such as natural gas, coal, oil or biomass. CHP captures thermal energy that would normally be lost in power generation and uses it to provide heating and cooling, which greatly enhances the energy efficiency of power generation.

The Technology

CHP was first used in the United States by Thomas Edison to power the world’s first commercial power plant in 1882. However, early regulations discouraged decentralized power generation, and CHP systems were not widely used until the late 1980s, when new policies to promote energy efficiency encouraged their adoption. Today, the United States has installed more than 82 gigawatts of CHP generation, representing about 8 percent of total capacity, with the widest deployment in energy-intensive industries — including steel, chemical and petroleum-refining plants — and at large institutions such as universities and hospitals. In recent years, smaller systems have also become common in commercial and manufacturing industries.

CHP is not an individual technology but rather an integrated energy system that produces both heat and power for industrial and commercial locations. Unlike traditional systems in which power is generated at a central power plant and then distributed to users, a CHP system allows both electricity and heat to be generated onsite. The two most common CHP systems configurations are a gas turbine, or reciprocating gas engine, with a heat recovery unit or a steam boiler with a steam turbine. In the former, the gas turbine or reciprocating engine generates electricity by burning natural gas or biomass while a recovery unit captures heat from the system’s exhaust stream. In the latter, steam turbines generate electricity as a byproduct of heat generation. In both cases, heat is converted to steam or hot water, which can then be used for heating or cooling a nearby building or for industrial processes.

The Benefits

- **Increased efficiency:** CHP systems can operate at up to 80 percent efficiency — almost double the national average of 45 percent efficiency for traditional separated heat and power systems.

- **Enhanced energy security:** CHP increases the resiliency and flexibility of the United States’ energy infrastructure by being able to run when the grid is down, reducing distribution congestion and offsetting transmission losses. In addition, CHP can use both fossil- and renewable-based fuels.
Combined Heat and Power
A System that Produces Electricity and Heating/Cooling from a Single Fuel Source
Waste Heat Recovery System
Capturing and Converting the Unused Energy from Tractor Trailers for Useful Work

The waste heat recovery (WHR) system captures a portion of the unused energy from the powertrain of heavy-duty trucks and returns it to useful work. By adapting a well-known heat recovery technology — the Organic Rankine Cycle — and applying it to the vehicle’s entire energy system, the WHR system increases vehicle efficiency, reduces the operating costs of heavy-duty trucks and lessens the environmental impact of long-distance trucking.

The Technology

The WHR system is the product of 10 years of technology development, supported by a series of U.S. Department of Energy (DOE) programs and privately funded research. Currently, third-generation WHR system technology has been installed on three trucks, including the Cummins-Peterbilt SuperTruck, which represents a partnership between more than a dozen companies and the DOE that aims to increase the fuel economy of heavy-duty trucks by 50 percent.

Typically, only about 40 percent of the energy produced by an on-highway, heavy-duty truck engine is used to power the truck forward, with the remaining 60 percent lost as waste heat through its radiator or tailpipe. To improve this ratio, the WHR system employs an integrated system of four heat exchangers that responds to changes in the engine and vehicle environment — acceleration and deceleration, road conditions, and variable load weight — to capture a portion of otherwise wasted heat energy. Specifically, the exchangers use waste heat from the truck’s powertrain to heat a working fluid, which is converted into mechanical energy that is used to optimize the vehicle’s operational efficiency.

The Benefits

• Increased energy efficiency: The WHR system significantly improves the fuel economy of heavy-duty trucks.

• Improved environmental performance: The WHR system represents a significant opportunity for emissions reduction. A future fuel-efficient tractor trailer operating with the WHR system could avoid up to 87 tons in carbon dioxide emissions over its lifetime.
Waste Heat Recovery System
A System for Converting Waste Heat to Mechanical Energy in Heavy-Duty Trucks

1. Four heat exchangers respond to changes in the engine and vehicle environment to capture otherwise wasted heat energy.

2. The waste heat from the truck’s powertrain is used to heat a working fluid.

3. The expander and drive module convert the energy in the working fluid into mechanical energy, which optimizes the vehicle’s operational efficiency.
Hybrid Wheel Loader

Improving Fuel Economy and Operator Productivity at Worksites

The 644K Hybrid Wheel Loader uses a hybrid electric drivetrain to boost fuel economy while providing operating advantages that allow the wheel loader to do its job more efficiently, including responsive and smooth hydraulics, fast ramp-climbing ability, and strong pushing power. Additionally, the hybrid-electric transmission contributes to improved worksite conditions by reducing fuel exhaust (as well as associated emissions) and the noise level inside and outside the cab.

The Technology

Wheel loaders are particularly well-suited to the application of electric drive technology due to the need for frequent direction changes and time spent engaging the loader’s hydraulic system as well as running the engine. In a hybrid drivetrain configuration, the wheel loader’s engine runs at a selectable constant engine speed to power the loader and a brushless generator, which delivers electricity to the electric motor and three-gear power shift transmission. During braking, the hybrid design captures otherwise lost energy by recycling it back to the engine and hydraulic system. Liquid-cooled solid-state electronics provide precise control over the entire system.

The Benefits

- **Increased efficiency:** The Hybrid Wheel Loader’s PowerTech™ IT4 engine and hybrid-electric transmission can boost fuel economy by 25 percent.
- **Improved environmental performance and cost savings:** The Hybrid Wheel Loader’s electric drivetrain configuration results in significant fuel savings, thereby lowering emissions by capturing and recycling energy during braking and reducing the amount of conventional engine torque required to power the loader.
Hybrid Wheel Loader
A Hybrid-Electric Transmission that Improves Loader Performance and Fuel Efficiency

6.8L PowerTech™ engine running at constant speed

- Brushless three-phase generator
- Liquid-cooled solid-state control electronics
- Brake resistors
- Brushless motor attached to powershift transmission
Heat Mirror Insulating Glass

Letting in the Light, Keeping out the Heat

Heat Mirror Insulating Glass suspends one or more lightweight films inside the airspace of a dual-pane glass unit, resulting in glass performance comparable to that of an insulated wall. When combined with coated glass and gas fill technologies, Heat Mirror glass improves the insulating performance of dual-pane glass by up to 500 percent, enabling significant energy cost savings. These savings reduce the energy consumption and associated carbon emissions required to heat and cool buildings.

The Technology

Heat Mirror technology was first invented by scientists at the Massachusetts Institute of Technology as part of a research program funded by the U.S. Department of Energy to improve energy efficiency in buildings and homes in 1980. Since then, manufacturing automation processes that are critical for the cost-effective, high-volume production of Heat Mirror Insulating Glass have been developed.

Heat Mirror technology suspends one or more lightweight polyethylene terephthalate (PET) films inside the airspace of a dual-pane insulating glass unit to create multiple superinsulating cavities. The films use nanoscale coatings of metal to reflect heat back to its source. Because Heat Mirror film is thin and lightweight compared to glass, more than one film can be suspended in the airspace of a standard dual-pane glass unit to create multiple insulating cavities without adding weight, which significantly increases energy efficiency and improves environmental performance.

The Benefits

- **Increased energy efficiency:** By creating multiple independent and superinsulating cavities, Heat Mirror technology improves the insulating performance of dual-pane glass by up to 500 percent, dramatically improving the energy efficiency of commercial and residential buildings.

- **Improved environmental performance:** Because the energy required to produce Heat Mirror film is 16 times less than that of glass, a Heat Mirror Insulating Glass unit has a 30 percent lower cradle-to-gate environmental footprint than a comparably sized triple-pane glass unit.
Heat Mirror® Insulating Glass
Windows that Insulate Like Walls

Heat Mirror Insulating Glass (IG) contains one or more clear, low-emissivity films suspended within the sealed airspace of a dual-pane IG unit.

Films create up to four super-insulating cavities that buffer against heat loss or heat gain.

Project facts
- **Project:** David & Lucile Packard Foundation
- **Location:** Los Altos, California USA
- **Architect:** EHDD, San Francisco
- **IG technology:** Heat Mirror® dual-cavity
- **IG Certifications:** LEED® Platinum, Net-zero Energy

For more information, call 773-640-5500 or contact us at sales@southwallglass.com.
Solid-State Lighting

A Compact, Durable and Efficient Source of Targeted Light

Solid-state lighting (SSL) is a type of lighting that uses semiconductor light-emitting diodes (LEDs) as a source of light instead of filaments, plasma or gases. SSL’s unique characteristics, including compact size, long life span, directional lighting, and lack of infrared or ultraviolet emissions, make it more energy efficient than traditional lighting technologies, resulting in lower overall emissions.

The Technology

The first LED was invented and demonstrated more than 50 years ago. Unlike other lamps (e.g., fluorescent), LEDs are not inherently white light sources, making them more suitable for colored light applications such as backlit mobile devices, traffic signals, backlit signage, and automotive stop and indicator lighting. It was not until 1995 that the first white LED (a combination of blue emitter and yellow phosphor) was demonstrated. LEDs did not become viable for general use lighting until high-power 1-watt LEDs were made available in the early 2000s.

LEDs create light through a process called electroluminescence. During electroluminescence, electrons are sent through the semiconductor material in the lamp to fill electron holes. When an electron finds a hole, it releases energy in the form of a photon (light). One of the defining features of LEDs is that they emit light in a specific direction, allowing LED fixtures to deliver light more efficiently to the intended location. By comparison, traditional fluorescent and bulb incandescent lights emit light in all directions, which can cause much of the light to be lost within the fixture, reabsorbed by the lamp or emitted in other nonuseful directions.

The Benefits

- **Improved energy usage:** A single SSL household luminaire consumes 85 percent less wattage than century-old light sources commonly used. The U.S. Department of Energy estimates that switching to SSL could reduce domestic electricity consumption by one-third by 2025, equivalent to the energy consumption of 20 million households.

- **Improved environmental performance:** Whereas traditional lighting sources — such as compact fluorescent lamps — contain mercury and need to be replaced every one to three years, SSL contains no mercury and can last up to 20 years, significantly reducing maintenance cycles and waste.
Solid-State Lighting
A Compact, Durable and Efficient Source of Targeted Light

Transforming Our World with Connected, Solid-State Lighting

CONNECT, INTEGRATE, INNOVATE
Solid-state lighting and controls work intelligently together on a network to improve the lives of everyone in the space. These innovative solutions are available today and can be applied to all environments. Through coordinated efforts we can speed up the adoption of these technologies. **Connectivity between these technologies will benefit and transform our society.**
Versatile Plug-In Auxiliary Power Unit

Clean, Mobile Power for Utility Work Crews

The Versatile Plug-In Auxiliary Power System (VAPS) is a portable battery system that provides power to utility and telecommunication workers while at the worksite. VAPS, which can power a worksite for approximately four hours, provides a clean, cost-effective alternative to diesel generators or truck engines, which are currently the most common sources of power at worksites.

The Technology

The first VAPS prototype was built by Southern California Edison (SCE), the utility subsidiary of Edison International, in 2011 in partnership with U.S. Hybrid, which assembled the unit, and the Electric Power Research Institute, which provided project management oversight of the prototype’s development. The prototype is currently still in the testing phase, with progress being made toward a production version. Multiple utilities and telecommunications companies have expressed interest in testing VAPS units.

Each VAPS unit provides 16 kilowatt hours of power, enough to power the typical worksite for four hours. The unit attaches to the storage bin compartment in the back of work trucks, allowing for easy loading for utility workers. The VAPS unit provides power to the truck’s onboard electrical systems (e.g., lights and air conditioning) using the same connection that workers would use to connect the truck to a diesel-powered generator. Further fuel savings can also be achieved by connecting the vehicle’s hydraulic equipment to the battery system to power the truck’s bucket (e.g., a cherry picker). In addition to fuel savings, the VAPS battery system provides a cleaner, quieter work environment.

The Benefits

- **Improved environmental performance:** VAPS units allow utilities to operate on battery power rather than diesel. SCE estimates that each VAPS unit can displace more than 1,000 gallons of diesel fuel per year, avoiding more than 22,000 pounds of carbon dioxide emissions annually.

- **Greater fuel flexibility:** VAPS units provide a cost-efficient method for the existing fleet of diesel-powered trucks to use battery power at the worksite.
Versatile Plug-In Auxiliary Power Unit
A Portable Battery System for Utility and Telecommunications Crews

Versatile Plug-In Auxiliary Power System (VAPS) units supply power for worksites, providing a cleaner and cost-effective alternative to diesel generators.

VAPS units attach to the storage bin compartment of utility and telecommunications trucks.

VAPS units can power a typical worksite for up to four hours.
SenseAware®, powered by FedEx, monitors the condition and location of shipments through the use of state-of-the-art sensor technology coupled with a customizable web-based application system. SenseAware provides companies with near-real-time shipment data that enhance productivity and supply chain management, thereby reducing waste, fuel consumption and carbon emissions.

The Technology

SenseAware was conceived and developed in early 2006 by the FedEx Innovation Team, followed by the piloting of a functional prototype with numerous early adopting customers. SenseAware was widely released in August 2011 and has continued to evolve and expand its reach globally.

Unlike traditional track-and-trace technology in which packages are scanned at designated points along their route, SenseAware provides near real-time information on a shipment’s location and its environmental conditions. SenseAware’s sophisticated sensors not only provide accurate location data but also monitor light, humidity and barometric pressure as the shipment travels. These data are then transmitted using cellular technology to a secure server where they can be viewed on a customizable user interface. This interface allows for near-real-time triggers and alerts that facilitate proactive supply chain management. In addition, systemic reporting enables companies to analyze and enhance logistical operations in many different areas, including route and transport mode optimization, improved packaging efficiencies, and loss reduction.

The Benefits

- **Increased efficiency**: Combining SenseAware’s GPS capabilities with advanced data analytics helps companies to optimize shipment routes and transport modes, reducing overall fuel consumption.
- **Improved environmental performance**: SenseAware technology helps to increase the efficiency and productivity of the supply chain, reducing energy requirements and related emissions.
**SenseAware®**

Software that Tracks the Condition and Location of Shipments in Near Real Time

1. **Set up, pack and ship**
   Set up a journey in the SenseAware application and invite business partners, such as a third-party logistics service, to monitor the journey and receive alerts. Place the activated SenseAware device in the package and ship.

2. **Monitor and collaborate**
   Monitor near-real-time data about in-transit shipment conditions (e.g., temperature, humidity, light exposure). Communicate with your partner about shipment conditions, and take action before products are compromised.

3. **Coordinate and confirm**
   Coordinate delivery for time-sensitive products with location data and proximity alerts. Know when the package has been received, and confirm that it has been opened. Have the recipient return device.

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Inventing the Future: How Technology Is Reshaping the Energy and Environmental Landscape
Solstice® Products

Low-Global Warming Refrigerants, Blowing Agents, Solvents and Propellants

The family of Solstice® products provides an environmentally preferable alternative to hydrofluorocarbons, which have historically been used in a variety of applications, including stationary and mobile refrigerants, liquid and gaseous blowing agents, solvents, and propellants. This new generation of molecules breaks down faster in the atmosphere, allowing customers to have a lower impact on global warming without sacrificing the performance of their end products.

The Technology

While the prior generation of fluorocarbons had exceptional performance attributes, they tended to persist in the atmosphere for years before the natural degradation process eliminated them from the ecosystem. This atmospheric persistence contributed to the molecules’ global warming potential and prompted scientists to search for environmentally preferable alternatives. After intensive testing, researchers identified fluorinated olefins as the best alternative. Though the materials were previously known, many experts did not consider them viable substitutes for fluorocarbons, given their perceived reactivity and instability. However, research revealed that the carbon-carbon double bond present in the molecular structure of the materials allows them to break down faster in the atmosphere without sacrificing any safety or performance properties of the end product.

These new materials, known as haloolefins, are currently being brought to commercialization in the Solstice family of products. Some of the specific products include Solstice Liquid Blowing Agent (LBA) for the foam industry, Solstice zd for the commercial refrigeration industry, Solstice Performance Fluid for the solvent industry and Solstice yf for automobile air conditioning.

The Benefits

- **Improved environmental performance:** Honeywell projects that use of its low-global warming potential Solstice hydrofluorocarbon replacements will eliminate more than 350 million metric tons in carbon dioxide equivalents by 2025, equivalent to removing 70 million cars from the road for one year.

- **Increased efficiency:** When Solstice LBA is used in place of HFC-245fa, a hydrofluorocarbon widely used as a blowing agent for appliance insulation, in a domestic refrigerator, the energy efficiency of the refrigerator improves by as much as 4 percent.
**Solstice® Products**

Low-Global Warming Alternative to Hydrofluorocarbons

Solstice products — used in a variety of applications such as refrigerants and propellants — use a class of molecule known as haloolefins instead of the fluorocarbons. While fluorocarbons persist in the atmosphere for years and contribute to global warming, haloolefins break down much more quickly without sacrificing product safety or performance.

**Ultra-low GWP Hydrofluoro-olefin (HFP)**

Double bond reacts with natural radicals, breaking easily in the atmosphere, limiting GWP.

**High-Global Warming Potential (GWP) Hydrofluorocarbon (HFC)**

Single bond is stable in the atmosphere, leading to high GWP.

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Inventing the Future: How Technology Is Reshaping the Energy and Environmental Landscape
Micro Hybrid Battery Systems

Bridging the Gap between Electric and Conventional Vehicle Technologies

Low-voltage vehicle electrification, such as Micro Hybrid battery systems, bridges the gap between conventional vehicle battery technology and full hybrid electric vehicle technology. Micro Hybrid systems use dual battery architecture to reduce vehicles’ annual fuel consumption by as much as 15 percent.

The Technology

The first 48-volt Micro Hybrid battery system was introduced in 2013, following investment and research into advanced battery technologies that improve the fuel efficiency of traditional internal combustion engine (ICE) vehicles while avoiding the costs associated with full hybrid electric vehicle technologies.

Leveraging dual voltage architecture, Micro Hybrid battery systems integrate a 12-volt lead-acid starter battery and a 48-volt lithium-ion battery. The 12-volt battery powers conventional electrical systems (e.g., vehicle starter), while the lithium-ion battery is designed to quickly capture energy from braking and run vehicle accessories that require higher power (e.g., air conditioning). While a conventional hybrid vehicle battery pack typically consists of 300–400 volts and improves fuel economy by 25–30 percent, Micro Hybrid systems are just 48 volts and improve fuel economy by up to 15 percent.

The Benefits

- **Increased efficiency:** Due to the efficiencies created in the electrical system, as well as other parts of the vehicle, when two batteries work in tandem, Micro Hybrid systems have the potential to cut a vehicle’s annual fuel consumption, and emissions, by as much as 15 percent.

- **Cost savings:** Unlike traditional full hybrid vehicle systems, which add thousands of dollars to the cost of a new vehicle, Micro Hybrid systems cost around $1,000.
Micro Hybrid Battery Systems

Reducing Fuel Consumption in Conventional Vehicles

Higher-Voltage System
- A/C compressor
- Active chassis
- Regeneration

12-Volt System
- Interior and exterior lights
- Audio/entertainment
- Electronic modules
- Ignition

Battery requirements
Requires a more robust battery for direct propulsion and braking in addition to start-stop functionality.
- Increased cycling
- Expanded operating range
- Higher dynamic charging
- Operate on a 48-volt network

12V

Voltage Bridge
24 to 50V

Braking
48-volt battery captures power from braking and supports higher-energy use parts of the vehicle.

At idle
- Automatically shuts off the engine.
- Can support higher-energy loads such as air conditioning.

Accelerating
Restarts engine and provides direct power boost to the engine.

Coasting
Provides support while engine is off and vehicle is coasting.

Inventing the Future: How Technology Is Reshaping the Energy and Environmental Landscape
Smart Energy Enterprise Suite

Modernizing and Optimizing How the Electricity Grid Is Managed

Smart Energy Enterprise Suite (SEEsuite™) is a series of computer-based grid management applications that provide utilities with the functionality and integration needed to transition to responsive smart grid-enabled organizations. SEEsuite helps utilities comply with changing regulatory requirements; reduce energy loads during times of grid stress or volatile wholesale prices; and maintain grid stability as new sources of energy generation, storage and consumption come online.

The Technology

The country’s current electric grid was built more than 100 years ago. While it has evolved over the years, a new approach to modernizing the electric grid is needed to manage the increasingly complex electricity needs of the 21st century. To help utility companies successfully transition to this new era, the SEEsuite of advanced grid management applications was launched in 2010.

SEEsuite is comprised of three different applications. The first, SEEload™ for Demand Response Management, provides utilities with a dynamic load management solution that integrates all of a utility’s demand response programs, customers and aggregators into a single operational view. The second application, SEEview™ for Enterprise Energy Management, allows customers to integrate multiple systems; bridge multiple geographies; and automate monitoring, reporting, and control of critical resources and loads into a single, easy-to-use screen. The final application, SEEgrid™ for Integrated Grid Management, allows utilities to optimize the use of distributed energy resources to improve grid reliability, meet energy source and emissions targets, and reduce the cost of delivered electricity.

The Benefits

- **Increased efficiency:** SEEsuite provides utilities with the information to dynamically manage loads during grid stress or volatile wholesale market prices, which allows them to increase efficiency while reducing costs.

- **Improved environmental performance:** The flexibility provided with SEEsuite helps utilities comply with changing regulatory requirements and allows them to consistently meet more stringent renewable energy and emissions targets.
Smart Energy Enterprise Suite (SEEsuite™)
Software that Enables Demand Response, Systems and Integrated Grid Management

**Demand Response Management**
Precisely and easily manage demand response events across an entire distribution network, including individual substations and circuits, as well as manage distributed energy resources.

**Enterprise Energy Management**
Integrate multiple systems; bridge multiple geographies; and automate monitoring, reporting, and control of critical resources and loads into a single, easy-to-use screen.

**Integrated Grid Management**
Optimize the use of distributed energy resources to improve grid reliability, meet energy source and emissions targets, and reduce the cost of delivered electricity.
Movement Planner and Locomotive Engineer Assist Display and Event Recorder Software Systems

An Air-Traffic Control System for the Nation’s Railroads

The Movement Planner and the Locomotive Engineer Assist Display and Event Recorder (LEADER) software systems help trains more accurately track real-time performance, calibrate operation settings and develop optimal travel plans. The use of the complementary technologies allows more locomotives to run on the same track at faster speeds and with greater efficiency, generating significant fuel savings.

The Technology

Freight railroads are vital to the U.S. economy, transporting more than 40 percent of the country’s freight, with Movement Planner acting as the railroad equivalent of an air-traffic control system. The software integrates railroad logistics with traffic control systems, considering factors such as train schedules and train movements to develop an optimized traffic plan for the trains. Although the software is still in the early stages of implementation, on territories where Movement Planner has been implemented and fully utilized, Norfolk Southern’s analysis has shown that it increases velocity by 10 percent and greatly improves trains’ schedule adherence.

LEADER is a software application that operates on each locomotive’s computer. The application uses the characteristics of the train (e.g., the distribution of loaded and empty cars) and terrain information to accurately predict train performance. As the train traverses its route, the system continually compares the current locomotive control settings with the calculated optimal settings and coaches the engineer on how to achieve more efficient operation. This onboard software can then provide real-time feedback to the Movement Planner, allowing it to incorporate each train’s capability and performance to produce better plans.

The Benefits

- Increased efficiency: The use of Movement Planner and LEADER allows trains to adjust their performance to achieve operating and efficiency objectives on a daily basis. In fact, tests of LEADER software alone over varied terrain and train types produced 7 percent median fuel savings.

- Better performance: The use of both technologies in tandem leads to better overall performance for trains as well as the rail system as a whole. The more efficient technologies improve crew management, increase network performance and extend rail life.
Train Performance Optimization Software
A Software System for Improved Railroad Traffic Management

Locomotive Engineer Assist Display and Event Recorder software uses train and terrain data to provide engineer with feedback on how to improve efficiency.

Real-time data are transmitted to provide dispatchers with full visibility of train location and operating performance.

Movement Planner system uses data to develop traffic plans that optimize network efficiency.
Horizontal drilling and hydraulic fracturing are processes used to extract natural gas and oil from shale and tight rock formations. The operation involves drilling a vertical well more than a mile below ground and then extending the well horizontally 2,000 to 5,000 feet into the shale. Next, hydraulic fracturing injects large volumes of pressurized water along with sand and additives into the well to create small fractures in the rock that allow the natural gas or oil to travel back to the wellbore. This combination of horizontal drilling and hydraulic fracturing has unlocked previously unattainable U.S. oil and gas resources.

The Technology

Horizontal drilling and hydraulic fracturing first emerged in the early 20th century, although the technologies did not reach commercial viability until many decades later. The full integration of these two technologies — along with 3D seismic mapping — in the late 1980s is credited with unlocking the United States’ shale resources and sparking the current energy boom. Since the 1980s, both technologies have progressed considerably. Horizontal drilling is now so advanced that drillers can adjust the drill string’s position through the horizontal section of a shale formation to access the most promising areas. Meanwhile, new hydraulic fracturing techniques and fluid compositions have helped boost yields. At the same time, companies have increasingly emphasized environmental sustainability in the fracturing process by improving the precision of fractures, reducing the number of additives contained in fluids and strengthening the monitoring process.

The Benefits

- **Increased resource production**: Horizontal drilling and hydraulic fracturing have unlocked vast quantities of domestic unconventional resources — generating substantial economic growth and enhancing our country’s energy security.
- **Improved environmental performance**: In addition to boosting the production of natural gas — a relatively clean and energy-efficient fuel — these technologies have also increased the productivity of wells, thereby reducing the environmental footprint associated with extraction.
Horizontal Drilling and Hydraulic Fracturing
Technologies To Recover Oil and Gas and Boost Domestic Energy Production

Drilling companies use more than 3 million pounds of casing and cement to construct wells that typically reach 2,000 to 6,000 feet or more below the surface.

Natural gas wells go thousands of feet below the earth's surface and groundwater supplies to free trapped natural gas in shale rock.

That's equivalent to more than FOUR Empire State buildings below or farther than a mile.

Carbon Capture, Use and Storage

Driving Down Emissions from Coal-Fueled Power Plants, Driving Up Oil Production

Carbon capture, use and storage (CCUS) is a process in which fossil fuel-fueled power plants capture and then store the carbon dioxide (CO₂) that is released during power generation. During the use stage of CCUS, the CO₂ from coal combustion is pressurized and injected into oil reservoirs to increase the productivity of wells, a process known as enhanced oil recovery (EOR). By combining carbon capture and storage with EOR, CCUS not only reduces overall emissions from coal power generation but also increases oil production.

The Technology

There are three main categories of CO₂ capture systems: post-combustion, oxy-combustion, and pre-combustion. In post-combustion systems, CO₂ produced during coal combustion is bubbled through a solvent to separate it from the flue gas stream. An alternative method for separating CO₂ is to combust the coal in the presence of pure oxygen rather than air, a process known as oxy-combustion. Using pure oxygen produces a flue gas that is mainly water vapor and CO₂, which can easily be processed and compressed. Finally, in pre-combustion systems the coal is gasified to produce a synthetic gas composed of carbon monoxide (CO) and hydrogen. The CO is then reacted with water to produce CO₂, while the hydrogen is diverted to a turbine to generate power. Finally, CO₂ captured from these processes is pressurized and transported via pipeline to oil fields where it is injected into wells during the EOR process. Injecting CO₂ into the wells releases additional quantities of trapped oil that cannot be recovered by conventional means. When EOR is complete, the well is sealed, and the captured CO₂ is stored permanently.

The Benefits

- **Improved environmental performance**: CCUS technology dramatically decreases the amount of CO₂ emissions released from fossil fuel power stations, allowing for near-zero emissions power generation.

- **Enhanced energy security**: CCUS provides a low-cost, low-carbon method for generating power from coal, the world’s most abundant energy resource.

- **Increased efficiency**: When paired with EOR, CCUS increases the productivity and extends the productive life of oil reservoirs.
Carbon Capture, Use and Storage
A System To Capture, Store and Recycle Carbon Dioxide from Power Plants
Software Continuous Emissions Monitoring System

Accurately and Affordably Measuring Large-Source Emissions

The Software Continuous Emissions Monitoring (CEM®) system is a patented, model-based predictive emissions monitoring system that provides a cost-effective alternative to hardware-based monitoring systems. Software CEM® combines powerful process analytics with real-time sensor validation to provide predictive emissions values with unsurpassed accuracy.

The Technology

Introduced in 1992 and approved by the U.S. Environmental Protection Agency, Software CEM® was the first software-based predictive emissions monitoring system and is recognized by regulatory agencies worldwide as a solution that meets compliance requirements. The Software CEM® system can be used in a range of different unit operations including boilers, gas turbines, reciprocating engines, heaters, and regenerative and conventional thermal oxidizers. With more than 350 installations worldwide in its 22-year history, each requiring yearly certification, Software CEM® has achieved a track record of 100 percent compliance.

Software CEM® uses the Pavilion8 Model Analytic Engine to provide highly accurate measurements of nitrogen oxides, carbon dioxide and other emissions. The Software CEM® system continuously monitors emissions by means of an online model using historical and real-time source data from existing plant sensors. This dynamic system predicts emissions even in the extreme operating ranges of the unit by considering the combustion source and how pollutants are generated. In addition, the built-in sensor validation system detects and compensates for failed or drifting sensors — resulting in higher uptime, rapid reconstruction of bad sensor values and early detection of improper unit operation.

The Benefits

- **Improved environmental performance:** Highly accurate and reliable emissions and compliance information increases operational confidence and can help maintain emissions levels within limited parameters.
- **Increased efficiency:** Emissions monitoring can help maximize the efficiency of burner operation.
- **Cost savings:** Software CEM® results in lower installation and operating costs with higher reliability than hardware-based solutions.
Software Continuous Emissions Monitoring System
A Tool for Measuring Industrial Emissions in Real Time

OUTPUTS
Fuel flows
Fuel quality
Air Flow
Process O\textsubscript{2}
Temperatures
Ambient Humidity
NO\textsubscript{X}
O\textsubscript{2}
CO
Emission Alarms
Sensor Alarms

Real-Time Visualization & Environmental Management Reports

Patented Sensor Validation

Data Qualification and Sensor Validation

INPUTS
Cache

Data Analytics — Model Analytic Engine

Multiple Data Sources
Floating Liquefied Natural Gas Facilities

Expanding the Scope of Economically and Technically Feasible Natural Gas Resources

Floating liquefied natural gas (FLNG) facilities enable the development of offshore natural gas resources by housing production, processing, liquefaction and transportation capabilities in one floating, offshore facility. By eliminating the need for onshore pipelines and liquefaction infrastructure, FLNG facilities can provide a cost-efficient and flexible method of developing previously uneconomical natural gas resources.

The Technology

Building on years of industry experience designing and constructing land-based liquefied natural gas (LNG) plants, the early-stage project development of FLNG plants began in the 1990s. In 2011, a consortium of private companies began work on an FLNG facility off of Australia’s western coast. When completed, this facility will be roughly one-quarter of the size of a comparable conventional onshore LNG facility.

In the absence of pipelines, natural gas must be converted to a liquid prior to transport, shrinking the volume of the gas by 600 times to drastically reduce shipping costs. Typically, this process involves transporting natural gas from offshore fields via pipelines to onshore liquefaction facilities. FLNG facilities would eliminate the need to transport offshore gas to land-based facilities before shipping it to market, instead allowing the gas to be processed, treated, liquefied and loaded onto ocean-going carriers close to the offshore production site. To ensure that these operations are conducted safely, FLNG facilities will be outfitted with a number of new technologies such as LNG tanks that can withstand sloshing and LNG offloading arms to facilitate secure transfers in open water.

The Benefits

- **Improved environmental performance:** Offshore FLNG facilities reduce the energy industry’s impact on the marine environment by avoiding the construction of additional offshore pipelines.

- **Increased resource development:** FLNG facilities will enable the development of small or remote offshore gas resources that would otherwise be uneconomic or technically infeasible.
Floating Liquefied Natural Gas Facilities
An Offshore Facility for Processing, Liquefying and Transporting Natural Gas
H-Class Gas Turbine in Combined Cycle

More Flexible, More Efficient Gas-Powered Electricity

H-class gas turbines, used in combined cycle power plants (CCPPs), use both a natural gas and steam turbine to achieve high efficiency and low emissions. The H-class combined cycle plant also has the operating flexibility to start up quickly and the ability to vary its electricity output in just minutes, which improves generating efficiency while supporting grid reliability.

The Technology

After World War II, the aviation industry began to leverage jet engine technology for power generation. However, it was not until 1965 that gas turbines began to be used in power generation. Following a blackout in much of the Northeast, it was discovered that gas turbines, with their flexible fuel capability and short delivery cycles, provide a reliable and flexible source of backup power. Building on decades of improvements to gas turbine designs, the H-class turbine entered the U.S. market in mid-2010 with greater efficiency due to the combined cycle design. Operation of six H-class turbines has begun in the United States in the past two years.

Like other CCPPs, the H-class combined cycle plant contains both a gas turbine and a steam turbine. The exhaust heat from the gas turbine is recovered and then used to heat water and produce steam to run the steam turbine. Using the two turbines in tandem takes advantage of the high inlet temperature of the gas turbine and the low waste-heat of the steam turbine. By combining electrical output from both turbines, the H-class system produces more than 410 megawatts of electricity at more than 60 percent efficiency. H-class turbines can also vary their output in just minutes, while maintaining higher efficiency and reduced emissions compared to other CCPPs.

The Benefits

- **Increased efficiency:** Compared to simple cycle gas turbine technologies, the new generation of H-class gas turbines in combined cycle consumes one-third less natural gas and emits one-third less carbon dioxide while still generating the same amount of power.

- **Enabling grid flexibility and reliability:** It takes H-class gas turbines just minutes to switch from full to half power (or vice versa), enabling them to optimally compensate for natural fluctuations in rapidly increasing grid feed-ins from wind and solar energy sources.
H-Class Gas Turbine in Combined Cycle Power Plant
World-Class Efficiency and Flexibility for Power Generation

- High efficiency through evolutionary 3D blading
- Fast cycling capability through fast-acting variable guide vanes (VGV); improved efficiency through four stages of VGV
- All rotating blades replaceable without rotor destack or lift
- Emission control and fuel flexibility
  Advanced Can Annular combustion system
- High-performance four-stage turbine with advanced materials and thermal barrier coatings on stages 1 and 2
- High cycling capability due to fully air-cooled hot gas path without cooling air coolers
- Reduced service times through service-friendly design: vane 1 as well as blades 1 and 4 replaceable without cover lift; all turbine vanes and blades replaceable without rotor lift
- World-class fast cold and hot start capability by fast thermal response of rotor due to internal cooling air passages
- Easy rotor destacking onsite due to individual disc assembly with Hirth serration and central tie rod
- Reduced engine performance losses through active turbine clearance control via Hydraulic Clearance Optimization (HCO)
- Minimized degradation with HCO by protection of clearances at high-load transients

Inventing the Future: How Technology Is Reshaping the Energy and Environmental Landscape
Transport Integrated Gasification™

Converting Coal into a Clean-Burning Gas

The Transport Integrated Gasification (TRIG™) process is designed to provide a clean, efficient and reliable method for using low-cost, low-rank coal — an abundant fuel resource — in electric power generation. Specifically, TRIG™ converts coal into a clean-burning gas that can fuel integrated gasification combined-cycle power plants, which are designed to be more efficient and cleaner than traditional coal-fired plants. In addition, TRIG™ incorporates process enhancements that can increase affordability. For instance, in some markets, carbon captured in conjunction with the TRIG™ process can be sold for use in enhanced oil recovery, which can significantly offset the cost of fuel. In markets where the cost of natural gas is high or supply is constrained, TRIG™ offers the energy security of using an indigenous coal resource that often goes unused.

The Technology

TRIG™ has been developed over the last two decades at the Power Systems Development Facility — now the National Carbon Capture Center — in Alabama, which is a focal point of the U.S. Department of Energy’s efforts to expand technologies that reduce greenhouse gas emissions from coal- and natural gas-based power generation. The nation’s first commercial-scale deployment of TRIG™ is under development at the Kemper County energy facility in Mississippi.

During the gasification process, coal is fed into the gasifier and heated to a high temperature and high pressure. The combination of heat and pressure turns the coal into gas, facilitating removal of hydrogen sulfide and carbon dioxide and creating a clean-burning gas fuel. Specifically, TRIG™ improves upon the traditional gasification process by using air, rather than pure oxygen, to gasify the coal and by allowing a high rate of coal-to-gas conversion.

The Benefits

- **Improved environmental performance:** TRIG™ is designed to support coal-based generation with resulting carbon dioxide emissions equivalent to a similarly sized natural gas plant.
- **Increased efficiency:** TRIG™ is designed to produce more power with lower operation and maintenance costs than is currently possible with other gasification technologies.
- **Preserving a global fuel resource:** More than half the world’s coal reserves consist of lower-grade lignite and subbituminous coal, which TRIG™ was developed to use. As global electricity demand grows, TRIG™ can provide a valuable solution for 21st century coal generation, particularly in the countries of Eastern Europe, China, South Korea, Australia and Indonesia.
Transport Integrated Gasification (TRIG™)
An Advanced Technology for Use in Coal-Based Power Generation
Supersonic Ejectors

Capturing and Reusing Leaked Natural Gas from Pipeline Compressors

Supersonic ejectors (SSEs) are devices that capture low-pressure gas leakage from the gas seal vents of a compressor and then re-inject the captured gas into the fuel gas line of a gas turbine. By reclaiming gases normally vented into the atmosphere, SSEs help to decrease hydrocarbon emissions and reduce operating costs.

The Technology

SSEs were first developed in 2005 and have already experienced several rounds of modification and optimization under a collaboration agreement between TransCanada and Dresser-Rand. Dresser-Rand has been offering the technology to the market since 2009. For example, a family of three different ejector sizes was developed and tested in 2010. The different sizes allow the SSEs to cover a greater range of operating conditions associated with gas turbine-driven pipeline compressors.

SSEs are devices that capture and boost the pressure of leaks from gas seals so that they can be re-injected into gas turbine fuel systems. They contain no moving parts and do not require compressor modifications or a power source. To re-inject the emissions, the seal gas pressure must be increased from about 50 pounds per square inch (psi) to 500 psi.

This pressure increase can be achieved using a two-stage system with two ejectors working in tandem. In the first stage, a high-pressure motive gas from the compressor discharge accelerates through a supersonic nozzle into a mixing chamber. There, the motive fluid combines with the low-pressure fugitive emissions before going through a diffuser to create a higher (intermediate) pressure combined stream. In the second stage, another stream of motive gas accelerates through a second supersonic nozzle and into a mixing chamber where it mixes with the intermediate pressure combined stream. Finally, the combined gas enters a supersonic diffuser to achieve the pressure level required for re-injection. The ability of SSEs to increase the pressure of leaking gas by such a large degree, in order for it to be injected back into the fuel line, makes them unique in the industry.

The Benefits

- **Improved environmental performance:** By reclaiming gases that would otherwise leak into the atmosphere, SSEs reduce hydrocarbon-related emissions.
- **Cost savings:** SSEs get their energy from the pressure of the gas in the fuel line, so there is no cost associated with powering them. Captured leakage gas is consumed by the gas turbine, therefore operating and maintenance costs are reduced due to lower fuel use.
Supersonic Ejectors: How They Work
A Device for Capturing and Recycling Escaped Natural Gas

1. The supersonic ejector (SSE) captures gas leaked from the gas seal vents of a compressor.

2. A two-stage system increases the pressure of the leaked gas before re-injecting it into the gas turbine.

3. The re-injected gas leakage lowers operating and maintenance costs and reduces total fuel emissions.

KEY
- P1: 1st stage motive pressure
- P2: Suction pressure (1st stage)
- P3: Interstage pressure
- P4: 2nd stage motive pressure
- P5: Fuel gas pressure
Co-Extrusion Printing

High-Speed, Ultraprecise Printing of Structures for More Efficient Energy Devices

Co-extrusion printing is a novel technology developed to produce highly structured thick films used in solar cells and batteries. Thick films produced by co-extrusion printing improve device performance through the more precise use of active materials and can be run at speeds compatible with high-volume manufacturing for solar and batteries. The printheads, inks and processes required for co-extrusion printing have been successfully developed and tested and have already been delivered to a leading solar cell manufacturer for use in production.

The Technology

Traditionally, the efficiency of solar cells’ energy production has been limited by the electric wires that crisscross their surface. Although necessary for transmitting electric current through the cells, these wires also cast small shadows that reduce the amount of sunlight that can reach the cell for conversion into electricity. Co-extrusion printing addresses this limitation by producing exceptionally narrow wire gridlines that cast smaller shadows and allow more sunlight to reach the solar cell.

Specifically, the printhead on a co-extrusion printer is made up of many minute channels and nozzles that deposit a paste onto a substrate. The paste is made up of a combination of the materials needed to produce the gridlines for solar cells or electrodes for batteries. Co-extrusion printing is able to deposit single materials at a width that is smaller than the nozzle opening from which they were extruded. This enables the creation of solar cell or lithium-ion battery elements with a width of just 10–100 micrometers.

The Benefits

- **Increased efficiency:** Lithium-ion battery electrodes produced using co-extrusion printing are up to 20–30 percent more energy dense than typical lithium-ion batteries, resulting in higher storage capacity and leading to 20–30 percent longer ranges for electric vehicles.

- **Increased efficiency:** Finer wire gridlines on solar cells allow each cell to capture more sunlight and contribute to higher system efficiency and electricity production without increasing the number of cells.
Co-Extrusion Printing
A Novel 3D Printing Method for More Efficient Solar Cells and Batteries

1. Materials used as inputs in solar cells or lithium-ion batteries are mixed with additives to form a silver paste.

2. The paste is fed through a print head with minute channels and nozzles, depositing extremely thin strips onto metal foil.

3. The additive material disappears when the paste is heated or dried, leaving behind a thin silver wire for use in solar cells or a solid battery cathode.
Sanitaire OSCAR™ Process Performance Optimizer

Automating and Optimizing the Wastewater Treatment Process

The Sanitaire OSCAR™ Process Performance Optimizer automatically detects and reports conditions in wastewater treatment tanks to improve the quality of treated sewage water and conserve energy at treatment plants. The OSCAR system employs a new generation of process controllers, automated reports, summary graphics, and an online maintenance interface to provide plant operators real-time information and tools for managing chemical and biological conditions in treatment tanks. In addition, the OSCAR system’s advanced and comprehensive reporting tools and controls can help plant operators adapt and respond to emerging wastewater treatment challenges, such as more stringent regulatory requirements, resource limitations, population growth and aging infrastructure.

The Technology

To safely discharge or reuse wastewater for new applications, it first must be treated to remove contaminants that could damage human health or the environment. The “activated sludge process” — which uses living microbes to digest the nutrients and contaminants in wastewater — requires plant operators to constantly monitor and adjust equipment and energy inputs to keep the microbes alive and the treatment process stable. Over the past 20 years, advances in technology have facilitated the development of reactive and predictive process controllers that detect tank conditions and help optimize the treatment process.

Specifically, the Sanitaire OSCAR solution uses feedback from online sensor instruments to detect key conditions in wastewater tanks, such as ammonia, nitrate and oxygen levels, and make real-time adjustments to the equipment that controls the amount of air and biomass in the tanks. This continuous adjustment process eliminates the need for operators to manually monitor and adjust the aeration, pumping and mixing rates at treatment facilities, thereby improving the quality of sewage treatment, increasing overall system efficiency and reducing the energy inputs required for wastewater processing.

The Benefits

- **Increased efficiency:** The OSCAR system can reduce energy consumption up to 30 percent through the use of smart instrumentation and controls and save plant operators three to five hours per week in administrative tasks through the system’s automated reporting feature.

- **Improved environmental performance:** The OSCAR solution reduces chemical consumption by up to 45 percent through the precise measurement of needed inputs — both reducing the operating cost and lessening the environmental impact of the treatment process.
Sanitaire OSCAR™ Process Performance Optimizer: How It Works
A Responsive and Dynamic System for Managing Conditions at Wastewater Treatment Plants

OSCAR takes wastewater treatment plant equipment control to the next level by leveraging Xylem’s team of process, electrical and mechanical experts.

Advanced sensors allow OSCAR to dynamically adapt to changing influent conditions.

OSCAR optimizes the equipment performance to reduce energy consumption.

OSCAR offers reporting capabilities to analyze and optimize performance.