Greentech Media

THE 2008 GREENTECH MARKET TAXONOMY

AUTHOR.

DANIEL ENGLANDER Greentech Media

greentechmedia:

knowledge ≡ power

TABLE OF CONTENTS

1. INTRODUCTION

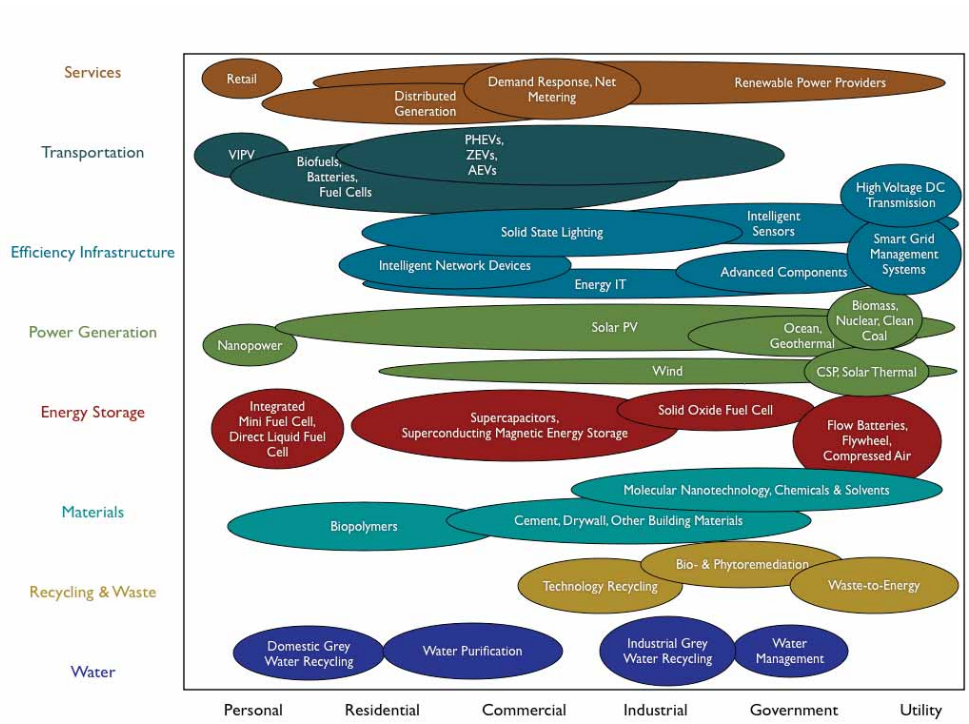
It is fair to say that green technology has moved beyond composting. Driven by the facts of global climate change, rising energy demand and shrinking fossil-fuel reserves, green technology has developed into a significant growth market. In 2006, green-technology companies received $3.9 billion in venture-capital investment and generated $55 billion in revenue. The year also was successful for firm exits, with green-technology companies raising $4.9 billion in IPOs -- nearly doubling 2005's record total -- and completing nearly 450 M&As. Behind this record-breaking market expansion are a widening array of technologies, processes, applications and services that are helping consumers, businesses, utilities and governments create a clean and sustainable world.

Green technology is a necessary solution to a complex problem -- generating economic growth without sacrificing the environment. Specifically, green technology is anything that seeks the efficient use of natural resources to limit or negate environmental impact while reducing costs and raising revenues, profits and value. It generates positive social, environmental and economic externalities across the entire product life cycle with innovative crossover technologies, processes, applications and services. This system constitutes a market in the broadest possible sense: The demand for a better quality of life and a healthier environment is met by a supply of innovation and capital that cuts across the industrial and knowledge economies.

Keeping track of the growing number of players and technologies is a major business challenge for green technology. The market has moved past power generation, branching out into sectors that affect nearly every aspect of modern life. Dressing, driving and eating are a few, and the list goes on. Who these technologies affect and the level at which they operate are becoming increasingly important questions for investors and entrepreneurs alike. Understanding the value of green technology requires one to understand the composition of the market.

This taxonomy represents Greentech Media's belief that green technology is understandable in an intuitive way. We have organized the green-technology market to reflect how the end user might interact with the variety of technologies, processes, applications and services flowing into the field. In the green-services sector, for instance, a homeowner might take advantage of retail PV outlets and systems integrators, while a demand-response program might make more sense for a mall or grocery store. By organizing the market in this way, and then by discussing each aspect of the market in depth, we have added a level of accessibility to the green-technology market where none previously existed. The companies we decided to include here were selected largely on the maturity of the technology. In some areas, only a handful of companies operate. In other areas, such as solar or wind, we have selected a mix of established producers and promising start ups. The company lists are not exhaustive, as new companies are entering the market almost every day.

An important aspect of the Greentech Media Taxonomy is the level of interaction we hope it will engender. The green-technology community is incredibly diverse, spanning science, business, government and you -- the end user. Though the initial taxonomy is intended as a top-down framework to structure the market, it is our hope that it will evolve with your input, criticism and comments. Our goal is to have this taxonomy develop into a folksonomy, driven as much by your knowledge as that of our analysts. We admit that the Greentech Media Taxonomy is far from complete. Instead, it is a starting point from which we plan to develop a reference point for the entire green-technology community.



See page 33 for full-size chart

2. POWER GENERATION

Green-power generation sources reduce significantly the need for fossil-fuel-based electricity generation. Electricity is generated primarily by burning coal and natural gas. While these fuel sources have a lower cost per kilowatt than green-power-generation sources, this will soon cease to be the case. Many observers believe fossil-fuel production will decrease dramatically in the next half-century, and will end completely before 2100. During that period we can expect energy consumption to increase dramatically, driving up costs for fossil-fuel-generated electricity. Cost increases and the ongoing negative environmental effects caused by fossil-fuel use are driving homeowners, businesses, governments and utilities to develop and adopt green-power-generation sources.

Green-power generation is among the most advanced segments of the green-technology market. Several technologies, such as wind and solar power, are commercially available now. Ocean-power technology and hydrogen production from sulfur-deprived algae are in development and prototyping stages. Government incentive programs and a steady stream of investment capital are driving growth in this segment. Investment and research support are expected to increase to match the growing economic and environmental costs of fossil-fuel-generated electricity.

2.1 Key Components

Renewables - Renewable energy sources such as wind, water, geothermal steam, biomass and solar provide zero-emission, zero-fuel-cost power to national power grids, commercial buildings and residential units. Efficiency gains in power generation coupled with low-cost scaleable technology are driving growth in this component, and helping it to garner the largest share of investment dollars in green technology. In more established technologies such as wind and solar, investment is migrating into different parts of the supply chain as companies continue innovating to bring down capital costs. Other technologies, such as ocean power, are achieving higher rates of early stage investment, which is driven by the confluence of technology advancements and positive policy climates.

- **Solar Power** - Solar power derives energy from the sun and converts that energy into electricity using photovoltaic (PV) panels or energy-conversion systems. Solar-power technology, while advanced and commercially available, produces electricity subject to available sunlight, making it suitable for peak-power support but unusable as a base-load system.

  - **Polysilicon** - Polysilicon panels and arrays are the most common form of solar-power generation. Polysilicon cells are collections of silicon wafers, made from either monocrystalline or polycrystalline silicon. The most advanced polysilicon cells reach efficiencies of 11 percent to 18 percent, though new production technologies offer higher efficiency possibilities. Most polysilicon cells are only able to capture visible areas of the light spectrum.

Veterans			
Q-Cells AG	Suntech	Solon Ag	Trina Solar
ReneSola	China Sunergy	LDK Solar	

Startups			
Day4 Energy	Solaicx	Silicon Valley Solar	SolarWorld

- **Thin Film** - High silicon prices have driven research into non- and low-silicon semiconductor materials, such as copper indium gallium diselenide, cadmium telluride and amorphous silicon. Thin films are less expensive by cost per kilowatt compared to polysilicon, but low efficiencies (5 percent to 8 percent) require large amounts of area for deployment. Thin films are able to capture light in invisible parts of the spectrum and during low-light periods and in low-light areas. The technology involved in manufacturing these materials is complex, and continued research in assembly and production processes are required to bring down costs and increase market share.

Veterans		
First Solar	United Solar Ovonic	Miasolé
XsunX	ICP Solar	

Startups		
Xunlight	G24 Innovations	Wakonda Technologies
Heliovolt	Nanosolar	Sierra Solar

- **Concentrated PV** - Concentrated PV arrays focus light onto polysilicon solar panels to increase the energy intensity and conversion efficiency of traditional PV panels. CPV requires less polysilicon than traditional PV arrays. This technology often employs single- and dual-tracking systems to keep pace with the sun as it moves across the sky.

Concentrated PV
Solfocus

- **Concentrated Solar Power (CSP) & Solar Thermal** - CSP and solar thermal reflect energy from the sun onto mirrors, which heats oil or water, and creates steam to power traditional-energy turbine generators. Parabolic trough and dish designs are effective means of concentrating solar heat and converting it into electricity. Excess superheated material can also be maintained in reserve and used to spin turbine generators when sunlight is not available.

Concentrated Solar Power (CSP) & Solar Thermal			
Solel	Ausra	BrightSource Energy	eSolar

- **Wind Power** - Wind turbines spin to convert mechanical energy from wind into electrical energy. Like solar power, wind power is subject to source intermittence problems from poor siting and low (or high) wind speed. Most wind-power production occurs during off-peak hours. Turbines are across generating scale, from distributed generation to grid-tied offshore wind farms. Wind power is driven primarily by a number of established and startup companies developing utility-scale onshore and offshore wind farms. These companies are listed below.

Veterans		
Vestas	Ecotècnica	Suzlon Energy
Alubar Energia	General Electric	Windflow

Startups
Clipper Windpower

- **Maglev Wind Turbine** - The magnetically levitating bearings in maglev wind turbines are more sensitive than traditional bearings, and achieve cut-in at low wind speeds. Maglev turbines are also able to spin at higher wind speeds compared to traditional turbine designs. While not commercially available, prototype designs are aimed at utility-scale power generation.

- **Vibrating Turbine** - Though technically not a turbine - it doesn't spin - the vibrating turbine has many potential uses in areas where spinning turbines are too large or too expensive to install. Vibrating turbines capture energy created by the vibration of taut, vertically aligned membranes through aeroelastic flutter effects. These are small devices intended primarily for roof-mounted distributed generation, though scale-up technology may be possible with continued research.

Vibrating Turbine
Humdinger Wind

- **Ocean Power** - Ocean-power technology converts mechanical energy from the near-constant movement of tides, currents and waves into electrical energy. The constant movement of water, combined with high potential and kinetic energy density, make ocean power an ideal candidate for base-load power generation, especially for off-grid island communities and areas with high-energy weather patterns and turbulent seas. Ocean-power devices are built around technology similar to that found in offshore oil and natural-gas platforms. Construction processes are capital-intensive and require high-grade, heavy-duty materials.

  - **Wave Power** - Wave power converts the elliptical kinetic mechanical energy of ocean swells into electrical energy. There are a variety of wave-power devices, including buoys, oscillating water columns and overtopping reservoirs. All devices act essentially the same: They use pressurized sea water to spin turbine generators located within the device body. A handful of prototype wave farms exist in the Pacific Northwest and in northern Europe, where prevailing sea breezes create the biggest ocean swells. Wave-park development and device deployment is largely dependent on government support.

Veterans			
WaveDragon	OceanLinx	Ocean Prospect Ltd.	Wavegen

Startups		
SeaPower Pacific Ltd.	Finavera Renewables	Ocean Power Technologies
British AWS Ocean Energy Ltd.	Pelamis Wave Power	Fred Olsen Ltd.

- **Tidal & Current Power** - Marine-propeller or shrouded-turbine installations are designs similar to wind turbines. High water density and constant tidal and current flows allow these devices to achieve high conversion efficiency and constant power output. However, tidal and current patterns work over extended periods typified by 25-hour patterns and diurnal flux, so power-output times often misalign with peak power demand.

Veterans	
Blue Energy Canada	SMD Hydrovision

Startups		
Verdant Power	Tidal Energy Pty Ltd.	Marine Current Turbines Ltd
Open Hydro	Ocean Renewable Power Co. LLC	

- **Ocean Thermal Energy Conversion (OTEC)** - Pumping near-freezing water through temperature zones in the ocean and onto shore to power heat engines is a relatively little-understood technology. High capital costs - OTEC requires well-insulated pipes sunk a mile or more into the ocean - have stunted growth in this technology. This technology has a range of side uses, including water desalinization and soil regeneration.

Ocean Thermal Energy Conversion (OTEC)
Common Heritage Corporation

- **Biomass** - Biomass conversion consists of harnessing the potential chemical energy within carbonaceous matter through burning and gas conversion. Early technologies converted biomass directly into heat. Advances in production and chemical and genetic engineering have found new uses for biomass, including conversion into liquid fuel and hydrogen. Realizing commercial-scale energy output is still largely dependent on creating efficiency gains in production technology and outsized investment in production facilities.

- **Hydrogen from Algae** - Algae can be engineered to produce hydrogen instead of oxygen during photosynthesis through sulfur deprivation. Prolonged sulfur deprivation has negative effects on the algae, so this process currently can occur only in short cycles. Continued research is required to lengthen sulfur-deprivation periods. Furthermore, commercial scale generation requires large, open bioreactors to harness the power of a critical mass of algae. There are currently no bioreactors large enough to accomplish this. If successful, though, sulfur-deprived algae could be the most efficient and sustainable means of creating hydrogen.

Hydrogen From Algae	
LiveFuels, Inc.	GreenFuel Technologies Corp.

- **Biomass Gasification** - Gasifying organic material (wood pellets, leaves, tree bark and livestock and poultry manure) consists of burning this material at high temperatures while mixing it with oxygen, which breaks down the carbon monoxide and hydrogen contained in the organic material. The result is a clean-burning, carbon-neutral synthetic gas. Inorganic matter left over from this process can be used as fertilizer. Syngas can be further converted into biomethane and methanol or carbon-neutral synthetic fuel with continued catalyst processing.

Biomass Gasification	
Biomass Technology Group	ZeroPoint Clean Tech, Inc.

- **Geothermal Power** - Underground thermal energy is nearly limitless. Geothermal-power plants pump underground steam and hot water and use the heat supplied to spin turbine generators. Major costs of geothermal-power plants come from exploration and excavation, and current technology is only cost-effective in areas with active underground tectonic movement observable through geysers and volcanic activity. Research on stimulating underground heat and creating artificial heat reservoirs might make geothermal power a promising source for base-load power.

- **Enhanced Geothermal Systems (EGS)** - EGS might provide a cost-effective work-around for areas where available geothermal power is located far below ground. These systems create permeable rock layers through high-pressure water injection, which is heated through contact with newly fractured rocks. The water is then pumped back above ground and used to spin turbine generators. Stimulating underground heat production and artificially engineering heat reservoirs is expensive, though, and requires vestment in pilot plants to prove its usability.

Enhanced Geothermal Systems (EGS)		
Altarock Energy	Geodynamics	Geopower Basel

► **Hydrothermal Power** - Hydrothermal is the more traditional form of geothermal power. It relies exclusively on existing reservoirs lying under permeable rock that are saturated with steam or heated water. Geographic limitations notwithstanding, areas where these resources are readily available at short distances below the surface will benefit from adopting this technology.

Hydrothermal Power	
Nevada Geothermal Power	Enel Green Power
EarthEnergy	Ormat Technologies Inc.

► **Nuclear Power** - Generating electricity from controlled nuclear reactions appears to be an efficient method of providing pervasive base-load power, though safety, environmental effects and costs must not be disregarded. Nuclear reactors are costly, upwards of $2 billion, though once built the power plants can run continuously. Internalizing costs across the fuel-production process increases the electricity costs from "too cheap to meter" to thousands of dollars per kilowatt-hour. There is also widespread debate about whether nuclear power is truly renewable, as it requires uranium fuel -- a depleting mineral -- for fission. Less than 2 percent of uranium is fissionable. Another substantial problem is thermal water pollution and reactor waste disposal. Neither problem has yet been solved. Public skepticism and fear also are major factors preventing the widespread adoption of nuclear power. These fears are not unfounded.

Several new theoretical technologies for nuclear reactors are currently under research. These new designs focus primarily on cooling mechanisms and non-uranium 235 fueling, including hydrogen-based nuclear fusion. Although the last commercial reactor in the U.S. was completed in 1996, nuclear power makes up nearly 16 percent of global electricity production. It has a particularly strong presence in Western Europe, Japan and Russia. Both General Electric and Westinghouse are currently seeking approval for new reactor designs from the U.S. Nuclear Regulatory Commission, the first such submissions in 30 years.

► **Experimental Power** - Early stage and experimental technologies are at the farthest edges of green technology. Primary examples of experimental green-power generation use nanotechnology to generate constant power for miniature devices or to provide less resistance for electricity pathways in green-technology devices.

► **Microgenerators** - Microgenerators harness mechanical energy from ambient vibrations and ultrasonic waves to vibrate arrays on nanowires across a saw-shaped electrode. A number of different prototypes currently exist, in sizes appropriate for devices ranging powering nanorobots to larger industrial sensors. A potential application for microgenerators is powering internal medical devices such as pacemakers.

Microgenerators	
PMG Perpetuum	Steorn

- **Nano Solar** - Light is present even at the smallest scales and new research is being done to take advantage of that. Coaxial silicon nanowires concentrically align different grades of silicon into a wire which acts as an electron harvester and proton-transfer unit. Coaxial nanowires are able to self-power nanowire-based logic circuits. Nanoparticle solar cells operate in a similar way. They transmit light through a series of carbon nanotubes, which pass electrons through electrodes to generate electricity. Another technology suspends silicon nanocrystals in a solvent to create silicon nanocrystalline ink, which can be poured on virtually any surface. While achieving efficiencies similar to polysilicon cells, nanocrystalline ink costs about 50 percent less to produce.

Nano Solar		
InnovaLight, Inc	Eikos, Inc.	Suniva

- **Clean Coal** - Fossil fuels will continue to be part of our energy mix for a number of years. While we wait out the death of coal, which some analysts predict will occur in the next 50 to 60 years, technologies developed and deployed today aim to reduce the impact that coal has on our environment. Clean coal technologies reduce the CO2, NOX, SOX, and CO content of coal plant effluent, capture and sequester these pollutants and convert coal into carbon-neutral liquid fuels for electricity generation. The U.S. government has sunk a considerable amount of money into the FutureGen project - the coal power plant of the future. FutureGen is a zero-emissions coal plant that combines coal-to-hydrogen conversion with carbon capture and storage. Waiting for FutureGen, which has a planned deployment in 2012 but currently lacks a final site, seems like a losing bet.

- **Internal Gasification Combined-Cycle (IGCC)** - A process of high-temperature coal gasification that creates syngas from the carbon monoxide and hydrogen end product. The syngas is combusted and used to power a turbine generator. The remaining heat and steam are also used to spin turbine generators. IGCC enhances the efficiency of coal-powered electricity generation while reducing emissions. Retrofitting coal plants for IGCC operation is cost-prohibitive, while new construction costs come out to roughly $3600 per kW (20 percent more than a typical coal power plant), when construction and operation costs are added in. However, IGCC plants are able to capture CO2 during gasification, significantly decreasing pollution levels.

Internal Gasification Combined-Cycle (IGCC)		
Altarock Energy	Xcel Energy	GretPoint Energy

- **Oxy Fuel**- This new technology uses oxygen-enriched gas to fire coal power plants. The oxy-fuel process yields an effluent stream that is nearly pure oxygen, and leads to a 75 percent reduction in the amount of flue gas. Oxy-fuel combustion for electricity generation is less efficient compared to IGCC, but its end-product effluent captures and stores CO_2 more effectively. Oxygen production is currently the most expensive component of oxy-fuel combustion.

Oxy Fuel
Clean Energy Systems, Inc.

3. TRANSPORTATION

Green transportation technologies refer to both the cars themselves and to what makes them move forward (and backward - or up and down). While vehicles are about as high up on the value chain as you can get, their key components are innovative green power sources that are lightweight, durable, high-performance and long-lasting. The trajectory of green vehicles is advancing away from fossil-fuel-only or fossil-fuel hybrid vehicles toward vehicles that use a combination of on-board electricity generation, biofuel and standalone electricity storage.

Bringing zero-emission vehicles (ZEVs) to commercial scale is dependent on increasing the storage capacity of batteries while decreasing their size and weight, increasing the availability of fuel for fuel cells and producing carbon-neutral biofuels on a level equivalent to gasoline. Growth trends in the transportation segment are all leading toward commercial-scale ZEVs. Technological issues aside, a number of growth-impeding infrastructure deficiencies exist. Funding and investment for biofuel-production facilities and distribution infrastructure are scarce, which limits the wide-scale reliability of vehicles reliant on these fuel sources.

3.1 Key Components

- **Battery** - Lightweight, high-density, quick-charging batteries are one of the key technologies competing to power electric vehicles. Rechargeable batteries in battery electric vehicles (BEVs) accelerate quickly and are able to achieve high speeds. BEVs with regenerative braking allow for battery-energy conservation, increasing distances between charging. One factor holding back wide-scale deployment of BEVs is recharging speeds and capacities. Continued research into fast-charging vehicle-grade batteries, as well as infrastructure investment for vehicle charging, is required before BEVs make significant inroads.

  - **Lithium Ion (Li-ion)**- Li-ion battery power systems are found in most BEVs, such as the Tesla Roadster and the Smart Car. These batteries are durable and can be made into virtually any shape, which makes them especially useful for installation in tight spaces within cars. Li-ion batteries also have a cycle durability of 1200, high-energy density, fast recharge rates and rated distances of between 250 miles and 300 miles per charge. Despite these aspects, li-ion batteries require a number of internal safety measures to prevent overheating or combustion that take up increased space within the battery. Li-ion batteries have time-dependent life spans and they begin to deplete soon after production.

Lithium Ion (Li-ion)	
A123Systems	Valence Technology
AltairNano	Lion Cells

  - **Lithium Polymer (LiPo)** - LiPo batteries are the next evolution of Li-ion batteries. Their fundamental strength is in the lack of a hard metal casing, which makes these batteries considerably lighter than their Li-ion predecessors. The newest technology extension of LiPo is the thin-film polymer electrolyte battery, which has a higher energy density than Li-ion and which use thin-film plastics to make them smaller and more flexible. LiPo batteries are also considered safer than Li-ion batteries. Where the primary electrolyte in Li-ion is suspended in a solvent, LiPo batteries hold electrolytes in a solid-state composite. LiPo batteries are currently deployed in electric bicycles, but continued research is needed to bring these batteries into BEVs.

Lithium Polymer (LiPo)	
Sion Power	Protanium

- **Nickel Metal Hydride (NiMH)** - NiMH batteries appeared in the first modern BEVs, including the GM EV1 and the Honda EV Plus. Compared to nickel cadmium batteries, NiMH batteries have a higher energy density and lower observable memory effects they maintain their whole charge capacity for longer. NiMH batteries also have a low internal resistance, which allows them to maintain an almost constant voltage output. However, NiMH batteries are heavier compared to Li-ion and LiPo while also having lower charge-cycle durability. These batteries are used in the Toyota Prius and the Honda Insight.

Nickel Metal Hydride (NiMH)
ECD Ovonics

- **Fuel Cell** - Fuel cells convert electrochemical energy into electricity, which is used to power an electric traction motor. Fuel cells work by combining a fuel (hydrogen, methanol) with an oxidant (oxygen) that then reacts across an electrolyte membrane. These systems can work almost continuously as long as they are provided with a constant stream of fuel.

  - **Proton Exchange Membrane Fuel Cell (PEM)** - PEMs are the most widely used type of vehicle fuel cell. These use electricity produced from hydrogen (like other fuel cells), but are able to do so at low-temperature and low-pressure ranges, which makes PEMs ideal for use in smaller cars. PEMs, like most fuel cells, require reformed hydrogen, which must be passed through an extremely hot, highly pressurized catalyst within the vehicle before it is injected into the fuel cell.

Proton Exchange Membrane Fuel Cell (PEM)	
Giner Electrochemical Systems, Inc.	Ballard Power Systems

  - **Direct Ethanol Fuel Cell (DEFC)**- DEFCs use non-reformed ethanol to feed into a fuel cell. By not reforming the fuel, these systems do not require a catalyst, which makes for easier storage without pressure or temperature requirements. DEFCs are also promising because they rely on planned or preexisting ethanol distribution infrastructure, which is more of a reality than a hydrogen distribution infrastructure. DEFCs have limited efficiencies and power densities, but the possibility of widespread non-hydrogen fuel cells is a promising opportunity.

Direct Ethanol Fuel Cell (DEFC)
Projekt Schluckspecht

- **Biofuel** - Converting biomass into liquid fuel for transportation is a natural extension of the biomass processes used in electricity generation. Biofuel commercialization is currently moving in two directions. One focuses on creating ethanol from sugar fermentation and biobutanol from starch fermentation, while the other focuses on engineering biomass to mimic the chemical structure (and energy output) of petroleum.

  - **Ethanol** - Ethanol is a liquid fuel produced from fermenting sugar found in biomass.

    - **Corn-Based Ethanol** - Corn-based ethanol is produced from the fermentation and distillation of sugars found in the vegetable part of the corn plant. It is considered relatively inefficient, as energy costs of materials are high and energy output is low. Corn production is both land- and energy-intensive, and common industrial agriculture practices rely heavily on fossil fuels to manufacture corn at such high intensities. Despite widespread government support for corn-based ethanol production, there is relatively little support for infrastructure development to distribute this kind of biofuel.

Corn-Based Ethanol	
BioFuel Energy, LLC	Iroquis Bio-Energy Company

    - **Sugarcane Ethanol** - Sugarcane ethanol is made from the cane itself, as well as the waste -- bagasse -- left over from harvesting. The cane and bagasse are ground down, fermented with yeast and distilled to create ethanol. This is a more efficient process than creating ethanol from starch-based biomass, as the starch needs to be converted to sugar before it can be processed into ethanol.

Sugarcane Ethanol	
Ethos	Farmacule BioEnergies

    - **Cellulosic Ethanol** - Cellulosic ethanol uses almost the entire biomass of a plant - lignin, cellulose and hemicellulose - to produce biofuel. Ultimately, cellulosic ethanol achieves a higher sustainability and lower environmental impact than traditional corn or sugarcane ethanol. It is also cheaper to produce than corn or sugarcane ethanol, since its feedstock consists of nearly all plant biomass. Cellulosic ethanol is produced from plant waste, which means food supplies are not diverted for fuel production. This is a concern with both sugarcane- and corn-based ethanol. There are currently a handful of demonstration plants in the U.S. that are producing good results, but which require continued investment to scale up late-stage development.

Cellulosic Ethanol	
Verenium	Range Fuels
Mascoma	Iogen Corp.

- **Biobutanol** - Biobutanol is a biofuel derived from the starch fermentaton of biomass. Its chemical makeup is more similar to petroleum than ethanol, and it achieves a higher energy density than ethanol. Biobutanol's primary benefit is its transportability. Unlike ethanol, biobutanol is neither corrosive nor hydrophilic, which means it can be transported across existing pipelines without eating them. Biobutanol's primary drawback is the inefficiency of its production process. Typical biobutanol fermentation yields only a small amount of useable liquid fuel -- less than 5 percent -- and it is very energy-intensive.

Biobutanol
Green Biologics

- **Synthetic Biofuel** - Synthetic biofuel mimics the chemical structure of petroleum to achieve petroleum's energy intensity without its carbon emissions. By engineering feedstock to act like petroleum, synthetic biofuel overcomes the compatibility problem faced by other biofuels. No new distribution infrastructure or automobile parts are needed for synthetic biofuel to become part of the energy mix. However, it is only produced by a handful of companies and is not yet available on a commercial scale.

Synthetic Biofuel		
LS9	Amyrs Biotechnology	SunEthanol

- **VIPV** - Vehicle integration of PV cells to provide complete power is a long way off. However, a niche consumer industry has developed to begin providing this technology as a supplement to ZEVs and PHEVs. Integrating thin-film panels on EVs could power on-board energy systems or provide immediately available starting power for drained batteries. Ultralight research VIPV vehicles do exist, though they resemble airplanes more than cars and fit only one person, uncomfortably.

  - **Green Vehicles** - Green vehicles are closely associated with the technology used to drive them. Often, the propulsion technology's inventor and the vehicle's manufacturer are the same company. Here's a quick rundown of some of the most important and interesting green-vehicle manufacturers.

Green Vehicles			
Tesla Motors	ZAP!	Th!NK	Aptera
Venture Vehicles	Venturi	Reva Electric Car Company	

4. ENERGY STORAGE

Energy storage is the backbone of the green technology economy. Storage technologies address power-source predictability, which many believe is a significant obstacle to the widespread adoption of green power-generation technology. Green energy-storage technologies also provide sustainable solutions for consumer electronics and transportation technologies.

Storage systems are grouped by storage method. Grid-storage technology is currently used to supplement diurnal power supplies, charging from nighttime base-load power and supplementing peak power demand during the day. When providing storage for green power generation, this technique would be reversed. Storage systems would charge during the day, collecting excess solar or wind energy, and would then provide base-load power at night.

4.1 Key Components

- **Electrochemical** - Electrochemical storage converts chemical energy into electrical energy and works in a way similar to fuel cells. A primary difference between fuel cells and electrochemical storage is the flow rate. Electrochemical storage maintains fuels and electrolytes outside of the reactor, pumping them through when electricity is needed. Fuel cells require a constant flow to generate electrical energy. The energy in electrochemical storage is determined by the amount of stored fuel, which can be recharged by processing through the reactor.

  - **Vanadium Redox Flow Battery**- Flow batteries are designed primarily for large-scale grid energy storage. Charged electrolyte fluid stored in large tanks is pumped through reactor cells and reacted upon, converting chemical energy into electrical energy. Excess fluid is held in outside tanks and re-energized before it passes through the reactor. By adding new tanks, flow batteries are easily scaled up. Vanadium redox flow batteries solve ion leakage, which was a major problem in maintaining functional flow batteries.

  - **Zinc-Bromide Hybrid Flow Battery**- Hybrid flow batteries differ from redox flow batteries in that hybrid flow batteries are limited in the amount of charged electrolyte they can process. Hybrid flow batteries require some amount of charged electrolyte to remain in the reactor, limiting storage ability and variable power output.

  - **Solid Oxide Fuel Cell (SOFC)**- Solid oxide fuel cells operate at extremely high temperatures (700° to 1000° C). High operating temperatures negate the need for the platinum catalyst required in kinds of non-reformed fuel cells. Solid oxide fuel cells are currently stationary storage devices - due to the high operating temperature - but are useful in providing backup power to gas turbines through hybrid heat and power devices. SOFCs are also used for co-generating hydrogen (through excess fuel production in fuel electrolysis) and electricity. Current research is focused on decreasing their operating temperatures for use in automobiles and mobile devices.

Solid Oxide Fuel Cell (SOFC)		
Bloom Energy	SiEnergy Systems LLC	Franklin Fuel Cells

- **Integrated Mini Fuel Cell** - A fuel cell's fuel-storage component often dwarfs the cell itself. One possible work around is storing hydrogen as methanol - liquid fuels store compactly - and freeing the stored hydrogen through a heating process. These are known as microchemical systems. Current research has developed the technology to process methanol in a series of concentric rings, with the core acting as a combustion unit that heats the rings to strip hydrogen out of the methanol solution. Integrated mini fuel cells can be as small as 5 centimeters in diameter, allowing them to fit into laptops, and can generate as much as 1000 watts/kg.

Integrated Mini Fuel Cell	
Tekion	Smart Fuel Cell

- **Direct Liquid Fuel Cell** - Storing hydrogen in sodium borohydride and combining that hydrogen with oxygen from the air is an efficient way of getting big power into compact spaces. Sodium borohydride has the advantage of high-capacity, small-volume hydrogen storage. It is also inflammable, alleviating a major concern with consumer-electronics fuel cells. A downside of this technology is that its power capacity is about the same as the most advanced li-ion batteries. Current research is focused on increasing the hydrogen content of the sodium borohydride, without increasing the boron-oxide byproduct. Some researchers have had success with adding ethylene glycol, a common ingredient in antifreeze.

Direct Liquid Fuel Cell
Medis Technologies

- **Electrical** - Electrical storage is an efficient way of delivering power without the need for chemical or mechanical conversion. Storing electrical energy is likely the most efficient way of maintaining electricity because there is no conversion element required.

  - **Supercapacitors** - Supercapacitors store electricity in their charge field and have almost infinite charge cycling. These storage devices contain of a thin-film polymer dielectric sandwiched in between two oppositely charged metal plates. Carbon nanotubes create porosity in the dielectric, which brings the metal plates closer and generates a more intense electric-field charge. Although they have a lower energy density than batteries, supercapacitors charge in milliseconds and emit high-voltage bursts, which are useful for starting engines in battery-drained ZEVs as well as for load leveling in power-generation systems.

Supercapacitors
EEStor

- **Superconducting Magnetic Energy Storage (SMES)**- SMES systems capture DC currents in the magnetic field of a cryogenically frozen superconducting coil and store that energy for an infinite amount of time. They allow for nearly instantaneous power output at high bursts over short periods and are useful for load leveling and grid stabilization.

- **Mechanical** - Mechanical energy-storage methods rely on the potential energy of mechanical motion. Energy conversion from potential to kinetic energy involves some efficiency losses, though it is the least technically complex form of energy storage. A widely used form of mechanical energy storage is water pumping, where water is moved to a higher elevation and pumped through a turbine generator. Mechanical storage requires high capital investment and construction costs. However, it is the most commercially advanced of the green energy-storage technologies and the only technology currently available to provide pervasive base-load support for green power-generation sources.

- **Flywheels** - Flywheels are wheels suspended in vacuum tubes and supported by bearings. Hybrid systems in newer technologies combine magnetic bearings with high-temperature superconductor bearings and divide work between load support for the former and stabilization for the latter. Energy is stored as rotational energy, and is converted by slowing the flywheel to produce an electric current. Flywheels serve to fill gaps for uninterrupted power supplies and for enhancing the power quality of green power-generation technologies.

Flywheels	
Pentadyne Energy Corp.	Vycon

- **Compressed Air Energy Storage (CAES)** - CAS systems use off-peak power to pump pressurized air in underground caverns. Oil exploration and recovery companies have used similar technology for a number of years to stimulate dried oil reserves below ground. When load demands increase, the pressurized air is heated and released to spin turbines that generate electricity. CAS systems have the benefit of easy retrofitting into existing power plants. When combined with natural gas to raise heat, these systems emit fewer GHGs than natural gas alone.

Compressed Air Energy Storage (CAES)	
CAES Development Co.	General Compression

5 GREEN MATERIALS

Green-materials companies create sustainable, cost-effective products to substitute or replace current building and living materials. These companies emphasize the use of zero-emission, non-hazardous inputs to create end-use products and processes that are as good as, and sometimes better than, their traditional-materials counterparts. Green materials also include nanotechnology processes that are more energy-efficient than their industrial-scale counterparts. Ultimately, green materials present environmentally friendly means of enjoying our current lifestyle while decreasing our reliance on harmful chemicals and pollution-heavy processes.

Green materials exemplify the pervasive and disruptive trend of green technology. In applying this logic to work in chemistry and architecture, we are able to capture a major green-technology trend: interlinkages. Advances in green chemistry have the possibility of affecting how cars are made, how long our clothes last and the materials we use in construction. Architecture and building are major extensions of this effort, as a number of these groundbreaking technologies are applied to efficiency and sustainability efforts in construction and design.

5.1 Key Components

- **Chemistry** - The U.S. Environmental Protection Agency has established 12 principles that guide the application of green chemistry. They boil down to emphasizing the use of environmentally safe substances, reducing waste in the chemical-engineering process and in the end product and encouraging efficiency in the production process. In this way, green chemistry encourages both finding replacement technologies and processes to make existing materials greener and the creation of replacement materials to substitute for inefficient materials.

  - **Biopolymers** - Traditional polymers used to make plastics and packaging are petroleum-derived. They have environmentally negative lifecycles and are hard to dispose of. Because they are petroleum-derived, traditional polymers and their end products will increase in price right along with petroleum. Plastics derived from biopolymers, rather than from polyethylene or polystyrene, are biodegradable in air or light, and cost less than traditional polymers. This is because biopolymers are derived from the same materials used to manufacture cellulosic ethanol. CO2 released in the biodegradation process will ultimately be absorbed by new biomass, making biopolymers carbon-neutral replacements for plastics.

Biopolymers		
Tepha, Inc.	EnCoate	Rodenburg Biopolymers
Metabolix	Earthcycle	

  - **Molecular Nanotechnology** - Molecular nanotechnology involves the fabrication of smart materials, nanosensors and nanorobots. These applications work on a molecular level to replace identical, macroscale technologies. This technology is applied toward the creation of atomic factories that assemble complex products

- light sensors, metals and computers, to name a few. They have the potential to produce materials that are stronger, lighter and more energy-efficient than any other process currently known. Combining nano devices with nano solar technologies will allow these devices to be self-powering, enhancing their sustainability.

Molecular Nanotechnology
Molecular Imprints

- **Solvents & Chemicals** - Industrial chemicals and cleaning solvents are heavy polluters. Whether it's runoff from a factory or dishwater going down the drain, chemicals found in modern materials eventually make it into the water system and soil. A primary application is using molecular chemistry to entirely replace the use of solvents in industrial processes. Another application is the use of biologically based cleaning materials.

Solvents & Chemicals
Vertec Biosolvents

- **Building** - Residential and commercial buildings account for 67.9 percent of total U.S. electricity consumption and 38.1 percent of total U.S. CO_2 emissions. Making more efficient buildings is clearly an important step in reducing environmental impact. Accomplishing this depends largely on creating buildings from materials that efficiently use energy inputs. Design is an important aspect of this, though we think it more pressing to focus on the ways in which buildings are created, how the materials and methods used reduce maintenance and operating costs and how this process improves both occupant and environmental health.

  - **Cement** - Cement manufacturing accounts for nearly 5 percent of total greenhouse-gas emissions. A ton of CO_2 is created for every manufactured ton of cement. A new cement-making process promises to not only limit the amount of CO_2 emitted during the process, but also to sequester CO_2 out of the atmosphere to prevent further environmental degradation.

Cement	
Calera	Planteco

  - **Dynamic Tinting Windows** - Windows that lack insulation or tint are a major source of heat and energy loss in buildings. Current applications for dynamic-tinting windows have stayed the same for the last five years. However, new technologies being developed to increase the light-capturing capabilities of these windows using nano-thin ceramic coatings is attracting interest from the semiconductor industry. One dynamic-tinting company has recently formed a joint venture with a supplier of semiconductor manufacturing materials.

  - **Drywall** - Conventional drywall, which is made from gypsum and requires numerous heating and mixing stages, emits nearly as many greenhouse gases as cement and steel. New drywall production processes eliminate heating stages, promising to drastically reduce the amount of energy consumed and pollution emitted during the drywall fabrication.

Drywall
Serious Materials

- **Solid-State Lighting** - Solid-state lighting is a high-intensity, energy-efficient means of lighting. It uses light-emitting diodes, instead of filaments or gas, to create a broad visible light spectrum with reduced heat output. Solid-state lighting is easily controlled to produce different colors, shades and intensities while also being shock- and vibration-resistant. The primary benefit of solid-state lighting is that it uses much less electricity than normal cathode-filament or fluorescent bulbs and lasts much longer than either technology.

Solid-State Lighting	
Light Beam Industries	LedEngin Inc.
BridgeLux	Plextronics

6 RECYCLING AND WASTE

Innovations in recycling and waste technology address pollution problems that directly affect our living environment. By focusing on the quantity and composition of waste going into the ground, new waste-disposal processes will help us regenerate soil and reduce the amount of land needed for disposal. Recycling and waste technologies, along with water, form the baseline for green technology. These innovations are both necessary and available. Improving waste-disposal and recycling processes are neither expensive nor highly technical. They have the potential to influence the quality of life for individuals across the globe.

The market potential for these technologies is huge. Ground contamination is a serious problem in a number of locations, especially in countries where the majority of individuals depend on agriculture to make a living. If China or India were to adopt widespread waste-disposal or recycling regulations, the companies producing the most efficient and effective technologies would have a ready-made market.

6.1 Key Components

- **Bioremediation** - These processes use microorganisms, fungi and enzymatic reactions to decontaminate soil. Bioremediation, which has both aerobic and anaerobic functions, uses the enzymatic pathways and catabolic reactions of microorganisms to break down soil contaminants or convert them into nonhazardous or nontoxic compounds. A well-known extension of this process is the use of hydrocarbanoclastic bacteria (HBC) to degrade petroleum in marine environments for waste cleanup. Microbiologists and genetic engineers are researching new micro-organic processes that will allow bacteria to break down a larger array of soil contaminants without needing to remove soil or alter the environment.

- **Phytoremediation** - Phytoremediation is used to extract and break down heavy metals, including uranium, lead, cadmium and arsenic. Plants in contaminated areas absorb chemicals through their root structure, transporting them to the leaves and stems. Plants will continue to absorb contaminants until their tops are harvested. This process requires numerous plant lifecycles to successfully clean contaminated sites. Current research on plant genetics is focused on building 'hyperaccumulators,' plants that grow faster and absorb more contaminants than those plants traditionally used in phytoremediation (sugar beets, sunflowers, poplar trees and ragweed).

- **Waste-to-Energy** - Waste-to-energy conversion is similar to the biomass-gasification and IGCC processes, except that the feedstock is trash and not biomass or coal. Instead of incinerating garbage, waste-to-energy plants use decomposing matter from landfills or fresh carbonaceous matter and convert it to liquid fuels using thermal and fermentation technologies. The biodiesel movement is a grassroots extension of waste-to-energy technology.

    - **Plasma-Arc Gasification** - Plasma-arc gasification is a new technology that melts and gasifies solid waste at extremely high temperatures. The plasma arc stretches across two electrodes, which vaporizes garbage as it falls through the closed-loop plasma converter. The two byproducts of plasma-arc gasification are gasified waste and solid rubble. The gasified waste is syngas, which can be used to fire a turbine generator. A plant planned for Port St. Lucie, Fla., will use the rubble byproduct to pave roads in the community. There are currently a handful of operating plants in Japan, and two plants in the works for Florida.

Plasma-Arc Gasification		
Geoplasma LLC	StarTech	PlascoEnergy Group

- **Mechanical Biological Treatment (MBT)** - MBT plants combine waste processing with anaerobic waste digestion, which allows for lower rates of overall waste disposal and conversion of waste into methane-rich biogas. Instead of having separate facilities for recycling, commercial and industrial waste and household waste, MBT plants aggregate all types of garbage into a single plant, and dispose of only what cannot be converted into fuel for energy. All waste that can be converted is sent into an anaerobic-digestion facility on site. Anaerobic-digestion processes subject waste to bacterial hydrolysis to begin the breakdown process. Acidogenic bacteria, which breaks down waste into hydrogen, ammonia and carbon dioxide, is then added into the mix. Finally the waste material is converted into methane using methanogenic bacteria. Anaerobic digestion requires high construction costs and produces biogas with low efficiency. Further research on anaerobic-breakdown technology, including the addition of temperate and pressure monitors to maintain a constant environment, is required to bring costs down while increasing the conversion efficiency required for wide scale commercial adoption.

- **Molten Closed-Loop Gasification** - Though most waste-to-energy gasification processes can be described as closed-loop, a promising new technology takes this a step further by making garbage disappear within the system. By melting construction and household waste into a bath of molten iron, molten closed-loop gasification produces only syngas and slag. Like nearly all waste-to-energy technologies, this process aims to reduce the use of landfills.

Molten Closed-Loop Gasification
Ze-gen

- **Technology Recycling** - The European Union, Canada, most American states and many countries in Asia have banned the disposal of electronic waste in landfills. Most electronic devices contain both high-value components (gold, platinum, copper) and toxic chemicals (mercury, lead, PCBs). One study estimates that electronic waste accounts for 70 percent of all toxic waste in the U.S. While many countries require device manufacturers to handle up to 75 percent of electronic waste disposal, common disposal practice involves shipping electronic waste to developing countries with light regulations on waste disposal and environmental health. Electronic-waste processing is a complicated process, requiring disassembly, materials sorting and recovery and safe disposal. As more countries continue to legislate against direct disposal, investment for streamlining and simplifying electronic-waste disposal will increase.

Technology Recycling	
eWaste	TechTurn

7 WATER

Ensuring access to clean water is one of the biggest challenges facing the global community in the 21st century. The amount of currently available fresh water is static, though growth in absolute population and population density is increasing dramatically. Every year millions of individuals in developing countries die because of lack of access to water or because of contaminated drinking water. In developed countries, overuse, mismanagement and underinvested infrastructure are creating water shortages and sanitation problems in many large cities.

Green-technology applications for water purification and water recycling present significant solutions to many of these problems. Investor interest in green water technology has been spurred by the recent upsurge in the application of new technologies to water problems. This is a market with a consumer base of more than 6 billion people and growing. The growing realization that a tightening supply is both a significant problem and a significant opportunity has led a number of scientists, investors and entrepreneurs into this segment of the green-technology market.

7.1 Key Components

- **Water Purification** - Purification technologies address a significant problem facing both developed and developing countries. Current commercial technology is effective at removing certain types of contaminants, but larger systems with integrated purification technologies are needed to filter out all contaminants. Another challenge facing water purification is flow rate. Larger systems necessarily take longer to process clean water, creating supply bottlenecks.

    - **Aerobic Granular Sludge Technology** - Certain anaerobic bacteria introduced into dirty or contaminated water will form solid granules around impurities such as heavy metals, human and animal waste, and chemicals. In prototype tests, it has acted successfully as a tool for desalination. The granules sink to the bottom of the bacteria reactor, while the remaining clean water is filtered out. Progressing this technology out of research phase may produce an inexpensive, accessible method for acquiring clean water.

► **Membrane Distillation** - This process addresses both purification and desalination issues, the latter of which is an important aspect of increasing global water supply. Dirty water is heated into a vapor and passed through a salt- and contaminant-catching hydrophobic membrane, and then cooled on the other side. This process is ideal for rural areas or developing countries, as it incorporates concentrated solar heat to vaporize water and is less energy-intensive than other membrane processes. Further advances in nanotechnology focused on membrane have the potential to increase the effectiveness of this process.

► **UV Disinfection** - The genetic material found in water-borne bacteria and viruses is effectively neutralized after absorbing radiation from an ultraviolet light source. The UV light rearranges the genetic material within DNA and RNA, making the organism unable to reproduce while sanitizing the infected water. UV radiation adds no chemicals, does not change the water's taste and does not remove water's nutritional elements and minerals. The process itself involves passing water through a chamber with a UV light source. However, existing UV disinfection technology is not completely effective, and provides better results with pretreated water.

UV Disinfection
Atlantium

► **Wastewater Treatment and Recycling** - Wastewater treatment and recycling addresses the specific need for creating additional freshwater resources. Household water is often used only once and then discarded, even though it is not technically contaminated. For areas with water limitations or shortages, or businesses that have high water needs, secondary water-recycling technologies will play a key role in future water-conservation efforts.

► **Domestic Grey-Water Recycling** - Grey water is the end-result of household water output from showers, sinks, washing machines and dishwashers. A number of different domestic water-recycling devices have been developed to divert grey water away from the drainage system and toward home-integrated treatment systems. Recycled water can then be used to water the garden or for renewed use in washing machines and dishwashers.

Domestic Grey-Water Recycling		
FreeWater UK	EcoNova	Perpetual Water

► **Industrial and Commercial Water Recycling** - These systems are nearly identical in function to the domestic grey water-recycling systems, but they are scaled up for use in construction sites, apartments and commercial buildings. Industrial and commercial recycling systems are ideal for providing onsite treatment and recycling of toilet water, which can be pumped back through the onsite sanitation system, as well as for equipment cleaning and industrial water uses.

- **Water Management & Monitoring** - Combining treatment, purification and desalination technologies into an efficient system requires constant monitoring and management of the water supply. Water-management technology uses sensors to monitor water quality and distribution. These sensors transfer information to software for systems optimization, which will ultimately create more conservation and efficiency gains for both residential and utility-scale water consumers.

Water Management & Monitoring
Sensicore

8 EFFICIENCY INFRASTRUCTURE

Efficiency infrastructure focuses on developing smart grid technology that supports varied generation sources and varied service models. Enhancing the efficacy and efficiency of power systems is dependent primarily on creating a data-rich, multi-modal smart grid. Moving the grid off analog, one-way communications and toward a networked, distributed operating model represents a crucial step in supporting the mainstream, end-user-oriented adoption of green power-generation sources. Efficiency infrastructure also focuses on applications that monitor power usage and output. These applications seek out system inefficiencies and reduce power usage.

8.1 Key Components

- **Monitoring** - Consumer monitoring of energy and resource use is an important means of driving down consumption. Efficiency technologies and applications operate regardless of the type of power generation (coal, wind, solar, biomass, etc.). Efficiency monitoring companies work to help consumers reduce their environmental impact while also keeping costs down.

  - **Energy IT** - Programmers and installers of system-optimization software for residential and commercial applications are creating investment opportunities in end-user-driven energy monitoring. Energy IT software identifies energy waste in electrical or networking systems and prescribes ways to eliminate it. More advanced software automates the waste-reduction process, and works to optimize the distribution of energy around the system.

Energy IT		
Verdiem	Optimal Technologies International, Inc.	Perpetual Water

  - **Sensoring** - Sensors monitor integrated systems in commercial buildings, factories, house, farms and utilities. They are programmable devices that monitor and regulate the use of electricity, lighting, water, HVAC, fertilizer and almost any other resource needed for integrated systems operations. Advances in nanotechnology are leading to new classes of autonomous, self-powered sensors that allow for efficiency gains in resource use.

Sensoring	
GoodCents	SensiNet
Orion Energy Systems	NxtPhase

- **Smart-Grid Infrastructure** - Higher-demand loads and varied-generation sources require an updated grid infrastructure to manage new capacity. Central control systems linked to networked, distributed meters provide the information hardware and software backbone for new smart-grid systems. Advanced materials for power transmission and distribution will help the smart grid bear higher load capacities, become self-healing, and flex between alternating- and direct-current generation sources.

► **Grid Management Systems** - Analog electricity grids are controlled from a centralized mainframe -- usually a SCADA system -- that relies on information bursts to distribute power load. Digital, information-rich grid management assumes a two-way connection between the central system and the nodes of a distributed generation network. Integrated communication through broadband-bearing power lines, for example, will allow for real-time data transfer and efficient asset allocation, load switching and monitoring of multiple power sources feeding into the grid. New grid-management systems will allow utilities to take advantage of different pricing models and power surpluses available from net metering and demand response.

Grid Management Systems		
GridPoint	Itron	Optimal Technologies International, Inc.
FatSpaniel	BPL Global	Broadbadn Energy Networks

► **Intelligent Network Devices** - Intelligent devices installed in homes and businesses that monitor energy production and consumption serve both the needs of both homeowners and utilities. These devices allow utilities to efficiently integrate demand response and net-metering programs within their decentralized smart-grid infrastructure. They allow homeowners the possibility of creating their own power and distributing that into the grid, streamlining income from demand response and net metering. Because communications between the smart-grid management systems and the intelligent home devices are networked, customers are able to track their energy consumption and production patterns online, in real time.

Intelligent Network Devices	
GridPoint	Enel SpA
Oxxio	Comverge

► **Advanced Materials and Components**- New generations of superconductive cables and power electronics will facilitate the increased load demand and increasing variety of power sources taking advantage of the smart grid. Intelligent hardware and networking software are only one component of the smart-grid infrastructure -- actual infrastructure is a necessity. New transmission and distribution materials will be switched between alternating- and direct-current load, be self-healing and incorporate communications architecture into the grid infrastructure.

Advanced Materials and Components
Echelon Corp.

9 GREEN SERVICES

Green-technology service companies bridge the gap between technology and consumer. They provide financing options, direct-install, retail and cost-saving solutions for end users of green power and renewable energy.

Developing innovative service models for providing green power generation is considered a major step toward enhancing green technology's accessibility and reach. For many of the established technologies, such as wind and solar, cost improvements are being made in business-model development aimed toward distribution and sales models. One benefit of this model is risk internalization -- many of these companies absorb the risk of owning and operating green power-generation sources for consumers.

9.1 Key Components

- **Renewable Power Providers** - Renewable power providers own, operate and finance green power-generation sources. These companies partner with systems installers and energy consumers to reduce the risks and costs associated with installing and managing green power-generation systems. Through innovative contracts, such as power-purchase agreements, renewable-power providers are able to distribute the costs of owning and operating green power-generation systems. Under a power-purchase agreement, the energy consumer locks into a set price over a set time period, while the service provider maintains ownership and responsibility for the green power-generation system.

Renewable Power Providers	
SunEdison	Tioga Energy
Solar Power Partners	GreenSun Energy Solutions

- **Integration** - Green-power integrators provide solutions for electricity consumers seeking to generate their own renewable energy. Integrated systems providers build turnkey systems for quick installation, provide installation support and site analysis and provide continued maintenance and upkeep on distributed-generation systems.

  - **Distributed Generation** - Distributed generation means skipping around the utilities and power grid and generating power at the point of use. This option has for a long time been especially attractive to individuals living off the power grid. Now, however, homes and business looking to reduce their electricity bills and their environmental impact are hooking up with distributed-generation installers to generate electricity at the point of use. These service providers provide entire packages, including installation - BIPV or mini-turbines, for example - pricing and payment options, ongoing systems maintenance, building permits and site analysis.

Distributed Generation		
Akeena Solar	SPG Solar	groSolar

- **Retail** - Retail stores represent the mainstreaming of green power generation. They provide consumers with technical training, installation support and advice, replacement parts for their distributed generation units, system maintenance and complete systems. Only a few stores devoted to renewable energy exist currently, though as prices come down on end units and as incentive programs become more widespread, we expect to see a number of companies take advantage of the growing retail market.

Retail
Yes! Solar Solutions

- **Efficiency Services** - Consumer monitoring of energy and resource use is an important means of driving down consumption. Efficiency technologies and applications operate regardless of the type of power-generation input (coal, wind, solar, biomass, etc.). Efficiency-monitoring companies work to help consumers reduce their environmental impact while also keeping costs down.

  - **Demand Response** - Demand-response service providers monitor consumer demand and scale up or down energy consumption depending on the load requirements of the power grid. For example, during peak load hours a demand-response provider might scale down electricity usage for lighting or HVAC systems, and sell the excess electricity back to the grid. Utilities pay demand-response providers for the extra electricity, and demand-response providers pass on these revenues to consumers. Demand-response providers work with all types of power generation and create revenue through efficiency gains in power distribution.

Demand Response	
EnerNoc, Inc.	Comverge
Consumer Powerline	Prenova

10 CONCLUSION

The Greentech Media Taxonomy is an ongoing effort involving the entire green-technology community. It is intended as a reference point for identifying sectors, technologies and companies across the green-technology market. The taxonomy will evolve to follow changes in the market, and we welcome your input. We are specifically interested in new technologies, ways to organize the taxonomy to make it more coherent and applicable and any new companies that you discover.

THE 2008 GREENTECH MARKET TAXONOMY