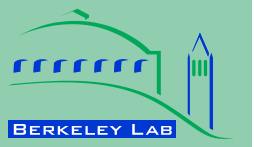

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Pre-Commercialized Energy Efficiency and Clean Energy Technologies from the United States

China Energy Group
Energy Analysis and Environmental Impacts Division
Energy Technologies Area

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Disclaimer

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Dark-Colored Cool Pigments for Materials Exposed to the Sun (Lawrence Berkeley National Laboratory)

For the building and automobile industries in need of dark-colored products that can stay cool in the sun, this technology uses fluorescent materials that re-radiate absorbed light rather than converting it all to heat. The Berkeley Lab invention promises a solar reflectance over 0.5 in dark colors — a significant improvement over commercially available products.

APPLICATIONS OF TECHNOLOGY:

Materials for

- Roofing
- Siding
- Automobile finishes
- PVC piping
- Outdoor enclosures for electronics (e.g., cell phone towers)

ADVANTAGES:

- Meets industry and consumer demand for dark-colored building and automotive materials that stay cool in warm or hot climates
- Solar reflectance over 0.5

ABSTRACT:

The building and automobile industries need to meet consumer demand for non-white or dark-colored products that can stay cool in warm and hot climates; however, their performance is limited by commercially available pigments that convert light from the visible spectrum to heat.

Paul Berdahl of Berkeley Lab has developed Dark-Colored Cool Pigments for Materials Exposed to the Sun. Unlike conventional technologies, the invention uses fluorescent pigments that re-radiate and reflect light from both visible and near-infrared (NIR) spectra rather than absorbing these light rays and converting them to heat. Because the invention is not limited to using white pigments, it will be possible to meet industry and consumer demand for non-white or dark-colored cool-roof materials, such as coatings, tiles, and roofing granules, as well as automobile paint.

The Berkeley Lab invention is a non-white coating with a solar reflectance of more than 0.5 — a significant improvement over commercially available non-white pigments — and will therefore remain cooler in the sun than conventional coatings pigmented with non-fluorescent particles.

With additional development, the technology would save consumers money by reducing their need for air conditioning during the summer, lowering residential and commercial building energy costs.

Widespread use of the Berkeley Lab Dark-Colored Cool Pigments on residential and commercial rooftops also promises to lower outside air temperatures and potentially less smog.

DEVELOPMENT STAGE: Early stage.

STATUS: Patent pending -- available for licensing or collaborative research.

FOR MORE INFORMATION:

Zalich, M., Berdahl, P., "Fluorescent Pigments for High-Performance Cool Roofing," 2014 Building Technologies Office Peer Review, U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy.

REFERENCE NUMBER: IB-3039

SOURCE: http://ipo.lbl.gov/lbnl3039/

Superinsulated Commercial Window Framing System (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

- Window and façade framing systems for non-residential building construction

ADVANTAGES:

- Yields R5 or better performance for commercial fenestration systems
- Comparable cost to conventional thermal break systems
- Can be integrated into existing manufacturing process
- Manufacturing process allows for color selection flexibility

ABSTRACT:

Berkeley Lab researcher D. Charlie Curcija has developed a thermal break technology that enables aluminum window framing to have equal or better thermal performance than wood or PVC at aluminum's cost effectiveness and high strength. The thermal break's unique design fabricated from traditional or bio-based polymers, results in substantially increased length of thermal break and reduced convection heat transfer while achieving the high strength required for commercial fenestration.

The expected performance improvement of the Berkeley Lab window framing system over the mix of framing options available today is 375%. This yields an overall improvement in a window's thermal resistance of 75%, assuming the frame represents about 20% of window area. The resulting U-factor (a measure of heat transfer rate) is a 50% improvement over PVC frames and a 100% improvement over wood.

The goal of the new technology is to achieve R5 or better thermal performance. The researchers determined that, with advanced glazing systems, windows incorporating their thermal break system can reach R10 thermal performance while meeting or exceeding the strictest code requirements (AAMA/WDMA/CSA 101/I.S.2/A440 AW ratings).

Commercial builders seek window framing solutions with the cost and strength of aluminum products plus improved thermal efficiency to meet more stringent building codes. Window framing approaches, such as those incorporating pultruded fiberglass and other fiber reinforced polymers, have proven to be prohibitively expensive, and they cannot be integrated into existing manufacturing processes. The Berkeley Lab technology offers a cost effective, structurally sound solution with high thermal efficiency to this construction sector.

DEVELOPMENT STAGE: Proven principle with prototype under construction

STATUS: Available for licensing or collaborative research.

SEE THESE OTHER BERKELEY LAB TECHNOLOGIES IN THIS FIELD:

EnergyPlus: Energy Simulation Software for Buildings, CR-2118

REFERENCE NUMBER: IB-3155

SOURCE: http://ipo.lbl.gov/lbnl3155/

Ultra-low Emission Natural Draft Burner (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

- Oil refinery process heaters
- Duct burners used in air heaters, heat recovery steam generators, selective catalytic reduction (SCR) reheating and combined heat and power systems
- Induced draft heating systems (furnaces, boilers and water heaters)
- Chemical reactors where reaction products need to be isolated from the reactor assembly

ADVANTAGES:

- Low air emissions, particularly NOx, without post-combustion emissions controls
- Enables refineries to continuing using natural gas or refinery gas for process heating
- Safe in applications where electric spark generation is hazardous

ABSTRACT:

Robert Cheng and David Littlejohn of Berkeley Lab have invented a technology that allows Berkeley Lab's Low Swirl Burner to operate in natural draft mode. This makes the technology useful in operations where electrically powered machinery poses a safety risk, such as refineries. With this technology, petroleum refineries can continue to use natural gas and refinery gas to efficiently heat their petroleum process heaters while significantly reducing air emissions, particularly NOx.

Refineries need to meet air quality regulations without adding complexity, high capital costs and maintenance resources. Berkeley Lab's Ultra-low Emission Natural Draft Burner can reduce burner emissions for refineries without adding the high capital and maintenance costs, as well as constant monitoring requirements, of its main competitor, add-on selective catalytic reduction (SCR) systems.

DEVELOPMENT STAGE: Bench scale testing completed.

STATUS: Patent pending -- available for licensing or collaborative research.

SEE THESE OTHER BERKELEY LAB TECHNOLOGIES IN THIS FIELD:

Ultraclean Low Swirl Combustion, IB-916

Lean Flame Stabilization Ring, IB-996

REFERENCE NUMBER: IB-2777

SOURCE: http://ipo.lbl.gov/lbnl2777/

Ultraclean Low Swirl Combustion (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

Laboratory UCLSB prototype with 5 cm internal diameter, firing at a rate of 15 kilowatts. This burner is made entirely out of plastic components to showcase its unique lifted flame feature.

- Commercial HVAC Systems
- Industrial Boilers
- Distillation Columns
- Water Heaters
- Furnaces
- Clothes Dryers
- Power Generators

ADVANTAGES:

- SAFETY: Broad operating range of the fuel-to-air ratio limits risk of blow-off and flashback
- FUEL EFFICIENCY: Improved fuel efficiency dependent on application
- NOx EMISSIONS: Ultra-low NOx emissions
- OZONE PRODUCTION: Ultra-low NOx means ultra-low ozone production.
- MANUFACTURABILITY: Low tolerance parts, Reynolds number scaling not necessary

ABSTRACT: Burners are used in industry for a wide range of applications including water heaters, power generators, boilers, and HVAC systems. Parallel consumer applications include gas-fired home water heaters, heating systems, and clothes dryers. Natural gas is more efficient and less expensive than electricity and is the current and future fuel of choice. However, conventional gas burners emit oxides of nitrogen (NOx) creating ozone in the lower atmosphere due to incomplete fuel combustion and high temperature operation.

Robert Cheng at Lawrence Berkeley Laboratory originally developed a weak swirl burner as a better way to stabilize flame for scientific study. As with many purely scientific investigations, the resulting device is a better performer than those commercially available. The new burner produces almost no NOx, the chemical responsible for ozone in the lower atmosphere. The shape and temperature of the flame are responsible for the improvement, but the actual result will be device dependent. The simplicity of the new design eliminates device scaling and tolerance problems thereby aiding manufacturability. The design could replace most medium and small scale burners with flame temperature requirements below 2,600deg.F.

Market Driver: NOx is responsible for the dirty brown air over most U.S. cities. More than 100 U.S. cities have unsafe ozone levels that exceed federal health standards. Many cities are considering limiting installation of new conventional gas burners. Government energy-saving incentives and pollution control regulations like those for efficient lighting and auto emissions should cause the market to grow at a rapid pace.

STATUS: U.S. Patent #5,735,681 and #5,879,148. Available for licensing.

REFERENCE NUMBER: IB-916/ IB-1175

FOR ADDITIONAL INFORMATION, PLEASE SEE:

Ultraclean Low-swirl Combustion in the News

- http://eetd.lbl.gov/newsletter/nl14/lowswirl.html

Ultraclean Low-swirl Combustion Will Help Clear the Air

- http://eetd.lbl.gov/newsletter/nl14/lowswirl.html
- http://www.lbl.gov/Science-Articles/Archive/EETD-low-swirl-combustion.html

Ultra-Low Emissions Low-Swirl Burner

- http://eetd.lbl.gov/aet/combustion/LSC-Info/

Ultra-Clean Low Swirl Combustion L2M 10 Years Later

- http://eetd.lbl.gov/l2m2/lowswirl.html

PUBLICATION:

Scaling and Development of Low -swirl Burners for Low Emission Furnaces and Boilers, *Proceedings of the Combustion Institute, V*olume 28, 2000/pp. 1305–1313

Laboratory Investigation of an Ultralow NOx Premixed Combustion Concept for Industrial Boilers, *Proceedings of the Combustion Institute,* Volume 29, 2002/pp. 1115–1121

SOURCE: http://ipo.lbl.gov/lbnl0916/

Fast Method to Mimic Soiling and Weathering of Cool Roofing and Other Building Materials (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

- Manufacturers of high-reflectance or "cool" roofing materials
- Other building materials manufacturers: roofing, siding, windows, facades
- Environmental testing laboratories
- Photovoltaics manufacturers
- Automakers

ADVANTAGES:

- Achieves results quickly to speed new product development
- Combines simulated soiling and weathering
- Can be tailored to local environmental conditions

ABSTRACT:

Berkeley Lab scientists led by Mohamad Sleiman, Thomas Kirchstetter, Hugo Destaillats, and Ronnen Levinson have developed an innovative technology that can mimic, in just a matter of days, the effect on new building materials of years of outdoor exposure to atmospheric dirt and variable weather conditions. This technology is of particular benefit to cool roof materials, which reflect a high proportion of sunlight into the atmosphere to reduce the energy and expense of air conditioning while lowering ambient air temperature in urban areas. Currently, the natural deposition of soot, salt, dust and organic matter conspire to degrade the reflectance of surface materials. Manufacturers can design soil-resistant roofing materials, but standards require three years of outdoor testing to gauge how effective a new product may be. This impedes development and investment in these innovative roofing materials.

The Berkeley Lab team addressed this problem by formulating a spray containing the agents that soil roofs. Roof surface soiling is typically a consequence of exposure to soot (black carbon), dust, salts, and decomposed organic debris. The mix in the spray can be tailored to match the environmental conditions of different locales. For example, Arizona roofs are affected mostly by dust; Florida roofs, by organics; and Ohio roofs, by soot.

The technology includes protocols for exposing the surface of roofing samples to ultraviolet light, water vapor, and simulated rain in a commercial "weatherometer" system; spraying the formulated soil mixture onto the surface; and finally subjecting the surface to a final cycle of weathering. Tests using roofing samples exposed to natural outdoor conditions show that the Berkeley Lab technique can accurately mimic the effects of multiyear exposure in as few as three days. The system works on roofing materials such as tiles, asphalt shingles, polymer membranes, metal, and modified bitumen. The technique can also be used to test coatings and other materials designed to reduce the effect of soiling on cool roofs, siding, glass, photovoltaic panels, or automobile exteriors.

DEVELOPMENT STAGE: Bench-scale prototype

STATUS: Patent pending. Available for licensing or collaborative research.

SEE THESE OTHER BERKELEY LAB TECHNOLOGIES IN THIS FIELD:

Superhydrophilic Nanostructure for Antifogging Glass, IB-2687

REFERENCE NUMBER: JIB-3082

SOURCE: http://ipo.lbl.gov/lbnl3082/

Ultraclean Low Swirl Combustion (Lawrence Berkeley National Laboratory)

DOE Program
Location: Cambridge, MA
Project Term: 06/01/2013 to 12/31/2014
Project Status: ALUMNI
Website: www.mit.edu(link is external)
Technical Categories: Renewable Power: Water

Critical Need:

Hydraulic fracking, the process commonly used for oil and natural gas extraction, uses significant amounts of water. The water that returns after being used in the process, called produced water, is contaminated and needs extensive treatment before it can be reused. Currently, there are only 2 options for treating this water: (1) transporting the water off-site to existing water treatment facilities that then become overburdened or (2) using very energy intensive, evaporation based water treatment processes on-site. There is a need to develop a robust, inexpensive, low energy on-site water treatment technology.

Project Innovation + Advantages:

MIT is developing a water treatment system to treat contaminated water from hydraulic fracking and seawater. There is a critical need for small to medium-sized, low-powered, low-cost water treatment technologies, particularly for regions lacking centralized water and energy infrastructure. Conventional water treatment methods, such as reverse osmosis, are not effective for most produced water cleanup based on the high salt levels resulting from fracking. MIT's water treatment system will remove high-levels of typical water contaminants such as salt, metals, and microorganisms. The water treatment system is based on low-powered generation enabling efficient on-demand, on-site potable water production. The process allows for a 50% water recovery rate and is cost-competitive with conventional water treatment technology. MIT's water treatment device would require less power than competing technologies and has important applications for mining, oil and gas production, and water treatment for remote locations.

Impact Summary:

If successful, MIT's water treatment system enables on-demand water production based on user requirements, therefore significantly increasing water generation efficiency and delivery in rural areas and the mining and gas industry.

Security:

Improving water treatments processes can help secure clean water for drinking, agricultural, and industrial applications and help the U.S. position regain its technological leadership in the area of water treatment.

Environment:

Improving water treatment processes and wastewater reuse could yield an estimated 290 trillion watts in energy savings over 10 years, corresponding to 177 million tons of carbon dioxide.

Economy:

Inexpensive and reliable access to potable water could help drive U.S. economic growth in both agricultural and industrial purposes.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/scalable-low-power-water-treatment-system

High-temperature topping cells from LED materials (Arizona State University)

DOE Program: FOCUS
Location: Tempe, AZ
Project Term: 05/30/2014 to 05/29/2017
Project Status: ACTIVE
Website: www.asu.edu(link is external)
Technical Categories: Renewable Power: Solar

Critical Need:

There are two primary methods for capturing and using sunlight today: direct conversion of sunlight to electricity using photovoltaic (PV) solar panels, or focusing sunlight onto a fluid that is used to drive a steam turbine in concentrated solar power (CSP) systems. Storing hot fluid in CSP systems is a less expensive way to generate electricity when the sun is not shining compared to storing electrical energy from PV in batteries. However, PV uses just part of the solar spectrum at high efficiency, while CSP systems use the entire solar spectrum but at low efficiency. Combining the best elements of these two technologies could provide a means to get the most out of the full solar spectrum, generating both electricity and storable heat (for later use) within the same system. Developing hybrid solar energy systems that perform both functions at the same time could provide electricity at cost comparable to traditional sources, whether the sun is shining or not.

Project Innovation + Advantages:

ASU is developing a solar cell that can maintain efficient operation at temperatures above 400°C. Like many other electronics, solar panels work best in cooler environments. As the temperature of traditional solar cells increases beyond 100°C, the energy output decreases markedly and components are more prone to failure. ASU's technology adapts semiconducting materials used in today's light-emitting diode (LED) industry to enable efficient, long-term high-temperature operation. These materials could allow the cells to maintain operation at much higher temperatures than today's solar cells, so they can be integrated as the sunlight-absorbing surface of a thermal receiver in the next generation of hybrid solar collectors. The solar cell would provide electricity using a portion of the incoming sunlight, while the receiver collects usable heat at high temperature that can be stored and dispatched to generate electricity as needed.

Impact Summary:

If successful, ASU's solar cell will extract far more energy from the highest-energy portion of the solar spectrum than today's solar cells when used at high temperatures in the next generation of hybrid solar energy systems.

Security:

Developing new hybrid solar systems that generate both electricity and dispatchable heat at the same time could provide clean domestic power at costs comparable to traditional sources, whether the sun is shining or not.

Environment:

Replacing energy systems powered by fossil fuels would provide an immediate decrease in greenhouse gas emissions, 40% of which come from electricity generation today.

Economy:

Cost-effective, dispatchable solar energy alternatives would stabilize electricity rates for consumers as the penetration of renewable energy increases in the coming years.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/high-temperature-topping-cells-led-materials

Renewable Energy Materials

- Field-effect P-N Junctions for Low Cost, High Efficiency Solar Cells and Electronic Devices (Lawrence Berkeley National Laboratory)
- Self-powered Gating and Other Improvements for Screening-engineered Field-effect Photovoltaics IB-3170 (Lawrence Berkeley National Laboratory)
- Highly Efficient Multigap Solar Cell Materials (Lawrence Berkeley National Laboratory)
- Direct Thin Film Path to Low Cost, Large Area III-V Photovoltaics (Lawrence Berkeley National Laboratory)
- Indium Phosphide Polycrystalline Films on Metal Foil for PV Applications (Lawrence Berkeley National Laboratory)
- Fully Integrated Nanosystem for Artificial Photosynthesis (Lawrence Berkeley National Laboratory)
- Artificial Photosynthesis: Chemical Synthesis Powered by Sunlight (Lawrence Berkeley National Laboratory)
- SODIUM-BETA BATTERIES FOR GRID-SCALE STORAGE (EaglePicher Technologies)
- AIRBORNE WIND TURBINE (Makani Power)
- POWER GENERATION USING SOLAR-HEATED GROUND AIR (Georgia Tech Research Corporation)
- SOLAR THERMAL ENERGY STORAGE DEVICE (Massachusetts Institute of Technology)
- LASER-MECHANICAL DRILLING FOR GEOTHERMAL ENERGY (Foro Energy)
- PRUSSIAN BLUE DYE BATTERIES (Alveo Energy)
- ALL-IRON FLOW BATTERY (Case Western Reserve University)
- STACKED HYBRID SOLAR CONVERTER (Massachusetts Institute of Technology)
- ALUMINUM PRODUCTION USING ZIRCONIA SOLID ELECTROLYTE (INFINIUM)
- MID-TEMPERATURE FUEL CELLS FOR VEHICLES (Ceramatec)
- IRON FLOW BATTERY (Energy Storage Systems)
- IMPROVING SOLAR GENERATION EFFICIENCY WITH SOLAR MODULES (California Institute of Technology)
- SODIUM-BASED ENERGY STORAGE (Sharp Laboratories of America)
- ADVANCED VANADIUM REDOX FLOW BATTERY (ITN Energy Systems)
- IRON-NITRIDE ALLOY MAGNETS (Case Western Reserve University)
- SOLAR-CONCENTRATING PHOTOVOLTAIC MIRROR (Arizona State University)
- HIGH-EFFICIENCY SOLAR CELLS (MicroLink Devices)
- FABRIC-BASED WIND TURBINE BLADES (GE Power & Water)
- HIGH-STORAGE DOUBLE-MEMBRANE FLOW BATTERY (University of Delaware)

Field-effect P-N Junctions for Low Cost, High Efficiency Solar Cells and Electronic Devices (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

- Solar cells
- Light-emitting diodes (LEDs)
- Laser diodes (LDs) for telecommunication, optical storage, and other devices

ADVANTAGES:

- Uses abundant, nontoxic materials
- Employs a straightforward technology
- Easily incorporated into current manufacturing processes
- Yields lower costs and higher efficiencies for solar cells and electronic devices using both industry standard and novel abundant materials.
- Provides access to several new light wavelengths for LEDs and LDs

ABSTRACT:

Berkeley Lab scientists Alex Zettl and William Regan have developed a straightforward technology that enables fabrication of high efficiency, single junction photovoltaic (PV) cells from inexpensive, abundant, and nontoxic materials—notably metal oxides and sulfides. Berkeley Lab's field-effect p-n junction lowers manufacturing costs and increases the efficiencies of PV cells and other electronic devices without the need for costly chemical doping techniques. In addition to solar cells, this technology can be used to produce LEDs and laser diodes from a variety of abundant, nontoxic semiconducting materials which emit at currently inaccessible wavelengths, providing new commercial opportunities in lighting systems, optical storage, and medical applications.

The technology adapts the well-known field-effect—in which a gate controls band bending in a nearby semiconductor—to produce electrically contacted p-n junctions in intrinsically singly doped semiconductors. Using a sophisticated theoretical model tailored to semiconductors of choice, the gate and top electrode configuration is systematically optimized to allow simultaneous electrical contact to and carrier modulation of the top surface of the semiconductor. This field-effect "doping" is a compelling alternative to chemical doping or intrinsic heterojunction formation. The process requires only electrode and gate deposition, without high-temperature chemical doping, ion implantation, or other processing.

Compared to existing p-n junction fabrication methods, the Berkeley Lab technology reduces the cost and complexity of fabricating devices such as solar cells and LEDs; results in higher quality p-n junctions; and allows the creation of p-n junctions in abundant, nontoxic materials that are difficult or impossible to dope by conventional methods. Such materials include metal sulfide and oxide semiconductors such as cuprous oxide, which has a theoretical photovoltaic efficiency greater than 20%. In addition, established photovoltaics and electronics manufacturers using toxic or rare materials could quickly

adapt this simple technology to current production processes, easing the transition to incorporating sustainable and inexpensive materials in their devices.

Photovoltaics are a promising source of renewable energy, but current technologies, including thin films, face a cost-to-efficiency tradeoff that has slowed their implementation. Chemically doped crystalline silicon is fast approaching fundamental cost minima. Competing thin film technologies depend on hazardous materials such as cadmium, or increasingly rare materials, such as indium (for copper-indium-gallide-selenide PV cells).

DEVELOPMENT STAGE: Proven principle.

STATUS: Patent pending. Available for licensing or collaborative research.

FOR MORE INFORMATION:

http://newscenter.lbl.gov/feature-stories/2012/07/26/photovoltaics-from-any-semiconductor/

Regan, W., Byrnes, S., Gannett, W., Ergen, O., Vazquez-Mena, O., Wang, F., and Zettl, A. "Screening-Engineered Field-Effect Solar Cells," *Nano Letters*, Vol. 12, pp. 4300−4304, 2012.

REFERENCE NUMBER: IB-3094

SOURCE: http://ipo.lbl.gov/lbnl30943170/

Self-powered Gating and Other Improvements for Screening-engineered Field-effect Photovoltaics (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

- Solar cells
- Light-emitting diodes (LEDs)
- Laser diodes (LDs) for telecommunication, optical storage, and other devices

ADVANTAGES:

- Uses abundant, nontoxic materials
- Employs a straightforward technology
- Easily incorporated into current manufacturing processes
- Yields lower costs and higher efficiencies for solar cells and electronic devices using both industry standard and novel abundant materials.
- Provides access to several new light wavelengths for LEDs and LDs

ABSTRACT:

The Berkeley Lab scientists further improved on IB-3094 by creating several methods for powering the gate field in the innovative p-n junction to eliminate the need for any external power sources. In one method, the gate electric field is maintained by a "self-gating" feedback loop in which a wire connects the cell output to the gate contact. An alternate method to power the gate utilizes materials with fixed surface or bulk charge, including many dielectrics (e.g., alumina), ferroelectrics, and electrolytes. Various configurations combining these two new techniques have been developed that boost the gating effect, which improves the cell performance even further. Strategies have been developed for both vertical and back-contact-only devices.

Zettl and Regan have also added a new architecture to their class of field-effect cells, especially suitable for thin film photovoltaics, in which screening is minimized. Strategies are proposed for self-gating this new architecture.

DEVELOPMENT STAGE: Proven principle.

STATUS: Patent pending. Available for licensing or collaborative research.

FOR MORE INFORMATION:

http://newscenter.lbl.gov/feature-stories/2012/07/26/photovoltaics-from-any-semiconductor/

Regan, W., Byrnes, S., Gannett, W., Ergen, O., Vazquez-Mena, O., Wang, F., and Zettl, A. "Screening-Engineered Field-Effect Solar Cells," *Nano Letters*, Vol. 12, pp. 4300−4304, 2012.

REFERENCE NUMBER: IB-3170

SOURCE: http://ipo.lbl.gov/lbnl30943170/

Highly Efficient Multigap Solar Cell Materials (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

- High efficiency solar cells

ADVANTAGES:

- Makes possible power conversion efficiencies surpassing 50% with a single p/n junction
- Promises low production costs

ABSTRACT:

Scientists at Berkeley Lab have invented multiband gap semiconducting materials for developing solar cells that could achieve power conversion efficiencies of 50 percent or higher. A single junction of the materials contains three band gaps that together absorb photons from virtually the entire solar spectrum, providing high efficiency without complex, high cost, multijunction fabrication. Layered, multijunction cells are the most efficient photovoltaics currently on the market. A power conversion efficiency of 30 percent has been achieved for the most efficient two-junction cell.

Wladyslaw Walukiewicz, Kin Man Yu, and Junqiao Wu have created highly mismatched alloys (HMAs) by replacing a fraction of group VI atoms in traditional IIVI group semiconductor alloys with oxygen. The alloys are called “highly mismatched” because of the size and electro negativity differences of the component atoms. The Berkeley Lab researchers have demonstrated creating epitaxial II-VI films, specifically ZnMnOTe and CdMgOTe, using ion implantation followed by pulsed laser melting.

A split band gap is created in the Berkeley Lab materials because oxygen is much more highly electronegative than the host metals. In most HMAs the split occurs inside the conduction band, which is not useful for solar cells. In others, a well defined band exists below the conduction band, allowing photons to be absorbed efficiently at three energy levels. The Berkeley Lab scientists have developed a band anticrossing model to predict the split gap effects of various materials. Using the model they successfully predicted that adding oxygen impurities to ZnMnTe and CdMgTe would result in highly efficient materials.

Berkeley Lab inventors have produced p-type and n-type versions of the split band material and observed photovoltaic response in a wide photon energy range. Optimal efficiency will be approached as researchers are able to increase the depth of the oxygen layer.

STATUS: Issued U. S. Patent 7,709,728 available at www.uspto.gov. Available for licensing or collaborative research.

FOR MORE INFORMATION:

Yu, K. M., Walukeiwicz, W., Wu J., Shan, W., Beeman, J. W., Scarpulla, M. A., Dubon, O. D., Becla, P. "Diluted II-VI Oxide Semiconductors with Multiple Band Gaps," *Physical Review Letters*, Vo. 91, No. 24, Dec. 12, 2003.

SEE THESE OTHER BERKELEY LAB TECHNOLOGIES IN THIS FIELD:

Low Cost, High Efficiency Tandem Silicon Solar Cells and LEDs, IB-2357

REFERENCE NUMBER: IB-1964

SOURCE: http://ipo.lbl.gov/lbnl1964/

Direct Thin Film Path to Low Cost, Large Area III-V Photovoltaics (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

- Photovoltaic cells
- Photoelectrochemical cells
- Thin film transistors

ADVANTAGES:

- High power conversion efficiency (25%)
- High material utilization (90%)
- Large crystal size (100 – 200 µm)
- Optical and electrical properties approaching state-of-the-art

ABSTRACT:

A team of Berkeley Lab researchers has invented the first vapor-liquid-solid (VLS) growth technology yielding III-V photovoltaics. The photovoltaics achieve 25% power conversion efficiency at a cost significantly lower than current approaches due to the non-epitaxial processing approach and high material utilization rate.

The films have grain sizes of 100-200 microns (100 times larger than yielded from conventional growth processes), minority carrier lifetimes up to 2.5 nanoseconds and electron mobilities reaching 500 cm2/V-s. Under one-sun equivalent illumination, an open circuit voltage of up to 930 mV can be reached, just 40 mV lower than measured on a single crystal wafer.

Berkeley Lab researchers fabricated continuous thin films of polycrystalline indium phosphide (InP) directly on metal foils by, first, depositing an indium (In) thin film directly on molybdenum (Mo) foil. Next, they deposit a thin capping layer to prevent dewetting of the indium from the substrate during subsequent high temperature processing steps. The resulting stack (Mo – In – capping layer) is then heated in the presence of phosphorous precursors causing supersaturation of the liquid indium with phosphorous, followed by precipitation of InP, thus turning all the In into InP.

III-V photovoltaics deliver the highest power conversion efficiencies, but significant processing costs (expensive materials and equipment, low precursor utilization rate) have limited their use. Berkeley Lab's non-epitaxial growth technology overcomes these limitations to deliver a promising low cost solar cell.

DEVELOPMENT STAGE: Proven principle

STATUS: Patent pending. Available for licensing or collaborative research.

FOR MORE INFORMATION:

Kapadia, R., Yu, Z., Wang, H-H H., Zheng, M., Battaglia, C., Hettick, M., Kiriya, D., Takei, K., Lobaccaro, P., Beeman, J.W., Ager, J.W., Maboudian, R., Chrzan, D.C., Javey, A. "A direct thin-film path towards low-cost, large-area III-V photovoltaics," *Nature Scientific Reports*, July 24, 3013.

SEE THESE OTHER BERKELEY LAB TECHNOLOGIES IN THIS FIELD:

Indium Phosphide Polycrystalline Films on Metal Foil for PV Applications, IB-3173, IB-3238

Co-implantation of Group VI Elements and Nitrogen for the Formation of Non-Alloyed Ohmic Contacts for n-type GaAs, IB-1609

REFERENCE NUMBER: 2013-069

SOURCE: http://ipo.lbl.gov/lbnl2013-069/

Indium Phosphide Polycrystalline Films on Metal Foil for PV Applications (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

- Photovoltaic panels

ADVANTAGES:

- Higher throughput, lower capital costs
- Compatible with roll-to-roll processing
- Low-cost metal foil substrates

ABSTRACT:

Berkeley Lab researcher Maxwell Zheng and colleagues have developed technologies for economic, high volume production of high optical quality polycrystalline indium phosphide (InP), with optical properties nearly identical to those of InP on single-crystal wafers, on low cost metallic substrates. The technologies reduce costs at both the growth stage and in downstream processing.

Specifically, the researchers demonstrated that polycrystalline InP can be grown on metal foils using closed space sublimation (CSS) process. Effective transfer of the InP source to the foil substrate is made possible in CSS by the small (~2 mm) gap between source and substrate. This technology is easily scalable and adaptable for other technologies, such as photo-electrochemical hydrogen production.

In addition to lower cost, CSS offers superior spatial control and crystalline morphology control, so that the properties of InP devices can be specifically tailored. By tuning the growth conditions, InP nanowires, patterned crystals, and polycrystalline films can be obtained with CSS. The team also used metal organic chemical vapor deposition (MOCVD) to grow InP on metal foil.

InP is a III-V semiconductor, a class of materials that has high absorptivity and mobility, with ideal band gaps for photovoltaic devices. However, use of InP has been constrained because indium is a rare element much costlier than silicon. Currently, leading photovoltaic III-V solar cells are fabricated by complex epitaxial growth processes and epitaxial layer transfer techniques.

DEVELOPMENT STAGE: Bench scale prototype.

STATUS: Patent pending. Available for licensing or collaborative research.

FOR MORE INFORMATION:

Zheng, M., Yu, Z., Seok, T.J., Chen, Y-Z., Kapadia, R., Takei, K., Aloni, S., Ager, J.W., Wu, M., Chueh, Y-L., Javey, A. "High optical quality polycrystalline indium phosphide grown on metal substrates by metalorganic chemical vapor deposition," *Journal of Applied Physics* 111, 123112 (2012).

Kiriya, D., Zheng, M., Kapadia, R., Zhang, J., Hettick, M., Yu, Z., Takei, K., Wang. H-H. H., Lobaccaro, P., Javey, A. "Morphological and spatial control of InP growth using closed-space sublimation." *Journal of Applied Physics* 112, 123102 (2012).

SEE THESE OTHER BERKELEY LAB TECHNOLOGIES IN THIS FIELD:

Hot Electron Photovoltaics Using Low Cost Materials and Simple Design, IB-2195

REFERENCE NUMBER: IB-3173, IB-3238

SOURCE: http://ipo.lbl.gov/lbnl3173_3238/

Fully Integrated Nanosystem for Artificial Photosynthesis (Lawrence Berkeley National Laboratory)

A modular nanosystem that can achieve a solar-to-fuel conversion efficiency of 0.12%.

APPLICATIONS OF TECHNOLOGY:

- Converting solar energy to chemical fuels for the renewable energy industry

ADVANTAGES:

- Efficient and cost-effective solar-to-fuel conversion
- Modular design allows affordable upgrades and mass manufacturing

ABSTRACT:

Researchers at Berkeley Lab have developed an artificial photosynthesis system that can achieve a solar-to-fuel conversion efficiency of 0.12%, which is comparable to that of natural photosynthesis, under simulated sunlight.

Unlike previous technologies, the Berkeley Lab invention does not use macroscopic bulk thin-film devices or non-integrated nanoparticle dispersions for water splitting in solar-to-fuel conversions. With its fully integrated system of nanoscale photoelectrodes assembled from inorganic nanowires for direct solar water splitting, the technology is instead modeled after the photosynthesis system of a chloroplast. All components in this integrated nanosystem are individually positioned to maximize the energy conversion efficiency.

The renewable energy industry has been interested in the mass commercialization of artificial photosynthesis — the biomimetic approach to converting sunlight's energy directly into chemical fuels — but the low conversion efficiency and high material costs of conventional approaches have not made this possible. The Berkeley Lab invention is the first demonstration of a functional, fully integrated nanosystem for a solar-driven water-splitting device. In addition to being highly efficient, the invention's modular design will allow industry to replace specific components without the cost of a whole-system upgrade to achieve competitive performance.

DEVELOPMENT STAGE: Proven principle. Researchers are working to improve the technology's efficiency.

STATUS: Patent pending. Available for licensing or collaborative research.

FOR MORE INFORMATION:

Liu, C., Dasgupta, N. P., Yang, P., "Semiconductor Nanowires for Artificial Photosynthesis," Chemistry of Materials, 2014, 26(1), 415-422, DOI: 10.1021/cm4023198.

Liu, C., Tang, J., Chen, H. M., Liu, B., Yang, P., "A Fully Integrated Nanosystem of Semiconductor Nanowires for Direct Solar Water Splitting," *NanoLetters*, 2013, 13(6), 2989–2992, DOI: 10.1021/nl401615t.

SEE THESE OTHER BERKELEY LAB TECHNOLOGIES IN THIS FIELD:

Tandem Photoelectrochemical Device for Water Dissociation, 2013-136

REFERENCE NUMBER: 2013-124

SOURCE: http://ipo.lbl.gov/lbnl2013-124/

Artificial Photosynthesis: Chemical Synthesis Powered by Sunlight (Lawrence Berkeley National Laboratory)

ABSTRACT:

For the researchers' complete publication ACS NanoLetters, go here.

Direct solar-powered production of value-added chemicals from CO_2 and H_2O, a process that mimics natural photosynthesis, is of fundamental and practical interest. In natural photosynthesis, CO_2 is first reduced to common biochemical building blocks using solar energy, which are subsequently used for the synthesis of the complex mixture of molecular products that form biomass. Here we report an artificial photosynthetic scheme that functions via a similar two-step process by developing a biocompatible light-capturing nanowire array that enables a direct interface with microbial systems. As a proof of principle, we demonstrate that a hybrid semiconductor nanowire–bacteria system can reduce CO_2 at neutral pH to a wide array of chemical targets, such as fuels, polymers, and complex pharmaceutical precursors, using only solar energy input. The high-surface-area silicon nanowire array harvests light energy to provide reducing equivalents to the anaerobic bacterium, Sporomusa ovata, for the photoelectrochemical production of acetic acid under aerobic conditions (21% O_2) with low overpotential ($\eta < 200$ mV), high Faradaic efficiency (up to 90%), and long-term stability (up to 200 h). The resulting acetate (~6 g/L) can be activated to acetyl coenzyme A (acetyl-CoA) by genetically engineered Escherichia coli and used as a building block for a variety of value-added chemicals, such as n-butanol, polyhydroxybutyrate (PHB) polymer, and three different isoprenoid natural products. As such, interfacing biocompatible solid-state nanodevices with living systems provides a starting point for developing a programmable system of chemical synthesis entirely powered by sunlight.

DEVELOPMENT STAGE: Proven principle.

STATUS: Patent pending. Available for licensing or collaborative research.

FOR MORE INFORMATION:

Yarris, L. "Major Advance in Artificial Photosynthesis Poses Win / Win for the Environment." *Berkeley Lab News Center*, April 16, 2015.

Chong, L., Gallagher, J. J., Sakimoto, K. K., Nichols, E. M. Chang, C. J., Chang, M. C. Y., Yang, P. "Nanowire-Bacteria Hybrids for Unassisted Solar Carbon Dioxide Fixation to Value-Added Chemicals." American Chemical Society, March 31, 2015 (online).

REFERENCE NUMBER: 2015-068

SOURCE: http://ipo.lbl.gov/lbnl2015-068/

Sodium-beta batteries for grid-scale storage (EaglePicher Technologies)

DOE Program: OPEN 2009
Location: Joplin, MO
Project Term: 02/01/2010 to 08/19/2015
Project Status: ACTIVE
Website: www.eaglepicher.com(link is external)
Technical Categories: Stationary Storage: Grid-Scale Batteries

Critical Need:

Our national electric grid has limited ability to store excess energy, so electricity must constantly be over-generated to assure reliable supply. Though wind and solar power are promising clean alternatives to fossil fuels, their natural unpredictability and intermittency present major challenges to delivery of the consistent power that is necessary to operate today's grid. The U.S. needs technologies that can store renewable energy for future grid use at any location. Flexible, large-scale storage would create a stronger and more robust electric grid by enabling renewables to contribute to reliable power generation.

Project Innovation + Advantages:

EaglePicher is developing a sodium-beta alumina (Na-Beta) battery for grid-scale energy storage. High-temperature Na-Beta batteries are a promising grid-scale energy storage technology, but existing approaches are expensive and unreliable. EaglePicher has modified the shape of the traditional, tubular-shaped Na-Beta battery. It is using an inexpensive stacked design to improve performance at lower temperatures, leading to a less expensive overall storage technology. The new design greatly simplifies the manufacturing process for beta alumina membranes (a key enabling technology), providing a subsequent pathway to the production of scalable, modular batteries at half the cost of the existing tubular designs.

Impact Summary:

If successful, EaglePicher would reduce the cost of grid-scale energy storage by as much as 50% and increase the grid's ability to store large quantities of renewable energy.

Security:

Grid-scale energy storage would provide a buffer against energy supply disruptions.

Environment:

Electricity generation accounts for over 40% of U.S. carbon dioxide (CO2) emissions. Enabling large-scale contributions of wind and solar power for our electricity generation would result in a substantial decrease in CO2 emissions. This technology would also reduce CO2 by storing electricity that was generated above short-term demand.

Economy:

This project could help establish a viable U.S. Na-Beta manufacturing industry. By 2013, the market for energy storage batteries is projected to exceed $1 billion, with the market for Na-Beta approaching $700 million.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/sodium-beta-batteries-grid-scale-storage

Airborne wind turbine (Makani Power)

DOE Program: OPEN 2009
Location: Alameda, CA
Project Term: 09/01/2010 to 10/16/2013
Project Status: ALUMNI
Website: www.makanipower.com(link is external)
Technical Categories: Renewable Power: Wind

Critical Need:

Renewable energy is critical to our environmental, economic, and national security. Demand for energy is on the rise, as is our national reliance on fossil fuel-based power plants for the bulk of our electricity generation. There is a drastic need for safe, clean, and cost-effective alternatives to coal, such as wind, solar, hydroelectric, and geothermal power. These technologies would reduce carbon dioxide (CO2) emissions and help position the U.S. as a leader in the global renewable energy industry.

Project Innovation + Advantages:

Makani Power is developing an Airborne Wind Turbine that eliminates 90% of the mass of a conventional wind turbine and accesses a stronger, more consistent wind at altitudes of near 1,000 feet. At these altitudes, 85% of the country can offer viable wind resources compared to only 15% accessible with current technology. Additionally, the Makani Power wing can be economically deployed in deep offshore waters, opening up a resource which is 4 times greater than the entire U.S. electrical generation capacity. Makani Power has demonstrated the core technology, including autonomous launch, land, and power generation with an 8 meter wingspan, 20 kW prototype. At commercial scale, Makani Power aims to develop a 600 kW, 28 meter wingspan product capable of delivering energy at an unsubsidized cost competitive with coal, the current benchmark for low-cost power.

Impact Summary:

If successful, Makani Power's airborne turbines would provide clean power at a fraction of the cost of conventional wind turbines and enable the widespread use of renewable energy, resulting in significant reductions in CO2 emissions.

Security:

Increased availability of renewable power would help diversify the U.S. energy portfolio, allowing homeowners and businesses access to a grid that is less dependent on any one source of power.

Environment:

Providing clean electricity would significantly reduce the greenhouse gas emissions associated with electricity generation. Presently, over 40% of U.S. CO2 emissions come from electricity generation.

Economy:

Enabling alternative sources of energy like wind and solar can help stabilize and reduce the price of energy. This could result in significant cost savings over fossil fuels in the years to come.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/airborne-wind-turbine

Power generation using solar-heated ground air (Georgia Tech Research Corporation)

Program: OPEN 2012
ARPA-E Award: $3,699,976
Location: Atlanta, GA
Project Term: 05/03/2013 to 05/02/2016
Project Status: ACTIVE
Website: sov.gatech.edu(link is external)
Technical Categories: Stationary Generation

Critical Need:

Renewable energy is critical to our environmental, economic, and national security. Demand for energy is on the rise, as is our national reliance on fossil fuel-based power plants for the bulk of our electricity generation. There is a critical need for safe, clean, and cost-effective alternatives to coal, such as wind, solar, hydroelectric, and geothermal power. These technologies would reduce carbon dioxide emissions and help position the U.S. as a leader in the global renewable energy industry.

Project Innovation + Advantages:

Georgia Tech is developing a method to capture energy from wind vortices that form from a thin layer of solar-heated air along the ground. "Dust devils" are a random and intermittent example of this phenomenon in nature. Naturally, the sun heats the ground creating a thin air layer near the surface that is warmer than the air above. Since hot air rises, this layer of air will naturally want to rise. The Georgia Tech team will use a set of vanes to force the air to rotate as it rises, forming an anchored columnar vortex that draws in additional hot air to sustain itself. Georgia Tech's technology uses a rotor and generator to produce electrical power from this rising, rotating air similar to a conventional wind turbine. This solar-heated air, a renewable energy resource, is broadly available, especially in the southern U.S. Sunbelt, yet has not been utilized to date. This technology could offer more continuous power generation than conventional solar PV or wind. Georgia Tech's technology is a, low-cost, scalable approach to electrical power generation that could create a new class of renewable energy ideally suited for arid low-wind regions.

Impact Summary:

If successful, Georgia Tech's technology would reduce the cost of energy by 20% over wind power and 65% over solar photovoltaic energy.

Security:

Cost-effective solar energy would increase U.S. renewable energy use and help reduce our dependence on fossil fuels.

Environment:

Replacing energy systems powered by fossil fuels would provide an immediate decrease in greenhouse gas emissions, of which electricity generation accounts for over 40%.

Economy:

Cost-effective renewable energy alternatives would reduce fuel prices and stabilize electricity rates for consumers. Integrating these renewable technologies directly into buildings will reduce stress on the electric grid.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/power-generation-using-solar-heated-ground-air

Solar thermal energy storage device (Massachusetts Institute of Technology)

DOE Program: HEATS
Location: Cambridge, MA
Project Term: 01/09/2012 to 01/08/2015
Project Status: ALUMNI
Website: www.mit.edu(link is external)
Technical Categories: Stationary Storage: Thermal

Critical Need:

Two of the most pressing challenges we face today are addressing our expanding energy needs and reducing our greenhouse gas emissions from the use of fossil fuels. Solar energy offers a promising solution to both challenges because of its abundance and lack of greenhouse gas emissions. However, a transformation from fossil fuels to solar energy requires efficient and cost-effective processes to collect, store, and transport our most plentiful--but intermittent--source of energy. One promising approach is the production of synthetic fuel that can harvest and store the sun's energy in chemical form via rearrangement of photoactive molecules--allowing solar energy to be easily transported and stored in the form of heat on demand.

Project Innovation + Advantages:

MIT is developing a thermal energy storage device that captures energy from the sun; this energy can be stored and released at a later time when it is needed most. Within the device, the absorption of sunlight causes the solar thermal fuel's photoactive molecules to change shape, which allows energy to be stored within their chemical bonds. A trigger is applied to release the stored energy as heat, where it can be converted into electricity or used directly as heat. The molecules would then revert to their original shape, and can be recharged using sunlight to begin the process anew. MIT's technology would be 100% renewable, rechargeable like a battery, and emissions-free. Devices using these solar thermal fuels--called HybriSol--can also be used without a grid infrastructure for applications such as de-icing, heating, cooking, and water purification.

Impact Summary:

If successful, MIT's technology could significantly decrease fossil fuel consumption and greenhouse gas emissions, enabling clean solar energy to be accessible to homeowners and businesses 24 hours a day.

Security:

Greater use of thermal fuels would reduce U.S. reliance on fossil fuels--strengthening America's energy security.

Environment:

Thermal fuel technologies typically do not emit greenhouse gases and can also reduce fossil fuel consumption--helping curb production of carbon dioxide emissions that contribute to global climate change, while enabling the development of transformational technologies for a range of applications.

Economy:

Thermal fuels could spur economic growth in new thermal fuel-related industries in the U.S.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/solar-thermal-energy-storage-device

Laser-mechanical drilling for geothermal energy (Foro Energy)

DOE Program: OPEN 2009
Location: Littleton, CO
Project Term: 01/15/2010 to 09/30/2013
Project Status: ALUMNI
Website: www.foroenergy.com(link is external)
Technical Categories: Renewable Power: Geothermal

Critical Need:

Geothermal energy is a potentially vast source of clean baseload electricity in the U.S. However, it is difficult and expensive to penetrate the ultra-hard rock formations found at many prospective geothermal sites. Conventional drill bits penetrate ultra-hard rock formations slowly and wear down quickly, which makes the drilling process time consuming and expensive. More economical drilling methods are required to enable access to next-generation energy resources, including geothermal and natural gas.

Project Innovation + Advantages:

Foro Energy is developing a unique capability and hardware system to transmit high power lasers over long distances via fiber optic cables. This laser power is integrated with a mechanical drilling bit to enable rapid and sustained penetration of hard rock formations too costly to drill with mechanical drilling bits alone. The laser energy that is directed at the rock basically softens the rock, allowing the mechanical bit to more easily remove it. Foro Energy's laser-assisted drill bits have the potential to be up to 10 times more economical than conventional hard-rock drilling technologies, making them an effective way to access the U.S. energy resources currently locked under hard rock formations.

Impact Summary:

If successful, Foro Energy's technology would be a key enabler of economical access to the estimated over 100,000 megawatts of baseload geothermal electrical power in the U.S. by 2050.

Security:

Increased access to domestic energy sources like geothermal and natural gas would help break U.S. dependence on foreign energy sources.

Environment:

Geothermal resources are a clean, renewable source of baseload electrical power.

Economy:

Cost-effective access to domestic energy resources could help spur expansion of the U.S. geothermal and natural gas industries.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/laser-mechanical-drilling-geothermal-energy

Prussian blue dye batteries (Alveo Energy)

DOE Program: OPEN 2012
Location: Palo Alto, CA
Project Term: 02/21/2013 to 02/20/2016
Project Status: ACTIVE
Website: www.alveoenergy.com(link is external)
Technical Categories: Stationary Storage: Grid-Scale Batteries

Critical Need:

Our national electric grid has limited ability to store excess energy, so electricity must constantly be over-generated to assure reliable supply. Though wind and solar power are promising clean alternatives to fossil fuels, their natural unpredictability and intermittency make them incapable of delivering the power on-demand necessary to operate today's grid. The U.S. needs technologies that can cost-effectively store renewable energy for future grid use at any location. Flexible, large-scale storage would create a stronger and more robust electric grid by enabling renewables to contribute to reliable power generation.

Project Innovation + Advantages:

Alveo is developing a grid-scale storage battery using Prussian Blue dye as the active material within the battery. Prussian Blue is most commonly known for its application in blueprint documents, but it can also hold electric charge. Though it provides only modest energy density, Prussian Blue is so readily available and inexpensive that it could provide a cost-effective and sustainable storage solution for years to come. Alveo will repurpose this inexpensive dye for a new battery that is far cheaper and less sensitive to temperature, air, and other external factors than comparable systems. This will help to facilitate the adoption and deployment of renewable energy technology. Alveo's Prussian Blue dye-based grid-scale storage batteries would be safe and reliable, have long operational lifetime, and be cheaper to produce than any existing battery technology.

Impact Summary:

If successful, Alveo's grid-scale storage battery would provide inexpensive, durable, high-power energy storage to help facilitate the widespread deployment of clean, renewable energy.

Security:

A more efficient and reliable grid would be more resilient to potential disruptions.

Environment:

Electricity generation accounts for over 40% of U.S. carbon dioxide (CO2) emissions. Enabling large-scale contributions of wind and solar power for our electricity generation would result in a substantial decrease in CO2 emissions.

Economy:

Increases in the availability of wind and solar power would reduce fossil fuel demand, resulting in reduced fuel prices and more stable electricity rates.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/prussian-blue-dye-batteries

All-iron flow battery (Case Western Reserve University)

DOE Program: OPEN 2012
Location: Cleveland, OH
Project Term: 01/01/2013 to 05/04/2016
Project Status: ACTIVE
Website: www.case.edu(link is external)
Technical Categories: Stationary Storage: Grid-Scale Batteries

Critical Need:

Our national electric grid has limited ability to store excess energy, so electricity must constantly be over-generated to assure reliable supply. Though wind and solar power are promising clean alternatives to fossil fuels, their natural unpredictability and intermittency make them incapable of delivering the power on-demand necessary to operate today's grid. The U.S. needs technologies that can cost-effectively store renewable energy for future grid use at any location. Flexible, large-scale storage would create a stronger and more robust electric grid by enabling renewables to contribute to reliable power generation.

Project Innovation + Advantages:

Case Western is developing a water-based, all-iron flow battery for grid-scale energy storage at low cost. Flow batteries store chemical energy in external tanks instead of within the battery container. Using iron provides a low-cost, safe solution for energy storage because iron is both abundant and non-toxic. This design could drastically improve the energy storage capacity of stationary batteries at 10-20% of today's cost. Ultimately, this technology could help reduce the cost of stationary energy storage enough to facilitate the adoption and deployment of renewable energy technology.

Impact Summary:

If successful, Case Western's all-iron flow battery would enable storage from renewable energy sources at a substantially reduced cost and with improved performance compared to today's designs.

Security:

A more efficient and reliable grid would be more resilient to potential disruptions.

Environment:

Electricity generation accounts for over 40% of U.S. carbon dioxide (CO2) emissions. Enabling large-scale contributions of wind and solar power for our electricity generation would result in a substantial decrease in CO2 emissions.

Economy:

Increases in the availability of wind and solar power would reduce fossil fuel demand, resulting in reduced fuel prices and more stable electricity rates.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/all-iron-flow-battery

Stacked hybrid solar converter (Massachusetts Institute of Technology)

DOE Program: FOCUS
Location: Cambridge, MA
Project Term: 06/17/2014 to 06/16/2017
Project Status: ACTIVE
Website: www.mit.edu(link is external)
Technical Categories: Renewable Power: Solar

Critical Need:

There are two primary methods for capturing and using sunlight today: direct conversion of sunlight to electricity using photovoltaic (PV) solar panels, or focusing sunlight onto a fluid that is used to drive a steam turbine in concentrated solar power (CSP) systems. Storing hot fluid in CSP systems is a less expensive way to generate electricity when the sun is not shining compared to storing electrical energy from PV in batteries. However, PV uses just part of the solar spectrum at high efficiency, while CSP systems use the entire solar spectrum but at low efficiency. Combining the best elements of these two technologies could provide a means to get the most out of the full solar spectrum, generating both electricity and storable heat (for later use) within the same system. Developing hybrid solar energy systems that perform both functions at the same time could provide electricity at cost comparable to traditional sources, whether the sun is shining or not.

Project Innovation + Advantages:

MIT is developing a hybrid solar converter that integrates a thermal absorber and solar cells into a layered stack, allowing some portions of sunlight to be converted directly to electricity and the rest to be stored as heat for conversion when needed most. MIT's design focuses concentrated sunlight onto metal fins coated with layers that reflect a portion of the sunlight while absorbing the rest. The absorbed light is converted to heat and stored in a thermal fluid for conversion to mechanical energy by a heat engine. The reflected light is directed to solar cells and converted directly into electricity. This way, each portion of the solar spectrum is directed to the conversion system where it can be most effectively used. The sunlight passes through a transparent microporous gel that also insulates each of the components so that the maximum energy can be extracted from both the heat-collecting metal fins and the solar cells. This unique stack design could utilize the full solar spectrum efficiently and enable the dispatch of electricity at any time of the day.

Impact Summary:

If successful, MIT's hybrid solar converter design will enable the capture and conversion of the full solar spectrum into both heat and electricity, allowing dispatch of solar-generated electricity when needed most.

Security:

Developing new systems that generate both heat and electricity at the same time could provide clean, domestically-sourced solar power at costs comparable to traditional sources, whether or not the sun is shining.

Environment:

Replacing energy systems powered by fossil fuels would provide an immediate decrease in greenhouse gas emissions, 40% of which come from electricity generation today.

Economy:

Cost-effective, dispatchable solar energy alternatives would stabilize electricity rates for consumers as the penetration of renewable energy increases in the coming years.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/stacked-hybrid-solar-converter

Aluminum production using zirconia solid electrolyte (INFINIUM)

DOE Program: METALS
Location: Natick, MA
Project Term: 12/12/2013 to 12/10/2016
Project Status: ACTIVE
Website: www.infiniummetals.com(link is external)
Technical Categories: Efficiency: Manufacturing

Critical Need:

Primary production of lightweight metals such as aluminum is an energy-intensive and expensive process that results in significant carbon dioxide (CO2) and other hazardous and corrosive emissions. Lowering the energy consumption, cost, and emissions associated with processing aluminum would make it competitive with incumbent structural metals such as steel. Enabling its widespread use in vehicles in particular--without compromising performance or safety--would substantially reduce fuel consumption and CO2 emissions from transportation.

Project Innovation + Advantages:

INFINIUM is developing a technology to produce light metals such as aluminum and titanium using an electrochemical cell design that could reduce energy consumption associated with these processes by over 50%. The key component of this innovation lies within the anode assembly used to electrochemically refine these light metals from their ores. While traditional processes use costly graphite anodes that are reacted to produce CO2 during refining, INFINIUM's anode can use much cheaper fuels such as natural gas, and produce a high-purity oxygen by-product. Revenue from this by-product could significantly affect aluminum production economics. Traditional cell designs also waste a great deal of heat due to the necessity of keeping the reactor open to the air while contaminated CO2 rapidly exits the chamber. Since INFINIUM's anode keeps the oxygen or CO2 anode gas away from the main reactor chamber, the entire system may be far more effectively insulated.

Impact Summary:

If successful, INFINIUM would deploy low-cost, energy-efficient aluminum-production cells as a drop-in replacement into large production plants.

Security:

Light-weighting vehicles to improve fuel efficiency could reduce U.S. dependence on foreign fossil fuel resources used in the transportation industry.

Environment:

Transforming aluminum production could reduce harmful CO2 emissions by 50-90% and completely eliminate other emissions compared to conventional processing methods.

Economy:

Retrofitting existing aluminum plants reduces risk and capital costs, making light metals a more cost effective option in manufacturing. This technology also enables aluminum plants to replace expensive graphite with cheap, domestically available natural gas as a key component of light metal manufacturing.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/aluminum-production-using-zirconia-solid-electrolyte

Mid-temperature fuel cells for vehicles (Ceramatec)

DOE Program: OPEN 2012
Location: Salt Lake City, UT
Project Term: 02/01/2013 to 01/31/2016
Project Status: ACTIVE
Website: www.ceramatec.com(link is external)
Technical Categories: Transportation Storage: Non-Battery

Critical Need:

Fuel cells can generate power for a wide range of electric vehicles (EVs) and stationary power applications, and they have long been touted as the ultimate clean and renewable energy source. Fuel cells are different from batteries in that they require a constant source of fuel and oxygen to run, but they can produce electricity continually for as long as these inputs are supplied. Fuel cells are a highly efficient form of energy conversion, but have not achieved widespread adoption due to high cost. Higher temperature fuel cells require expensive materials and can degrade quickly. Lower temperature fuel cells require precious metals such as platinum as catalysts. Substantial improvements to both the lifetime and cost of fuel cells are necessary in order to enable viable alternatives to battery-operated EVs and stationary power systems.

Project Innovation + Advantages:

Ceramatec is developing a solid-state fuel cell that operates in an 'intermediate' temperature range that could overcome persistent challenges faced by both high temperature and low temperature fuel cells. The advantages compared to higher temperature fuel cells are less expensive seals and interconnects, as well as longer lifetime. The advantages compared to low temperature fuel cells are reduced platinum requirements and the ability to run on fuels other than hydrogen, such as natural gas or methanol. Ceramatec's design would use a new electrolyte material to transport protons within the cell and advanced electrode layers. The project would engineer a fuel cell stack that performs at lower cost than current automotive designs, and culminate in the building and testing of a short fuel cell stack capable of meeting stringent transportation requirements.

Impact Summary:

If successful, Ceramatec's solid-state fuel cell would help power EVs at a cost and driving range similar to lithium-ion batteries.

Security:

The successful commercialization of this technology would directly enhance the economic and energy security of the U.S. by reducing the dependence of the automotive sector on foreign oil.

Environment:

Enabling the widespread use of fuel cells for advanced vehicle technologies could significantly improve the energy efficiency and emissions of the automotive sector.

Economy:

This technology would ensure the U.S. maintains a technological lead in developing and deploying advanced energy technologies.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/mid-temperature-fuel-cells-vehicles

Iron flow battery (Energy Storage Systems)

Program: SBIR
Location: Portland, OR
Project Term: 10/01/2012 to 03/31/2015
Project Status: ACTIVE
Website: www.energystoragesystems.com(link is external)
Technical Categories: Stationary Storage: Grid-Scale Batteries

Critical Need:

Our national electric grid has limited ability to store excess energy, so electricity must constantly be generated to perfectly match demand. Though wind and solar power are promising clean alternatives to fossil fuels, their natural unpredictability and intermittency make them incapable of delivering the power on demand necessary to operate today's grid. The U.S. needs technologies that can cost effectively store renewable energy for future grid use at any location. Flexible, large-scale storage would create a stronger and more robust electric grid by enabling renewables to contribute to reliable power generation.

Project Innovation + Advantages:

ESS is developing a cost-effective, reliable, and environmentally friendly all-iron hybrid flow battery. A flow battery is an easily rechargeable system that stores its electrolyte--the material that provides energy--as liquid in external tanks. Currently, flow batteries account for less than 1% of the grid-scale energy storage market because of their high system costs. The ESS flow battery technology is distinguished by its cost-effective electrolytes, based on earth-abundant iron, and its innovative battery hardware design that dramatically increases power density and enables a smaller and less costly battery. Creating a high-performing and low-cost storage system would enable broad adoption of distributed energy storage systems and help bring more renewable energy technologies--such as wind and solar--onto the grid.

Impact Summary:

If successful, the ESS' advanced all-iron flow battery technology would ultimately achieve an energy storage cost of $125 per kilowatt hour, representing a substantial price reduction relative to today's most advanced energy storage technologies.

Security:

A more efficient and reliable grid would be more resilient to potential disruptions. Distributed energy storage would improve consumer and grid electricity reliability.

Environment:

Electricity generation accounts for over 40% of U.S. carbon dioxide (CO2) emissions. Enabling large-scale contributions of wind and solar power for our electricity generation would result in a substantial decrease in CO2 emissions.

Economy:

Increases in the availability of wind and solar power would reduce fossil fuel demand, resulting in reduced fuel prices and more stable electricity rates. Distributed energy storage would reduce consumer electricity costs and improve efficiency.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/iron-flow-battery

Improving solar generation efficiency with solar modules (California Institute of Technology)

DOE Program: OPEN 2012
Location: Pasadena, CA
Project Term: 03/28/2013 to 03/13/2016
Project Status: ACTIVE
Website: www.caltech.edu(link is external)
Technical Categories: Renewable Power: Solar

Critical Need:

Photovoltaic (PV) solar electric systems are a growing clean energy alternative to traditional sources of electricity generation, such as coal-burning power plants. One of the biggest obstacles to the widespread deployment of PV systems is the fact that they are rarely cost competitive with conventional sources of electricity. New PV technologies must improve solar energy conversion efficiency while driving down costs in order to make them broadly competitive with traditional power generation methods and help position the U.S. as a leader in the global renewable electricity industry.

Project Innovation + Advantages:

Caltech is developing a solar module that splits sunlight into individual color bands to improve the efficiency of solar electricity generation. For PV to maintain momentum in the marketplace, the energy conversion efficiency must increase significantly to result in reduced power generation costs. Most conventional PV modules provide 15-20% energy conversion efficiency because their materials respond efficiently to only a narrow band of color in the sun's spectrum, which represents a significant constraint on their efficiency. To increase the light conversion efficiency, Caltech will assemble a solar module that includes several cells containing several different absorbing materials, each tuned to a different color range of the sun's spectrum. Once light is separated into color bands, Caltech's tailored solar cells will match each separated color band to dramatically improve the overall efficiency of solar energy conversion. Caltech's approach to improve the efficiency of PV solar generation should enable improved cost-competitiveness for PV energy.

Impact Summary:

If successful, Caltech's solar system would convert greater than 50% of incoming light energy into electrical power at a cost well below $1/watt.

Security:

Cost-effective PV systems would enable increased U.S. renewable energy use. As electric vehicles become more popular, the ability to power those using renewable energy would decrease our reliance on foreign oil.

Environment:

Replacing energy systems powered by coal would provide an immediate decrease in greenhouse gas emissions, of which electricity generation accounts for over 40%.

Economy:

Cost-effective renewable energy alternatives would reduce electricity rates for consumers in locales with renewable portfolio standards or greenhouse gas emissions targets.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/improving-solar-generation-efficiency-solar-modules

Sodium-based energy storage (Sharp Laboratories of America)

DOE Program: OPEN 2012
Location: Camas, WA
Project Term: 03/28/2013 to 03/27/2016
Project Status: ACTIVE
Website: www.sharplabs.com(link is external)
Technical Categories: Stationary Storage: Grid-Scale Batteries

Critical Need:

Our national electric grid has limited ability to store excess energy, so electricity must constantly be over-generated to assure reliable supply. Though wind and solar power are promising clean alternatives to fossil fuels, their natural unpredictability and intermittency make them incapable of delivering the power on-demand necessary to operate today's grid. The U.S. needs technologies that can cost-effectively store renewable energy for future grid use at any location. Flexible, large-scale storage would create a stronger and more robust electric grid by enabling renewables to contribute to reliable power generation.

Project Innovation + Advantages:

Sharp Labs and their partners at the University of Texas and Oregon State University are developing a sodium-based battery that could dramatically increase battery cycle life at a low cost while maintaining a high energy capacity. Current storage approaches use either massive pumped reservoirs of water or underground compressed air storage, which carry serious infrastructure requirements and are not feasible beyond specific site limitations. Therefore, there is a critical need for a scalable, adaptable battery technology to enable widespread deployment of renewable power. Sodium ion batteries have the potential to perform as well as today's best lithium-based designs at a significantly lower cost. Sharp Labs' new battery would provide long cycle life, high energy density, and safe operation if deployed throughout the electric grid.

Impact Summary:

If successful, Sharp Labs' sodium-based battery would offer a cost-effective and robust energy storage platform alternative to lithium-based batteries for grid storage applications.

Security:

A more efficient and reliable grid would be more resilient to potential disruptions.

Environment:

Electricity generation accounts for over 40% of U.S. carbon dioxide (CO2) emissions. Enabling large-scale contributions of wind and solar power for our electricity generation would result in a substantial decrease in CO2 emissions.

Economy:

Increases in the availability of wind and solar power would reduce fossil fuel demand, resulting in reduced fuel prices and more stable electricity rates.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/sodium-based-energy-storage

Advanced vanadium redox flow battery (ITN Energy Systems)

DOE Program: SBIR
Location: Littleton, CO
Project Term: 10/01/2012 to 06/30/2015
Project Status: ACTIVE
Website: www.itnes.com(link is external)
Technical Categories: Stationary Storage: Grid-Scale Batteries

Critical Need:

Our national electric grid has limited ability to store excess energy, so electricity must constantly be generated to perfectly match demand. Though wind and solar power are promising clean alternatives to fossil fuels, their natural unpredictability and intermittency make them incapable of delivering the power on demand necessary to operate today's grid. The U.S. needs technologies that can cost effectively store renewable energy for future grid use at any location. Flexible, large-scale storage would create a stronger and more robust electric grid by enabling renewables to contribute to reliable power generation.

Project Innovation + Advantages:

ITN is developing a vanadium redox flow battery for residential and small-scale commercial energy storage that would be more efficient and affordable than today's best energy storage systems. In a redox flow battery, chemical reactions occur that allow the battery to absorb or deliver electricity. Unlike conventional batteries, flow batteries use a liquid (also known as an electrolyte) to store energy; the more electrolyte that is used, the longer the battery can operate. Vanadium electrolyte-based redox flow battery systems are a technology for today's market, but they require expensive ion-exchange membranes. In the past, prices of vanadium have fluctuated, increasing the cost of the electrolyte and posing a major obstacle to more widespread adoption of vanadium redox flow batteries. ITN's design combines a low-cost ion-exchange membrane and a low-cost electrolyte solution to reduce overall system cost, ultimately making a vanadium redox flow battery cost-competitive with more traditional lead-acid batteries.

Impact Summary:

If successful, ITN's vanadium redox flow battery would provide storage capacity for residential and small-scale commercial applications at a cost approaching $1,000 per unit, compared to the $4,000+ price point of today's systems.

Security:

A more efficient and reliable grid would be more resilient to potential disruptions.

Environment:

Electricity generation accounts for over 40% of U.S. carbon dioxide (CO2) emissions. Enabling large-scale contributions of wind and solar power for our electricity generation would result in a substantial decrease in CO2 emissions.

Economy:

Increases in the availability of wind and solar power would reduce fossil fuel demand, resulting in reduced fuel prices and more stable electricity rates.

Iron-nitride alloy magnets (Case Western Reserve University)

DOE Program: REACT
Location: Cleveland, OH
Project Term: 01/01/2012 to 03/31/2015
Project Status: ACTIVE
Website: www.case.edu(link is external)
Technical Categories: Vehicle Designs & Materials: Engines & Motors

Critical Need:

Rare earths are naturally occurring minerals with unique magnetic properties that are used in electric vehicle (EV) motors and wind generators. Because these minerals are expensive and in limited supply, alternative technologies must be developed to replace rare-earth-based magnets in motors and generators. Alternatives to rare earths will contribute to the cost-effectiveness of EVs and wind generators, facilitating their widespread use and drastically reducing the amount of greenhouse gases released into the atmosphere.

Project Innovation + Advantages:

Case Western is developing a highly magnetic iron-nitride alloy to use in the magnets that power electric motors found in EVs and renewable power generators. This would reduce the overall price of the motor by eliminating the expensive imported rare earth minerals typically found in today's best commercial magnets. The iron-nitride powder is sourced from abundant and inexpensive materials found in the U.S. The ultimate goal of this project is to demonstrate this new magnet system, which contains no rare earths, in a prototype electric motor. This could significantly reduce the amount of greenhouse gases emitted in the U.S. each year by encouraging the use of clean alternatives to oil and coal.

Impact Summary:

If successful, Case Western would create iron-nitride magnets for electric motors that contain no rare earth minerals and could power an EV motor better than today's best commercial magnets.

Security:

The U.S. produces a small fraction globally of industrial rare earths. Developing alternatives to the use of rare earths has the potential to reduce our dependence on these materials and will have a positive impact on our national economic and energy security.

Environment:

The transportation and electric power sectors account for nearly 75% of U.S. greenhouse gas emissions each year. Better magnets would support the widespread use of EVs and wind power, significantly reducing these emissions.

Economy:

The U.S. spends nearly $1 billion per day on imported petroleum. Improvements in magnet technology would enable a broader use of EVs, which would help insulate our economy from unexpected spikes in the price of oil.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/iron-nitride-alloy-magnets

Solar-concentrating photovoltaic mirror (Arizona State University)

DOE Program: FOCUS
Location: Tempe, AZ
Project Term: 06/01/2014 to 05/31/2017
Project Status: ACTIVE
Website: www.asu.edu(link is external)
Technical Categories: Renewable Power: Solar

Critical Need:

There are two primary methods for capturing and using sunlight today: direct conversion of sunlight to electricity using photovoltaic (PV) solar panels, or focusing sunlight onto a fluid that is used to drive a steam turbine in concentrated solar power (CSP) systems. Storing hot fluid in CSP systems is a less expensive way to generate electricity when the sun is not shining compared to storing electrical energy from PV in batteries. However, PV uses just part of the solar spectrum at high efficiency, while CSP systems use the entire solar spectrum but at low efficiency. Combining the best elements of these two technologies could provide a means to get the most out of the full solar spectrum, generating both electricity and storable heat (for later use) within the same system. Developing hybrid solar energy systems that perform both functions at the same time could provide electricity at cost comparable to traditional sources, whether the sun is shining or not.

Project Innovation + Advantages:

ASU is developing a hybrid solar energy system that modifies a CSP trough design, replacing the curved mirror with solar cells that collect both direct and diffuse rays of a portion of sunlight while reflecting the rest of the direct sunlight to a thermal absorber to generate heat. Electricity from the solar cells can be used immediately while the heat can be stored for later use. Today's CSP systems offer low overall efficiency because they collect only direct sunlight, or the light that comes in a straight beam from the sun. ASU's technology could increase the amount of light that can be converted to electricity by collecting diffuse sunlight, or light that has been scattered by the atmosphere, clouds, and off the earth. By integrating curved solar cells into a hybrid trough system, ASU will effectively split the solar spectrum and use each portion of the spectrum in the most efficient way possible. Diffuse and some direct sunlight are converted into electricity in the solar cells, while the unused portion of the direct sunlight is reflected for conversion to heat.

Impact Summary:

If successful, ASU's hybrid solar energy system could offer a 50% boost in efficiency compared to the efficiency of existing CSP systems by capturing and converting different portions of the solar spectrum using the most suitable approach for each.

Security:

Developing new systems that allow storage and dispatch of solar energy provides clean domestic power whether the sun is shining or not.

Environment:

Replacing energy systems powered by fossil fuels would provide an immediate decrease in greenhouse gas emissions, 40% of which come from electricity generation today.

Economy:

Cost-effective, dispatchable solar energy alternatives would stabilize electricity rates for consumers as the penetration of renewable energy increases in the coming years.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/solar-concentrating-photovoltaic-mirror

High-efficiency solar cells (MicroLink Devices)

DOE Program: OPEN 2012
Location: Niles, IL
Project Term: 03/20/2013 to 03/19/2016
Project Status: ACTIVE
Website: www.mldevices.com(link is external)
Technical Categories: Renewable Power: Solar

Critical Need:

Photovoltaic (PV) solar electric systems are a growing clean energy alternative to traditional sources of electricity generation, such as coal-burning power plants. One of the biggest obstacles to the widespread deployment of PV systems is the fact that they are rarely cost competitive with traditional sources of electricity. High-efficiency concentrating photovoltaic (CPV) solar cells--which concentrate a large amount of sunlight onto a small area to generate electricity--can reduce the cost of PV systems.

Project Innovation + Advantages:

MicroLink is developing low-cost, high-efficiency solar cells to capture concentrated sunlight in an effort to increase the amount of electricity generated by concentrating solar power plants. The continued growth of the CPV market depends strongly on continuing to reduce the cost of CPV solar cell technologies. MicroLink will make an all-lattice-matched solar cell that can achieve greater power conversion efficiency than conventional CPV technologies, thereby reducing the cost of generating electricity. In addition, MicroLink will use manufacturing techniques that allow for the reuse of expensive solar cell manufacturing templates to minimize costs. MicroLink's innovative high-efficiency solar cell design has the potential to reduce PV electricity costs well below the cost of electricity from conventional non-concentrating PV modules.

Impact Summary:

If successful, MicroLink's solar cells would achieve greater than 50% sunlight-to-electricity efficiency which would provide a significant technological lead for the U.S. in this area of energy generation.

Security:

Cost-effective solar energy would increase U.S. renewable energy use and help reduce our dependence on fossil fuels.

Environment:

Replacing energy systems powered by fossil fuels would provide an immediate decrease in greenhouse gas emissions, of which electricity generation accounts for over 40%.

Economy:

Cost-effective renewable energy alternatives would reduce electricity rates for consumers in locales with renewable energy standards or greenhouse gas targets.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/high-efficiency-solar-cells

Fabric-based wind turbine blades (GE Power & Water)

DOE Program: OPEN 2012
Location: Fairfield, CT
Project Term: 05/01/2013 to 04/30/2016
Project Status: ALUMNI
Website: www.ge-energy.com(link is external)
Technical Categories: Renewable Power: Wind

Critical Need:

Wind power represents a small but rapidly growing contribution to the U.S. renewable energy portfolio. While the cost of wind power has decreased as a result of building at ever-larger scales, challenges such as manufacturing and transportation of large blades, expensive operations and maintenance, siting and transmission limitations, and higher energy costs from smaller scale turbines continue to hinder further deployment.

Project Innovation + Advantages:

GE is developing fabric-based wind turbine blades that could significantly reduce the production costs and weight of the blades. Conventional wind turbines use rigid fiberglass blades that are difficult to manufacture and transport. GE will use tensioned fabric uniquely wrapped around a spaceframe blade structure, a truss-like, lightweight rigid structure, replacing current clam shell wind blades design. The blade structure will be entirely altered, allowing for easy access and repair to the fabric while maintaining conventional wind turbine performance. This new design could reduce production costs by 70% and enable automated manufacturing while reducing the processing time by more than 50%. GE's fabric-based blades could be manufactured in sections and assembled on-site, enabling the construction of much larger wind turbines that can capture more wind with significantly lower production and transportation costs.

Impact Summary:

If successful, GE's technology would lower the cost of electricity by enabling cost effective wind blades, helping the wind industry produce electricity as economically as fossil fuel energy based production.

Security:

Enabling electricity generation from alternative energy sources like wind can alleviate reliability and security concerns associated with the electric grid.

Environment:

Facilitating the widespread use of clean energy reduces the level of greenhouse gases released by electric power generation across the U.S. each year.

Economy:

Enabling alternative sources of energy like wind and solar can help stabilize the cost of electricity generation in the long run, which will ultimately benefit consumers.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/fabric-based-wind-turbine-blades

High-storage double-membrane flow battery (University of Delaware)

DOE Program: OPEN 2012
Location: Newark, DE
Project Term: 01/09/2013 to 12/31/2015
Project Status: ACTIVE
Website: www.udel.edu(link is external)
Technical Categories: Stationary Storage: Grid-Scale Batteries

Critical Need:

Our national electric grid has limited ability to store excess energy, so electricity must constantly be over-generated to assure reliable supply. Though wind and solar power are promising clean alternatives to fossil fuels, their natural unpredictability and intermittency make them incapable of delivering the power on-demand necessary to operate today's grid. The U.S. needs technologies that can cost-effectively store renewable energy for future grid use at any location. Flexible, large-scale storage would create a stronger and more robust electric grid by enabling renewables to contribute to reliable power generation.

Project Innovation + Advantages:

The University of Delaware is developing a low-cost flow battery that uses membrane technology to increase voltage and energy storage capacity. Flow batteries store chemical energy in external tanks instead of within the battery container, which allows for cost-effective scalability because adding storage capacity is as simple as expanding the tank, offering large-scale storage capacity for renewable energy sources. However, traditional flow batteries have limited cell voltages, which lead to low power and low energy density. The University of Delaware is addressing this limitation by adding an additional exchange membrane within the electrolyte material of the battery, creating 3 separate compartments of electrolytes. Separating the electrolytes in this manner allows unprecedented freedom for the battery to exchange ions back and forth between the positive and negative end of the battery, which improves the voltage of the system.

Impact Summary:

If successful, The University of Delaware's double-membrane, triple electrolyte flow battery would offer 2-3 times the storage capacity of today's state-of-the art flow batteries at 60-90% of the cost.

Security:

Flexible, large-scale energy storage would create a more efficient and reliable grid more resilient to potential disruptions.

Environment:

Electricity generation accounts for over 40% of U.S. carbon dioxide (CO2) emissions. Enabling large-scale contributions of wind and solar power for our electricity generation would result in a substantial decrease in CO2 emissions.

Economy:

Increases in the availability of wind and solar power would reduce fossil fuel demand, resulting in reduced fuel prices and more stable electricity rates.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/high-storage-double-membrane-flow-battery

Tools for energy saving

- eProjectBuilder for Energy Savings Performance Contracting (Lawrence Berkeley National Laboratory)
- EnergyPlus: Energy Simulation Software for Buildings (Lawrence Berkeley National Laboratory)
- Simergy: Practitioner-Oriented Graphical User Interface for EnergyPlus (Lawrence Berkeley National Laboratory)
- V2G-Sim (Lawrence Berkeley National Laboratory)
- APIs for Online Energy Saving Tools: Home Energy Saver and EnergyIQ (Lawrence Berkeley National Laboratory)
- USTOMIZED TIDAL POWER CONVERSION DEVICES (Brown University)
- SELF-TRACKING CONCENTRATOR PHOTOVOLTAICS (Glint Photonics)

eProjectBuilder for Energy Savings Performance Contracting (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

- Project tracking and reporting by Energy Services Companies (ESCOs) and their contracting agencies
- Benchmarking energy savings projects

ADVANTAGES:

- Saves time on required project reporting
- Yields consistent reports and proposals for easy evaluation
- Enables tracking and benchmarking within an ESCO, across regions, and across market sectors
- Supported by the world's largest database of ESCO project information

ABSTRACT:

eProjectBuilder is a secure, web-based data entry and tracking system for energy savings performance contracting (ESPC) projects. eProjectBuilder enables energy services companies (ESCOs) and their contracting agencies to upload and track project level information in a streamlined, standardized, and secure platform that facilitates basic project reporting required for contracts; compliance with local, state and / or federal requirements; and other needs. ESCOs can also use eProjectBuilder to present proposals in a consistent format for easy customer review.

In addition to tracking and comparing project performance metrics within their own organization, eProjectBuilder users can benchmark project performance across regions and market sectors using aggregated project data from the Lawrence Berkeley National Laboratory / National Association of Energy Service Companies (NAESCO) project database – the largest database of ESCO project information available. Available benchmarking metrics include total project costs ($ / sq ft), simple payback time (years), and annual energy savings (kBTU / sq ft; kWh / sq ft; % baseline energy).

For documentation and additional information about eProjectBuilder, go **here.**

STATUS: Source code available for licensing. Currently, eProjectBuilder is free to use at https://eprojectbuilder.lbl.gov/home/#/login

SEE THESE OTHER BERKELEY LAB TECHNOLOGIES IN THIS FIELD:

EnergyPlus: Energy Simulation Software for Buildings, CR-2118
Simergy: Practitioner-Oriented Graphical User Interface for EnergyPlus, CR-2998

REFERENCE NUMBER: 2014-076

SOURCE: http://ipo.lbl.gov/lbnl2014-076/

EnergyPlus: Energy Simulation Software for Buildings

APPLICATIONS OF TECHNOLOGY:

Computer rendering of the new federal building built in San Francisco. The building was designed with the aid of the EnergyPlus software distributed and partly developed by Berkeley Lab.

- Modeling building heating, cooling, lighting, ventilating, and other energy flows

ADVANTAGES:

Simulation capabilities include:

- time steps of less than an hour
- modular systems and plant integrated with heat balance-based zone simulation
- multizone air flow, thermal comfort, and photovoltaic systems

ABSTRACT:

EnergyPlus is a building energy simulation program for modeling building heating, cooling, lighting, ventilating, and other energy flows. While it is based on the most popular features and capabilities of BLAST and DOE-2, it includes many innovative simulation capabilities such as time steps of less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, and photovoltaic systems.

The simulation program allows designers to calculate the impacts of different heating, cooling, and ventilating systems, as well as that of various types of lighting systems and windows. EnergyPlus was developed as a collaborative effort between Berkeley Lab's Simulation Research Group, led by Fred Winkelmann of the Environmental Energy Technologies Division, the University of Illinois at Urbana-Champaign, and the U.S. Army Construction Engineering Research Laboratory, with assistance from other research organizations.

STATUS:

- Available for licensing

FOR MORE INFORMATION:

To download the latest version of EnergyPlus and learn about future planned updates visit the link below. These webpages also offer software highlights and licensing information.

http://www.eere.energy.gov/buildings/energyplus/

REFERENCE NUMBER: CR-2118

SEE THESE OTHER BERKELEY LAB TECHNOLOGIES IN THIS FIELD:

Simergy: Practitioner-Oriented Graphical User Interface for EnergyPlus, CR-2998

SOURCE: http://ipo.lbl.gov/lbnl2118/

Simergy: Practitioner-Oriented Graphical User Interface for EnergyPlus (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

- Modeling building heating, cooling, lighting, ventilating, and other energy flows

ADVANTAGES:

Interface capabilities include:

- Create or import building geometry
- Drag and drop HVAC schematic editor
- Extensive system of libraries and templates
- Graphical schedule editor
- Standard reports
- Interactive results visualization

ABSTRACT:

Simergy is a graphical user interface (GUI) for the DOE building energy simulation program EnergyPlus for modeling building heating, cooling, lighting, ventilation and other energy flows. Simergy was designed with extensive input and review from design practitioners and other stakeholders. The overall development was led by LBNL and the software development was led by Digital Alchemy, with contributions from Infosys Technologies Ltd, The Trane Company and Hydro-Québec.

Version 1.0 was released in July 2013, and version 1.1 was released in April 2014.

STATUS: Source code available for licensing. Executible file is free to download and use; go tohttp://simergy.lbl.gov for the latest version.

FOR MORE INFORMATION:

For information, training videos and the latest version of Simergy, go to http://simergy.lbl.gov. Following are sample pages from the GUI:

SEE THESE OTHER BERKELEY LAB TECHNOLOGIES IN THIS FIELD:
EnergyPlus: Energy Simulation Software for Buildings, CR-2118

REFERENCE NUMBER: CR-2998

SOURCE: http://ipo.lbl.gov/lbnl2998/

V2G-Sim (Lawrence Berkeley National Laboratory)

V2G-Sim is a simulation platform incorporating and aggregating individual vehicle powertrain and charging dynamics plus driver usage patterns to systematically address the real-world effects of any number of plug-in electric vehicles (PEVs) on the electricity grid. V2G-Sim can also be used to quantify battery degradation in PEVs from driving or from vehicles delivering grid services.

APPLICATIONS OF TECHNOLOGY:
Power distribution grid planning

- Power pricing analysis
- PEV and battery design
- PEV range and cost savings demonstrations

For specific applications for all stakeholder groups (automotive, electricity grid, policy, business, end users) see: http://v2gsim.lbl.gov/applications

ADVANTAGES:

- Modeling based on real-world driving behaviors over a range of distances and times
- Scalable for any number of PEVs
- Customizable to enable users to examine any vehicle charging or discharging control strategy
- Predictions of both aggregate grid impacts, and individual vehicle impacts
- Computationally efficient, enabling simulations of large numbers of vehicles on standard computer workstations

For further details on advantages, see: http://v2gsim.lbl.gov/overview/key-features

ABSTRACT:

The Vehicle-to-Grid Simulator (V2G-Sim) invented at Berkeley Lab provides systematic quantitative methods to address the uncertainties and barriers facing vehicle-grid integration (VGI). The model is scalable to simulate impacts and opportunities for any number of vehicles (from one to one million or more PEVs).

In the real world, each person drives a different vehicle, in different ways, with different trip distances, at different times. Predicting the adequacy of plug-in electric vehicles (PEVs) for the needs of drivers, and accurately predicting the impacts and opportunities to the electricity grid from increased PEV deployment require models that can consider these differences at the individual vehicle level.

V2G-Sim models the driving and charging behavior of individual PEVs to generate temporally- and spatially-resolved predictions of grid impacts and opportunities from increased plug-in electric vehicle (PEV) deployment. V2G-Sim provides bottom up modeling from individual vehicle dynamics all the way up to aggregate grid impacts and opportunities. Any managed charging or discharging control approach

can be modeled to predict the impacts on individual vehicles, or at any grid scale. Battery degradation from driving or vehicle-grid services can be modeled with battery degradation models integrated into V2G-Sim.

STATUS: Copyright permission requested. Available for license.

FOR MORE INFORMATION:

Chao, J. "Goodbye, Range Anxiety? Electric Vehicles May Be More Useful Than Previously Thought," *Berkeley Lab News Center*, March 30, 2015.

For more information, including case studies, go to the V2G-Sim website.

REFERENCE NUMBER: 2014-0021

SOURCE: http://ipo.lbl.gov/lbnl2014-021/

APIs for Online Energy Saving Tools: Home Energy Saver and EnergyIQ (Lawrence Berkeley National Laboratory)

APPLICATIONS OF TECHNOLOGY:

- Access to online energy-saving tools Home Energy Saver and EnergyIQ through Application Programming Interfaces (APIs)

ADVANTAGES:

- APIs enable businesses, utilities and other entities to create online energy saving tools customized and streamlined for their customer bases.
- Real time and automatic data assessment capability supports building energy management programs.
- A wide variety of programming languages (PHP, Java, Perl and others) can be used to connect to the APIs.

ABSTRACT:

Berkeley Lab is offering direct access to Application Programming Interfaces (APIs) for two popular, proven energy saving online tools: Home Energy Saver and EnergyIQ. The APIs allow software developers to access the algorithms and underlying data for Home Energy Saver and EnergyIQ and to use them for the development of customized web interfaces or other services.

Home Energy Saver
http://hes.lbl.gov/consumer/ (for homeowners)
http://hespro.lbl.gov/pro/ (for energy auditors, inspectors, contractors)

Home Energy Saver is a web-based residential calculator that provides customized estimates of energy use, energy bills and CO2 emissions based on the user's location and home construction. Energy use for heating and cooling equipment as well as appliances, lighting and other equipment is estimated using engineering models developed at Berkeley Lab. Energy bills are calculated using either average energy price data or actual utility tariffs. The software also includes extensive default values if the user chooses to answer a minimum number of input questions.

Licensing the APIs for Home Energy Saver enables web developers to create a customized interface and presentation that can, for example, collect and save home description information from customers, perform asset ratings, generate summary and drill down reports, and save / recall individual user sessions.

To evaluate the APIs for Home Energy Saver, click **here**.

EnergyIQ
http://energyiq.lbl.gov/

EnergyIQ is a web-based benchmarking tool used by energy managers, building owners, architects and engineers seeking to improve energy efficiency, save money and reduce carbon emissions in non-residential buildings.

The software offers a wide array of benchmark metrics—energy, costs, greenhouse gas emissions and other characteristics such as building components or operational strategies. The tool can compare the user's building to its peers at one point in time as well as track the performance of an individual building or enterprise portfolio over time. A decision support module provides information on best practices, links to other energy analysis tools and helps users refine action plans and implement improvements.

To evaluate the APIs for EnergyIQ, click **here**.

STATUS: Available for licensing. For more information or to initiate licensing either the Home Energy Saver or EnergyIQ API, e-mail APILicensing@lbl.gov.

SEE THIS BERKELEY LAB TECHNOLOGY IN THIS FIELD:

EnergyPlus: Energy Simulation Software for Buildings, CR-2118

REFERENCE NUMBER: CR-2690, CR-2892

SOURCE: http://ipo.lbl.gov/lbnl2690_2892/

Customized tidal power conversion devices (Brown University)

DOE Program: OPEN 2012
Location: Providence, RI
Project Term: 03/15/2013 to 11/19/2016
Project Status: ACTIVE
Website: www.brown.edu(link is external)
Technical Categories: Renewable Power: Water

Critical Need:

Renewable energy is critical to our environmental, economic, and national security. Demand for energy is on the rise, as is our national reliance on fossil fuel-based power plants for the bulk of our electricity generation. There is a drastic need for safe, clean, and cost-effective alternatives to coal, such as wind, solar, hydroelectric, and geothermal power. These technologies would reduce carbon dioxide (CO2) emissions and help position the U.S. as a leader in the global renewable energy industry.

Project Innovation + Advantages:

Brown University is developing a power conversion device to maximize power production and reduce costs to capture energy from flowing water in rivers and tidal basins. Conventional methods to harness energy from these water resources face a number of challenges, including the costs associated with developing customized turbine technology to a specific site. Additionally, sites with sufficient energy exist near coastal habitats which depend on the natural water flow to transport nutrients. Brown University's tidal power conversion devices can continuously customize themselves by using an onboard computer and control software to respond to real-time measurements, which will increase tidal power conversion efficiency. Brown University's technology will allow for inexpensive installation and software upgrades and optimized layout of tidal power generators to maximize power generation and mitigate environmental impacts.

Impact Summary:

If successful, Brown University's tidal power conversion device would reduce the costs of producing electricity from flowing water and reduce harmful emissions associated with energy production because there are no emissions associated with tidal power conversion.

Security:

Increased availability of renewable power would help diversify the U.S. energy portfolio, allowing homeowners and businesses access to a grid that is less dependent on any one source of power.

Environment:

Providing clean electricity would significantly reduce the greenhouse gas emissions associated with electricity generation. Presently, over 40% of U.S. CO2 emissions come from electricity generation.

Economy:

Enabling alternative sources of energy like wind and solar can help stabilize and reduce the price of energy. This could result in significant cost savings over fossil fuels in the years to come.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/customized-tidal-power-conversion-devices

Self-tracking concentration photovoltaics (Glint Photonics)

DOE Program: OPEN 2012
Location: Burlingame, CA
Project Term: 04/01/2013 to 06/30/2016
Project Status: ACTIVE
Website: www.glintphotonics.com(link is external)
Technical Categories: Renewable Power: Solar

Critical Need:

Photovoltaic (PV) solar electric systems are a growing clean energy alternative to traditional sources of electricity generation, such as coal-burning power plants. One of the biggest obstacles to the widespread deployment of PV systems is the fact that they are rarely cost competitive with conventional sources of energy generation. New PV technologies must improve solar energy conversion efficiency while driving down costs in order to make them broadly competitive with traditional power generation methods and help position the U.S. as a leader in the global renewable electricity industry.

Project Innovation + Advantages:

Glint is developing an inexpensive solar concentrating PV (CPV) module that tracks the sun's position over the course of the day to channel sunlight into PV materials more efficiently. Conventional solar concentrator technology requires complex moving parts to track the sun's movements. In contrast, Glint's inexpensive design can be mounted in a stationary configuration and adjusts its properties automatically in response to the solar position. By embedding this automated tracking function within the concentrator, Glint's design enables CPV modules to use traditional mounting technology and techniques, reducing installation complexity and cost. These self-tracking concentrators can significantly decrease the cost of solar power modules by enabling high efficiency, while eliminating the additional costs of precision trackers and specific mounting hardware. The concentrator itself is designed to be manufactured at extremely low-cost due to low material usage and compatibility with high-speed fabrication techniques. Glint's complete module costs are estimated to be $0.35/watt-peak.

Impact Summary:

If successful, Glint's low-cost solar power module will bring CPV technology to building rooftops.

Security:

Cost-effective solar energy would increase U.S. renewable energy use and help reduce our dependence on fossil fuels.

Environment:

Replacing energy systems powered by fossil fuels would provide an immediate decrease in greenhouse gas emissions, of which electricity generation accounts for over 40%.

Economy:

Cost-effective renewable energy alternatives would reduce electricity rates for consumers. Integrating these renewable technologies directly into buildings will reduce stress on the electric grid.

Source: http://www.arpa-e.energy.gov/?q=slick-sheet-project/self-tracking-concentrator-photovoltaics