Global Energy: Challenges To Technology And Opportunities For Licensing

Edited By Gus G. Orphanides

At the Fall 2006 LES (USA & Canada) Annual Meeting in New York City, the Chemicals, Energy and the Environmental Committee of LES International and the Chemicals, Energy and Materials Committee of LES (USA & Canada) sponsored a mini-plenary session on *Global Energy*. Leaders from government, industry and funded institutes presented facts, figures, insights, challenges and hopeful options that society is relying on to solve one of the greatest, if not the greatest, challenges to our way of life: having enough energy to spur and sustain economic growth and development without strangling humanity in a noose of greenhouse gas emissions and climate change. Just about all conceivable energy source challenges and options were covered at the session, as was the realization that licensing was going to figure into the solution as a mechanism to ally interested parties into collaborations and ventures that can solve the problem and motivate the committed participants.

What follows is a collection of presentation excerpts by each of the presenters who are as follows: Samuel F. Baldwin, Ph.D., Peter Dobson, Ph.D., Norma Formanek, Andrew Barron, Ph.D., Simon Hobbs, Stanley Gembicki Ph.D., M. Rashid Khan, Ph.D., Carsten Heide.

This is their story.

Addressing The Energy Crisis: Efficiency And Renewables

By Samuel Baldwin

Our current energy use raises serious security, environmental, and economic challenges. The United States has 2 percent of the world's oil reserves but consumes 26 percent of world's oil production. This dependence on foreign oil increases our trade deficit and risks our national security and economic vitality. We can't end our dependence on oil soon, but we can develop alternative fuels and improve vehicle fuel efficiency to significantly reduce it. Optimistic forecasts of conventional oil outside the Middle East estimate that those supplies will peak around 2020 to 2030. (Non-conventional oil from oil shale or tar sands can make up some of the gap, but also faces additional technical, economic, and environmental constraints). It takes time to make change happen on such a large scale, so waiting is not an option; the time to act is now.

"There is strong evidence that global warming is occurring and that the warming of recent decades can be attributed to human activities," state the National Academies of Science of Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, the United Kingdom and the United States, and they urge all nations to take prompt action to reduce the causes of climate change. The effects of climate change include extremes of rain and drought, melting glaciers and ice caps, large scale movement of agricultural zones, and acidification of the ocean. The use of coal, oil and natural gas for global energy needs is the largest contributor to the atmospheric emissions that are the primary cause of global warming.

Energy is vital for modern life and economic strength. Consider the result when power is disrupted. The Northeast power blackout in the summer of 2003 paralyzed the region. Overall, power interruptions—momentary and longer—have been estimated to cost the U.S. economy, very roughly,

■ Gus G. Orphanides, President gNOSSIS, LLC
E-mail: gusorphanides@gnossisllc.com

■ Samuel F. Baldwin, Ph.D., U.S. Department of Energy: Chief Technology Officer and Member, Board of Directors, Office of Energy Efficiency and Renewable Energy
E-mail: sam.baldwin@ee.doe.gov

■ Peter Dobson, Ph.D., Professor, Oxford University and Oxonica
E-mail: peter.dobson@begbroke.ox.ac.uk

■ Norma Formanek, Sr. Vice-President and General Counsel and Corporate Secretary, Electric Power and Research Institute
E-mail: nformane@epri.com

■ Andrew R. Barron, Ph.D., Associate Dean for Industry Interactions and Technology Transfer in the Weiss School of Natural Sciences, Rice University
E-mail: arb@rice.edu

■ Stanley Gembicki, Ph.D., Vice-President, UOP

■ Simon Hobbs., Business Development Director, UOP
E-mail: simm.hobbs@uop.com

■ M. Rashid Khan, Ph.D., Intellectual Assets Management and Technology Consultant of Saudi Aramco (current assignment to King Abdullah University of Science & Technology)
E-mail: Rashid.Khan.1@aramco.com

■ Carsten Heide, Associate Director, University of North Dakota Energy and Environmental Research Center
E-mail: cheide@undeerc.org

$80 billion per year. More reliable energy systems are needed that can reduce these costs.

The Advanced Energy Initiative announced by the President in 2006 includes research in nuclear energy and coal energy with carbon sequestration for capturing green house gases and, in the Office of Energy Efficiency and Renewable Energy (EERE), biomass, solar, and wind energy supply, hydrogen, and energy efficiency, particularly in transportation. Advances in energy efficiency since the early 1970's have cut our consumption rate today nearly in half compared to what it would otherwise have been if efficiency improvements had not been implemented across our economy. Continuing efforts at EERE to improve the efficiency of end-use systems still offer tremendous potential to lower energy consumption in the future. Buildings account for 2/3 of the electricity consumed in the U.S., of which some 30 percent is for lighting. EERE has a goal to increase the efficiency from the current 17 lumens per watt for incandescent lights or 80 lumens per watt for fluorescents to 160 lumens per watt using advanced solid state lighting technology. Research over the past 30 years led the way to cut refrigerator energy use by a factor of 4—an example of what can be done through energy efficiency.

Transportation is another area of opportunity. Advanced fuels such as ethanol from cellulosic biomass, advanced hybrid vehicles, reduced aerodynamic drag, and lightweight composite frames are just a few of the areas we are conducting research on. Plug-in hybrid vehicles can actually help support electricity grids and also allow greater use of intermittent renewables such as wind and solar. Hydrogen fuel cell vehicles may be an important contributor in the longer term.

Biomass provides roughly 3 percent of our energy needs today, such as for firing boilers in the paper industry. In future years, research could enable replacement of as much as 30 percent or more of current gasoline use with ethanol from cellulosic biomass. Our goal is to drive the cost of cellulosic ethanol down to $1.07/gallon by 2012. Biomass can be a feedstock for producing a wide range of biodegradable plastics and other high value materials.

Wind energy today costs 4-5 cents/kWh (kilowatt hours), with research targeting 3 cents/kWh by 2012. Land based wind energy systems offer more than 2800 GW (giga watts) of potential; offshore wind systems offer more than 1000 GW. In comparison, the total installed capacity for all power systems in the U.S. today is roughly 1000 GW.

Solar energy costs have been reduced to roughly 20 cents/kWh, down from over $2 twenty-five years ago. The President's Solar America Initiative has a goal of driving photovoltaic costs down to 5-10 cents/kWh by 2015. Although Europe and Japan are ahead of the U.S. in photovoltaics production in recent years, in part due to their very high electricity prices compared to those in the U.S., the work we currently have underway will enable us to catch up and to cost effectively tap the enormous4 solar resources we have in the U.S.

We have a tremendous opportunity and obligation to advance these new energy efficiency and renewable energy technologies as quickly as possible to help ensure our national security, environmental quality, and economic vitality.

Oxonica Tales: Challenges of an Energy Solution Start-up

By Peter Dobson

Multiple challenges are faced by those entering or wanting to enter the global energy arena the least of which include how do we utilize natural sources to produce chemicals and higher value derivatives having high functionality in a safe and energy efficient manner, how do we use hydrocarbon fuels more efficiently and reduce CO2 emissions, how do we lower the costs of manufacturing materials as we try to make them more functional, and how do we conserve energy. Entrepreneurs who want to get in this arena are further challenged by the time it takes to go from a lab idea, to a patent, to a prototype, to a commercial product success. Nothing new to the reader so far who perhaps has lived through new product development and commercialization ventures, but to the start-up company that is about to embark on the journey, especially for the first time, these challenges are survival issues which might be solved by licensing.

Taking lessons from others, Oxonica, a spin-out company formed in 1999 from the University of Oxford, has succeeded in licensing and partnering early-on in the cycle with parties who possessed necessary and complementary success factors that could shorten the time to commercial launch. Oxonica has a pipeline of opportunities as shown in Figure 1. And two of them, Sunscreens and Fuel Emission Catalyst, have been moved faster to commercialization by licensing and partnering.

Oxonica developed a 'Sunscreen' derived from titanium dioxide doped with an active ingredient that is more effective than existing products at mitigating the effects of light induced free radicals on the skin. Resistance to accepting the claims of this sunscreen product was encountered from the more well known market players, for a variety of reasons. Then Oxonica

Figure 1: Oxonica Product Pipeline

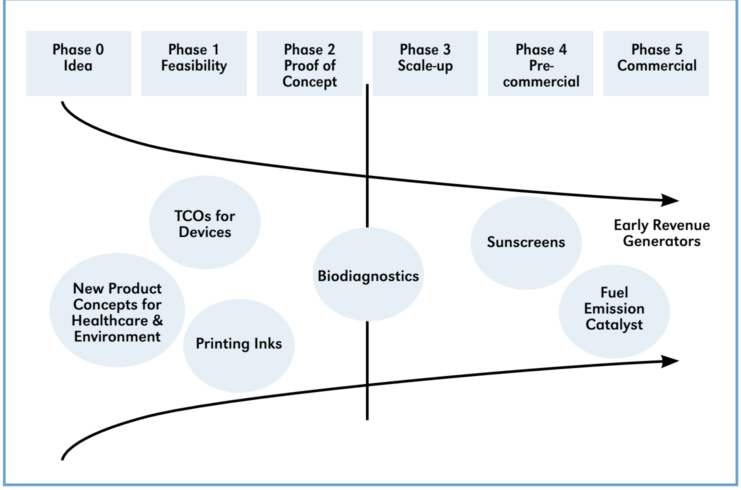


Figure 2: EPRI's Collaborative Research Program

Power Generation	Nuclear Power	Power Delivery and Markets	Environment
Distributed Resources	Materials Reliability	Transmission & Distribution	Air Quality
Fossil Steam Plants	Component Reliability & Safety	Substations	Global Climate Change
Combustion Turbines	Nuclear Operations & Asset Management	Grid Reliability	Land & Groundwater
Market Analysis	Nondestructive Evaluation	Energy Utilization	Water & Ecosystems
Renewables	New Plant Technology	Transportation (PHEV)	Electromagnetic Fields (EMF)
Hydroelectric		Power Quality	Occupational Health & Safety

found an alternate market path by partnering with a supermarket food chain in the United Kingdom, Boots Chemists, who brought the product to the store shelves in 2006 and are about ready to roll out the product in other countries.

Similarly, the 'Fuel Emission Catalyst' venture was energized by a non-obvious market player. The product is trademarked Enivox™ fuel catalyst and is derived from cerium oxide nanoparticles dispersed in diesel fuel. The product increases fuel efficiency by up to 10 percent and minimizes the carbon-based particulate emissions from diesel combustion engines. The big oil companies, who naturally would be at the top of the list of potential partners, were not interested because Oxonica was too small an entrant. A bus company in the United Kingdom, Stagecoach, showed enough interest to justify larger-scale controlled field trials that brought the attention of others and that eventually led to license deals elsewhere.

The lesson to be learned is to seek early-on good partners who possess the skills and capabilities that you lack and thereby complement the critical success factors that can shorten the time to commercialization.

Nuclear Energy: An Option to Our Energy and Environmental Problem

A Presentation by Norma Formanek, Senior VP and General Counsel of Electric Power Research Institute (EPRI)

EPRI founded in 1973 is a tax exempt 501C (3) organization whose research, licensing and patenting activities are directed solely toward the public interest. Ongoing energy research includes power generation, clean coal, fossil fuels, renewables, power delivery, hydroelectric and nuclear that are all overarched with a concern for advancing technologies in the most environmentally sensitive way (Figure 2). EPRI's licensing goal, unlike that of 'for profit' organizations, is not to gain the maximum amount of money from licensing deals, but to get the technology out and used to benefit stakeholders and consumers, and to do it in a non-discriminatory manner to as many parties as possible.

Critical success factors for the U.S. electric power industry will continue to include energy efficiency improvements, cost effectiveness, reliability and safety of supply and environmental consciousness. No one power option can achieve all those success factors. But a portfolio of options can. One piece is nuclear which has had virtually no attention paid to it in the United States for decades, but that is now resurfacing as an important option for the U.S. power industry going forward. EPRI works with its stakeholder partners and membership to find ways to maximize utilization of existing nuclear assets and to promote and deploy new nuclear technology.

One program is aimed at eliminating "crud," an acronym for Chalk River Unidentified Deposits on nuclear fuel rods. These deposits cause fuel rods to run hotter leading to efficiency loss and increasing the radiation field in the system that poses a danger to plant workers and necessitates careful and costly removal. A solution developed and patented under U.S. 6,396,892 is ultrasonic cavitation, a process that shatters deposit particles. Several utilities have already licensed this technology, including method and apparatus, for deployment in the USA, France, Spain and South Korea.

A second program is aimed at cleaning low level nuclear wastewater. The technology is patented under U.S. 6,972,095 and involves the addition of "magmolecules," chelated magnetic ferritin compounds, to the low level radioactive wastewater to bond the radioactive isotopes and separate them away by magnetic filtration. This promising technology would reduce the volume of low level wastewater and selectively remove the troublesome heavy metal nuclides under better environmentally controlled conditions. Today, pilot field tests are underway with commercialization expected by 2010.

Big Energy Solutions with Complex Licensing Issues

By Andrew R. Barron

In our time, the top two challenges to humanity are energy and water for which a growing world population is competing for access and consumption. Today, energy in the form of electricity is limited both by the distribution of materials—fuel oil, gas and coal—to the combustion and steam generation sites and by the loss factors of moving electrons over wires. A vision of the future, say in 2050, is a worldwide power grid capable of delivering 30-60 terawatts of power distributed, stored and transported as electricity. A vast global electrical power grid comprising 5-6 main centers could supply the world's electricity needs to power industries and commerce if the electricity could be transported cheaply with very low losses.

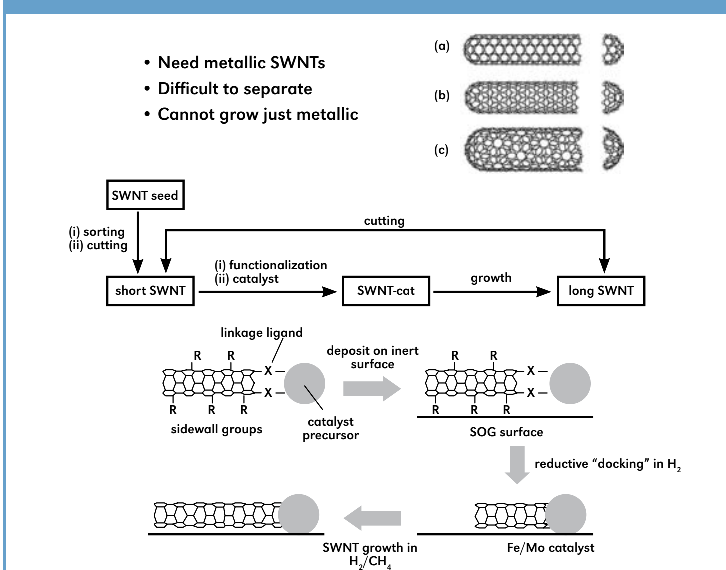
Realizing this vision requires a solution that is potentially available in carbon nanotubes, a field of research for which Rice University is world renown and holdsa world leading patent portfolio. Single wall carbon nanotubes (SWNT) have the electrical conductivity of copper and zero thermal loss of power—the two properties required to realize this vision—and have exceptional fiber strength that is required for wiring. However, limited by today's SWNT manufacturing technology, many isomers of SWNT are formed and only a few of them have the metallic conductive properties capable of performing as electricity conduits.

New technology under development at Rice is aimed at a solution to this problem, illustrated in Figure 3. A complete solution requires first separating the desired metallic conductive isomers from the rest, cutting these desired metallic forms into smaller ones, functionalizing them so that a metal catalyst can be attached at their ends, using the resultant cut and functionalized metallic SWNT to seed growth of longer SWNT that are subsequently purified. The resultant desired SWNT are formed into fibers and some held out to be recycled back into the process to be cut, functionalized, seeded and purified, thus repeating the process.

In addition to the technical challenge, there is also a licensing challenge. Although Rice does hold more SWNT patents than any other institution, there are 128 other university patent holders of 554 patents, as of September 2006. And the free arena of public information includes nearly 6,000 articles on the subject, worldwide. As in other fields of new energy development, licensing becomes an enabler to commercialization for interested parties willing and capable of technical and commercial execution. Negotiating deals that satisfy the licensor and motivate the licensee to invest and develop further continues to be a challenge.

Rice University has had early success in spinning-off four start-ups in the field: CNI, NanoComposites, NanoRidge and NewCyte. These start-ups have been licensed rights to practice in fields-of-use in selected market segments. The rapid proliferation of patents and publications in this area presents challenges to Rice and to other patent owners necessitating institutions like Rice to work harder to control the disclosure and dissemination of ideas under investigation

Figure 3: A New Technology



and to manage ensuing partnerships with commercial sponsors, start-up licensees and entrepreneurs

Innovation and Methanol in the Economy

By Simon Hobbs and Stanley Gembicki

It is indisputable that global economic growth is driving up energy consumption as proven fossil fuel resources are reaching their limits, and as the search for alternative fuels is surfacing a new set of technological, processing and transportation problems. Figure 4 shows the life expectancy of the known worldwide fossil fuel reserves and reveals that the planet will be out of oil and natural gas by mid-century and out of coal by end-of-century, if consumption continues to grow at 2.5 percent annually.

That forecast alone justifies the need to reduce the growth rate of energy consumption and to drive the search for (1) alternatives, including biofuels from lignocellulose, (2) methods to utilize difficult-to-process resources (e.g. tar sands), and (3) advancements in nuclear, hydroelectric, geothermal, wind, tidal and solar power. The search for diversified energy sources should be accompanied by development and deployment of technologies for recovering and recycling CO2 if climate change is to be mitigated.

Part of the answer is methanol. A lot has changed since the 1830s when the first methanol technology from the wood distillation was implemented. Today methanol is readily manufactured on a large scale and is transportable as a high energy density, usable transportation fuel—either directly, or by blending, or as a converted dimethylether product. Methanol also is convertible to useful chemical intermediates, such as ethylene and propylene, and can be an electricity source in methanol fuel cells. Today's large scale production technology starts from methane that is partially oxidized or reformed with steam into an intermediate 'syngas' mixture of carbon monoxide and hydrogen that is further converted to methanol. Production costs have dropped significantly as advancements in technologies with their greater economies of scale have been deployed in mega-size methanol projects. The largest plant today is a 5,000 megaton per day facility in Trinidad. Two larger units are in design and planning for deployment in Nigeria and Qatar. Beyond scale, a key economic factor is that methanol can be produced from low value, stranded natural gas, thereby multiplying the economic profile it offers as an alternative fuel and raw material source to high value-added materials.

Figure 4: Worldwide Carbon Energy Reserves

	Oil	Gas	Coal
Proven Reserves *Billion Tonnes Oil Equivalent*	163.6	161.9	448.5
Reserves/2005 Production *Years*	65	40	155
Reserves/2005 Production, @2.5%/yr CAGR *Years*	38	27	63

Source: BP Statistical Review of World Energy, June 2006

Licensing is an enabler for the transformation to a 'methanol economy.' UOP offers licenses for its 'methanol to olefins technology.' Projects in Nigeria, the Middle East and China are planned using UOP technology that fits well at locations having access to limited quantities of natural gas. UOP is developing new methanol technology by direct, selective oxidation from natural gas that would avoid the intermediate 'syngas' step. Novel catalysts are in development for this direct methane-to-methanol conversion. Pilot trials are expected in 2008-2009.

Figure 5 illustrates another advantage that methanol has in the energy-climate equation, namely its derivability from CO2, thereby enabling CO2 to be recycled. More research and resources are needed to implement this option and before a methanol based economy can emerge as a possible solution to the energy-climate equation.

Energy for the World by Innovation

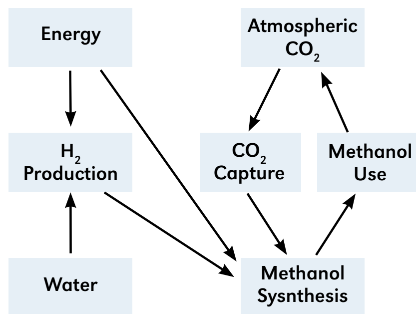
By Rashid Khan

Global energy demand is projected to increase nearly 50 percent over current levels by 2030, and Saudi Aramco, world's largest and the state owned oil producer in Saudi Arabia, intends to remain a critical provider of products to meet that demand challenge. Realizing that merely sitting atop the world's largest oil reserves is not enough to maintain its leadership, Saudi Aramco launched an enterprise innovation program with stated aims of providing energy to the world, creating local jobs in energy and diversifying the local economy.[1] Their enterprise solution included the creation and assembly of technology and intellectual asset management groups and the deployment of an idea management system that in total constitute an enterprise climate where innovation can bare, birth and nurture new products and businesses around energy. Management has embraced this initiative.

1. M. Rashid Khan and Al-Ansari (2006), "Idea Management System (IMS), An Innovation System to Create Value from Concepts," *les Nouvelles*, December 2006, p. 246-252.

Figure 5: Methanol Based Economy: Sustainability Issues

- Methanol is a convenient means to transport and use energy and carbon
- Still need an energy *source* to produce it
  - Coal, Natural Gas, Tar Sands
  - Biorenewables, Nuclear, Solar, Wind
- Can use methanol to recycle CO_2



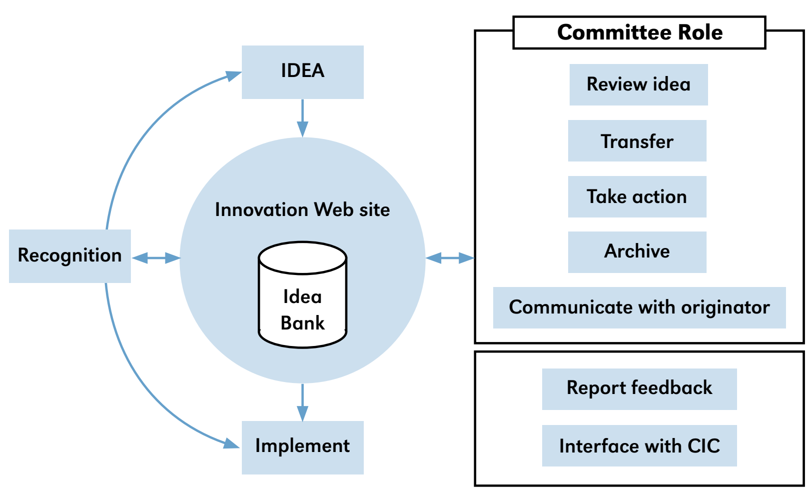
Methanol Can Play a Role in Sustainable Energy

Since first instituted 5 years ago, Saudi Aramco's innovation and idea management system has yielded over 50,000 ideas and is providing a steady pipeline of inputs to support operations. The process works by collecting ideas and processing them through a knowledge sharing phase, with minimal filtering and limiting, where improved-upon ideas are further processed into solutions and patents as is appropriate. The process is measured and metrics are fed-back to the community to stoke more creativity and empower and reward employees. Figure 6 illustrates how ideas flow through the process.[2]

Information technology ideas have worked their way through the innovation process and idea management pipeline and have played a significant role at Saudi Aramco in maximizing efficiency in all aspects of company operation from exploration and production, efficient recovery to refining, pipeline, and HR management. And some of those technologies also were externally deployed as licensing deals in related and non-related fields-of-use. Examples of technology and software that have resulted from this initiative include differentiated capabilities to measure real time reservoir characteristics, to enable accurate sizing and design of process equipment, to provide precise online process flow control and to enable novel flare design for reducing air pollution. These technologies were levered through licensing deals in the pharmaceutical market space where they can help minimize errors in integrated prescription management.

Saudi Aramco intends to maintain its focus on supplying energy to the world through innovation and it sees part of the solution to the world's energy problem in innovation and idea management.

Figure 6: Saudi Aramco's Corporate Idea Management Process



Saudi Aramco's Corporate Idea Management Process: Idea submitter submits an idea to the Idea Bank by addressing the idea to a particular Idea Management Committee (IMC). The Idea Management Committee then reviews the idea in order to take the appropriate action. The actions may include communicating with the originator to determine the most appropriate action to be taken for the ideas, including transferring to another IMC, or considered for immediate implementation depending on the maturity of the idea. In the extreme case, the idea is "archived" for future usage. The responsible department implements the idea no matter where the idea was generated. The Corporate Innovation Committee (CMC) monitors the overall innovation and the software program.

2. M. Rashid Khan (2005) "Sustainable Innovation as a Corporate Strategy," *Journal of TRIZ, http://www.triz-journal.com/archives/2005/01/02.pdf*

Quoting Professor Dickey who back in 1958 said, "We usually find oil in a new place with new ideas. Sometimes, we find oil in an old place with a new idea, BUT we seldom find much oil in an old place with an old idea. Several times in the past we thought we were running out of oil, whereas actually we were running out of ideas."[3]

Innovation and Future Energy Challenges–An R&D View

By Carsten Heide

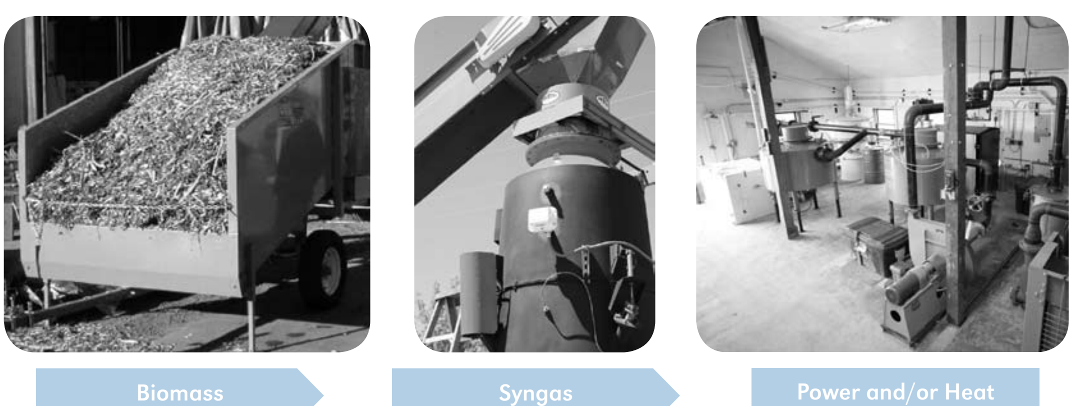
The Energy & Environmental Research Center (EERC) in North Dakota is a leading developer of cleaner, more efficient and innovative energy technologies. The EERC is a research center that develops and creates the innovations and supporting intellectual property. Associated with the center is a Foundation, which extracts value through licensing. The EERC develops energy options intended to guarantee the United States clean and reliable energy supplies and environmental options to protect its air, water and soil. The EERC applies a business model that emphasizes the demonstration and commercialization phases of technology development based on partnerships.

The need for both "more energy" and "more environmental protection" will continue to drive change in the industry and in the overall global economy for decades to come. The challenge is to provide solutions that are practical and cost-effective. Energy and environmental innovation, as the EERC sees it, requires efforts in research, development and demonstration (RD&D) to bring practical solutions into the market. Pursuits in coal, emission controls, hydrogen, CO2 sequestration, toxic metals, renewables, waste management, alternative fuels, and supercritical extraction technologies are all part of the ongoing EERC efforts. Over 90 percent of the EERC's contracted projects are co-funded by non-federal institutions through "cash-only" contributions, and its on-site demonstration facilities enable realistic technical and economic evaluations. Demonstration usually occurs with a partner, and commercialization typically involves an investor.

One of the major challenges in the energy sector and to national security is the power grid. The large-scale energy infrastructure in the United States comprises a few large nodes that offer an economy of scale but also present an inflexible response time when perturbations disrupt supply. Note that the blackout in the Northeastern United States in 2003 affected 15 percent of the U.S. population and that Hurricane Katrina caused blackouts for 3 million people requiring years to return power. Furthermore, the inherent efficiency losses of large distributed electrical systems reveal that only 30 percent of the energy input reaches retail consumers and end users.

A potential solution to this inflexibility and inefficiency may be in smaller distributed energy systems developed and licensed by the EERC. One such is the biomass gasification technology illustrated in

Figure 7: Biomass Gasification Technology



3. Dickey, P.A. (2002), "Oil is Found with Ideas," *Oil & Gas Journal*, 100 (35).

Figure 7, which is a packaged power generation system capable of generating 100 to 1,000 kilowatts of electricity for mobile and stationary heat and power. Wood is most commonly used, but other agricultural residues and coal can also be used in the system. Advantages include 50 percent lower capital requirements than that for a conventional combustion-based boiler of equal size and lower fuel transportation costs because the fuel is on-site and avoids long distance shipping.

The role licensing played in this EERC innovation is an interesting one. UTEK, a company specializing in facilitating technology transfer, showed an early interest in a specific biomass gasification system for a client looking for lower-cost, biomass-based power systems to sell. UTEK formed a subsidiary in order to facilitate the technology transfer from the EERC Foundation to UTEK's client. The subsidiary licensed the technology from the EERC Foundation, and the technology was later sold to the client in exchange for equity. The client and the EERC are co-funding the continued demonstration and "productizing" of the technology. The client intends to become the leader in distributed energy solutions to industrial and commercial clients that have the simultaneous needs to use their waste biomass while satisfying their power and gas requirements.

Licensing is managed by the EERC Foundation and is an integral part of the Foundation's business practices. Integral to all commercialization efforts is the development of the business opportunity in conjunction with the licensed technology. Commercialization requires demonstration of the technology and forms the basis of the EERC/EERC Foundation business model. ■