Solar Power and Sustainability in Developing Countries

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Abstract

Renewable energy is not an entirely new concept, but it continues to rapidly emerge as an alternative to fossil fuels and, hopefully, other deleterious energy sources. Products within this industry are being created on an unprecedented scale, and various systems are available for use. However, none are as applicable to the sustainability of developing countries as is solar power. Solar technologies are extremely promising with ever-increasing output efficiency and the capability to be used in a variety of locations. The intrinsic qualities of solar design afford it great utility for the following reasons: 1) most developing countries are located in a remote region with optimal access to the sun's rays, and not much else; 2) most resources for fuel and energy that are available to developing countries can only be used by exploitation of the ecosystem, which leads to social decline; 3) rising global independence of fossil fuels quickens the need for solar technology, which will increase competition and lower prices; 4) solar systems are relatively affordable and applicable to both homes and villages, as households of industrialized nations are using solar more than ever before; 5) within solar technologies, passive solar design is absolutely the ultimate in renewable energy for buildings, and can be coupled with solar panels to achieve maximum comfort and sustainability. Many projects capitalizing on solar power have already been implemented in developing countries, and serve as encouraging results for many more to come. In this paper, the aforementioned topics will be addressed to exemplify why solar power is the best choice for sustainability and renewable energy in developing countries, and how completed projects and on-going work in remote locations may lay the foundation for standards of excellence in this field.

Introduction

Harnessing the sun's energy is within our grasp, and for developing countries, this is a golden opportunity. Solar power is an increasing market for more developed countries, which can benefit from less electric expense over time. It is also good for the environment because it replaces the traditional, and in effect harmful, methods of energy production. There are other renewable energy sources besides solar, but it is especially practical for sunny areas which have less wind and water resources.

Because of the extensive research being conducted in this field, solar panels are developing into more efficient models than ever. The higher competition level between manufacturers allows for cheaper prices as well. Reasons for choosing solar energy are also clearly indicated by the growing number of projects conducted by various organizations and governments. Applications for this energy source can be from single houses and large electrical grids to cars, exhibiting a versatility perfect for the needs of a developing country.

Sunny locales

Most developing countries are geographically located for optimal absorption of the sun's rays. Many can be found along the equator or upon vast expansions of desert. In these locations, there is a great amount of sunlight year-round, but a shortage of water and biomass, and possibly wind in some areas. Solar photovoltaic (PV) systems are perfect for maximizing the potential of energy production in these settings.

There are several types of renewable energy sources in existence today. These include the sun, wind, flowing water, biomass, hydrogen gas, and geothermal heat. Because the transition into a new alternative energy phase may take at least 50 years, as well as huge investments, a set of criteria may be considered in order to decide the right energy source for a given region. These are the resource's (1) availability in near future (15-25 years) and long term (25-50 years), (2) net energy yield, (3) cost to develop, phase in, and use resource, and (4) environmental effects from extracting, transporting, and using resource [1]. For all these reasons, solar energy is generally an excellent choice for consumer use. It might not be the best choice for every location, such as a windy region with less sunlight. Most areas in developing countries are, however, extremely well-suited for its applicability, making solar power one of the most widely-known renewable energy sources chosen for projects funded therein.

Traditional resources

The remote homes and villages in these countries derive their energy from environmentally harmful practices due to unavailability of clean, renewable energy sources. The traditional and most important energy source is fuelwood and charcoal made from fuelwood. Also called potentially renewable biomass, these are "the main sources of energy for heating and cooking for roughly half the world's population. Within a few decades one-fourth of the world's population in developed countries may face an oil shortage, but half the world's population in developing countries already faces a fuelwood shortage" [1].

Their traditional method of energy production continues to degrade the ecosystem. Especially with some types of soil, land can be over-harvested until it is rendered useless. Land that has been removed of all vitality cannot replenish itself adequately for another harvest. The world is already burdened with the threat of global unsustainability. To encourage sustainability, an increasing number of programs are being implemented to expand the use of alternative fuels and energy. Renewable energy resources can improve quality of life by promoting sustainable development. Systems such as solar power are "practical, reliable, cost-effective, and healthier for people and the environment" [2].

Competition and lower prices

The diminishing supply of fossil fuels further addresses the need for cleaner, renewable fuel sources. Solar energy will be able to supply the power needed for housing and transportation alike. These expanding technologies are discussed later in this paper. Competition created with additional solar automotive technologies will really put solar power on the map. In the U.S., "developing renewable energy resources would (1) save money, (2) create two to five times more jobs per unit of electricity produced than coal and nuclear power plants, (3) eliminate the need for oil imports, (4) cause much less pollution and environmental degradation per unit of energy used, and (5) increase military, economic, and environmental security" [1].

Shell International Petroleum in London projected in 1994 that by 2050, half of world energy production will come from renewable energy, especially solar. The types of resources used for global energy consumption in 1973 and 1998 can be seen in Figure-1. In 1999, 8% of U.S. commercial energy came from renewable energy sources, and 1% from wind and solar. The results were very similar in 2000. Figure-2 shows the resources used for U.S. electricity net generation in 2000. In 1999, renewable resources accounted for 13% of the energy demand globally, and solar electric installations grew from 200MW in 1999 to 427MW in 2002. Even with this steady rise, it still only accounts for about 0.1% of primary energy demand globally [3]. "However, this means that relatively small increases in market penetration by solar energy as costs decline, lead to very rapid growth rates in this industry" [3]. This provides more of a competitive outlook after comparing the amount of solar energy installations to that of wind energy (which had 18 times more MW in 1999).

Solar electric prices today are at approximately 30 cents per kilowatt-hour, or around 2-5 times the average residential electricity tariffs (the calculation depends on installation location and local electric rates) [3]. This is the cost for grid connected solar markets, but Figure-3 shows that the cost for remote habitational solar markets is only 0.2-0.8 times the average residential electricity tariff. At a fraction of the energy cost of traditional electricity, remote solar installations can provide enough energy to power a single household's needs. Developing countries contain a large number of remote homes and villages, so the costs for PV systems here are going to be less.

In the commercial grid markets, solar competition is stronger in countries or regions with the highest electricity rates. Current prices will continue to drop, and upon reaching 10 cents per kilowatt-hour, better competition with other renewable energy sources will ensue. Figure-4 shows the current guideline electricity costs of generation for major renewable energy sources. The process of installing more solar PV systems will in turn lower costs, making it even more affordable to make the switch to cleaner energy.

Incentives in solar energy

Governmental incentives to strengthen the solar PV market within leading countries may positively affect installations for developing nations. Governments create budgets for solar because of the environmental and economic benefits, which are lower carbon dioxide emissions and the creation of high technology jobs within its industry. The use of high subsidies for stimulating domestic solar markets is led by Japan and Germany. "This has caused evolution of the industry structure in each country and led to strong distributor and dealer networks with well-trained installers and good customer support capabilities" [3]. More funding will make solar economical in on-grid markets, which will then lower the prices because of the high volume of manufacturing. A global comparison of grid-tied, off-grid, and consumer PV installations can be seen in Figure-5. The difference between annual government funding in Japan, Europe, and the U.S. can be seen in Figure-6.

The driving forces of connecting regional solar energy to the electric grid are (1) regional, governmentally-led programs and the subsidies within, (2) customer enthusiasm for green energy, especially solar, (3) higher electricity rates, encouraging alternative energy sources, (4) higher levels of sunlight, making solar electricity prices fall, (5) solar company marketing strategies, and (6) the number of local suppliers and qualified installers. These forces have a powerful effect on the market, as solar energy is being used more than ever for single homes, entire blocks, and a growing list of other versatile product uses. Because we are learning how well these systems work in our own countries, we can better implement larger or smaller programs for others.

Passive solar design

Solar energy can heat buildings in two ways, which are passive and active heating systems. Passive solar design can capture sunlight in a structure such as a room or building and then convert it to low-temperature heat for use as space heating. Well-known examples of this solar collection are greenhouses, sunspaces, and energy-efficient windows.

The most important aspect of passive design is the ability to capture the sun's energy as cheaply and efficiently as possible simply by the design of the structure and the types of materials with which it is built. In most climates, like those found in many developing nations, a backup heating system is not even needed with the passive solar gain. Materials which are frequently used for passive design walls and floors are concrete, adobe, brick, stone, salt-treated timber, and water in 55-gallon drums. During the day, these materials collect a large amount of solar energy as heat, and then release it slowly throughout the rest of the day and night. There are different ways in which these buildings can be designed because the combination of their position to other objects, direction towards the sun, and roof overhang can establish the desirable internal temperature for a given climate and location.

A passive solar design is optimal for any household's energy efficiency because once built, the materials do all the work. It allows for cooler summers and warmer winters with the reflective properties and heat sinks contained within. Daylighting uses windows on the walls and ceiling windows to produce a well-lit room during the daytime, and even allows for some moonlight at night. This concept is not only energy efficient; it also boosts mental well-being and cognitive functioning. Various school studies have shown that their students performed approximately 14% higher on tests after being exposed to their new day lit classrooms.

By building a solar design house even before attaching solar PV panels, the most can be made out of the sun's energy. This will absolutely ensure the greatest efficiency and cheapest. Houses built in this way contribute to sustainability, by "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [4]. When contemplating solar power for developing countries, this is the route to go because it permanently allows impoverished families to maintain maximum comfort for minimal expenditure.

Projects in developing countries

The 2002 UN World Summit on Sustainable Development in Johannesburg, South Africa, was held "to strengthen partnerships between governments, business, nongovernmental organizations, and other stakeholders and to seek to eradicate poverty and make more equal the distribution of the benefits of globalization" [5]. One such group that does this is Solar Energy International (SEI), which works together with grassroots and development organizations to utilize renewable energies for developing sustainability. SEI further educates and trains people that are involved with these technologies, and also plans and engineers sustainable projects. Volunteering programs are also supported by SEI. Their trained professionals have experience in the Americas, Africa, Micronesia, and the Caribbean. The staff "have delivered services to the Pan American Health Organizations, Non-Governmental development organizations (NGOs), foreign, national and state governments, universities and individuals seeking the benefits of renewable energy" [2]. They are one of very many groups involved in various projects conducted for the sustainability of developing countries. Establishing their organization for the betterment of conditions sufferable to human life, Solar Energy International serves to help lay the foundation in standards of excellence in this field.

The ability to promote a clean power source and improve basic living standards is the major attraction for international funding of solar energy in developing countries. Funding for developing countries is available through various venues. Developmental aid funding from several multi-lateral and bi-lateral aid agencies specifically include solar activities, which has benefited the market [3]. "Major projects of tens of $M have installed PV systems in remote villages in countries such as Indonesia and the Philippines. An increasing trend is the funding of sustainable, locally-based enterprises that can provide PV systems in an affordable way through micro-finance, for example using revolving funds" [3]. Increasingly, solar power is being used for programs which develop education, water supply, and healthcare in these countries. Because the initial costs of installing a PV system is so high, and even though they are economical over their life, micro-finance is becoming more of a focus toward assisting its affordability. Kenya is the most notable developing nation with a strong un-subsidized market, wherein their customers can obtain low power (10-20W) "entry level" modules [3].

Engineering sustainable vehicles

While the majority of space heating comes from passive solar, and the minority of high-temperature industrial heat comes from direct solar, no significant solar energy system is used for transportation. The future of solar-driven vehicles is dawning. Two professors at Middle Tennessee State University, Dr. Cliff Ricketts and Dr. Saeed Foroudastan, have conducted their very own research projects utilizing solar power. Obtaining amazing results, their work will contribute to a near future of solar automotive technology for all nations alike.

Dr. Ricketts, an Agricultural Education professor at Middle Tennessee State University, has been researching and building alternative fuel vehicles for 25 years. In 1991, Dr. Ricketts "set the world record for speed for hydrogen-powered cars at 108.4 miles per hour" [6]. A newspaper article features the car in Figure-7. Starting out with ethanol and methane engines, he now works on a vehicle fueled by sunlight and water.

The PV panels positioned next to his building store solar power in the grid line of the city electric service. They have stored as much as 10,000 kW in the grid bank, and the panels can provide enough fuel for a 70-mile trip. For long-distance capability, Ricketts incorporates hydrogen power. His Nissan truck's hybrid engine uses hydrogen. The solar panels generate power to a hydrogen electrolysis unit, which purifies water and then separates the hydrogen from the oxygen, displacing the hydrogen into a metal hydride tank to solidify. Another process further converts it to a gaseous state in order for the hydrogen to carry the truck an additional 70 miles. With a lighter vehicle and the proper equipment, his hybrid hydrogen truck could travel 300 miles.

Ricketts plans a 600-mile trek across the state of Tennessee. "Making the trip across the state on only sun and water as the power sources should, I believe, have as much impact as the Wright Brothers flying the first airplane," Ricketts said. "My hope is that we make this an annual event, and every year, somebody will do it faster, more efficiently and more economically. If we show it can work, due to supply and demand, it'll get cheaper" [7]. He receives $19, 000 annually from the Tractor Supply Company and Middle Tennessee State University. "With the right amount of funding, Dr. Ricketts is sure he can prove hydrogen's pertinence to the automobile industry" [8]. "Solar hydrogen," he says, "is the future of cars" [6].

Also established within Middle Tennessee State University's Engineering Technology and Industrial Studies Department is the Solar Raider, a race cart-style solar-powered vehicle. Dr. Saeed Foroudastan supervises a team of young engineers who build this vehicle from the ground up. Teams compete with vehicles that are powered by both solar and battery power, which can reach speeds up to 60 kM/h for distances of 100 kM. This vehicle has competed in the annual Solar Bike Rayce USA, an international racing event, in 2003 and 2004. "The objectives of the event are to stimulate interest in science and technology and to raise awareness of alternative energy" [9]. The vehicle won first place for the 200 meter sprint race and 100 kilometer race in 2003, but fell to second and third place in the same races, respectively, the following year. Figure-8 features the 2004 Solar Raider. Last year it was redesigned, and the 2006 prototype can be seen in Figure-9. "MTSU's 2005 Solar Vehicle design features a super-lightweight, low drag carbon fiber body, efficient NiMH batteries, and advanced power management and remote monitoring systems" [9]. It features increased aerodynamics and efficiency with flexible solar panels, and 60% of it has already been built. The new and improved solar vehicle is scheduled for a race during the upcoming summer of 2006.

The automotive break-throughs engineered by these professors will help eliminate the harmful environmental and sociopolitical effects created by fossil fuels. Locations using Dr. Rickett's incredible method of transportation will just need to have a water supply. Dr. Foroudastan's Solar Raider maintains even greater environmental standing by having less of a footprint than traditional cars. Both projects are examples of the grassroots initiative taking place within universities, and the great productivity which can stem from it.

Conclusion

Sustainability is the most precious gift that we can give to our future generations. Solar power, especially as it reaches more competitive levels with other renewable energy sources, may serve to sustain the lives and families of millions of underprivileged peoples in developing countries. Solar energy can be directed both actively (by solar PV panels) and passively (by green building design) in order to shed the warm, bright light of opportunity upon the many dark recesses of the globe. Through engineering, this technology can also be applied to the transportation industry.

So much has already been accomplished by countless international, governmental, and non-governmental organizations in the funding and development of projects involving renewable energy systems for these nations. It is incredibly uplifting to view the pictures and read about the amazing work being done to transform uninhabitable conditions into cozy living spaces. The ability to simply cook indoors without gathering a dwindling supply of firewood is a luxury awaiting many more deserving families.

Ecosystems, developing societies, and the solar energy market will only benefit from an increase solar PV system installations. Funding for these systems, however, is a challenging aspect when there is so much need. Fortunately, as more and more people give donations and volunteer their professional and technical services, solar energy will become cheaper. The initial installation is basically the only cost, so the investment will simply pay for itself for the rest of its life and for the lives shared beneath its comforting glow.

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Biographies

DR. SAEED FOROUDASTAN is an Associate Dean of the College of Basic and Applied Sciences and Professor in the Engineering Technology and Industrial Studies Department. He received his Ph.D. in Mechanical Engineering (1987) from Tennessee Technological University. Professor Foroudastan is involved with several professional organizations and honor societies, and has many publications to his name. He also holds U.S. and European patents.

OLIVIA DEES is a graduate research assistant for the Masters of Science in Professional Science degree program at Middle Tennessee State University. She has an undergraduate degree in Biology with an emphasis on plant biology and a minor in Environmental Science and Technology. She is currently pursuing a Masters of Science degree in Professional Science, with a concentration in Biotechnology.

Appendix

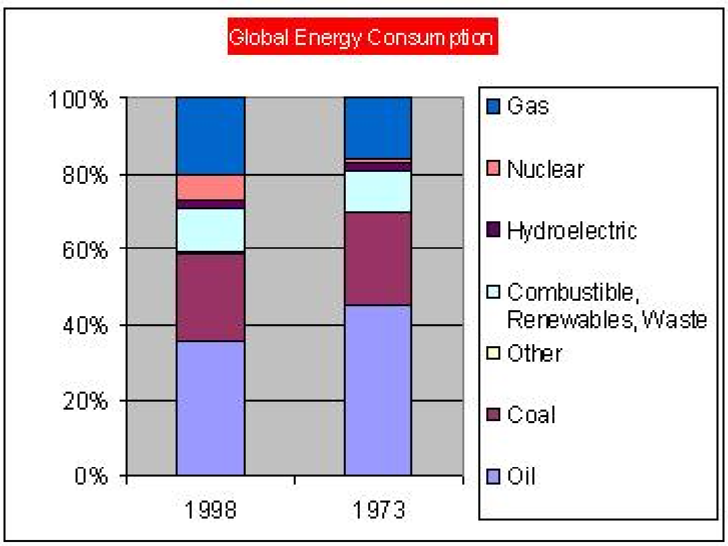

Figure-1. Global Energy Consumption of 1973 and 1998

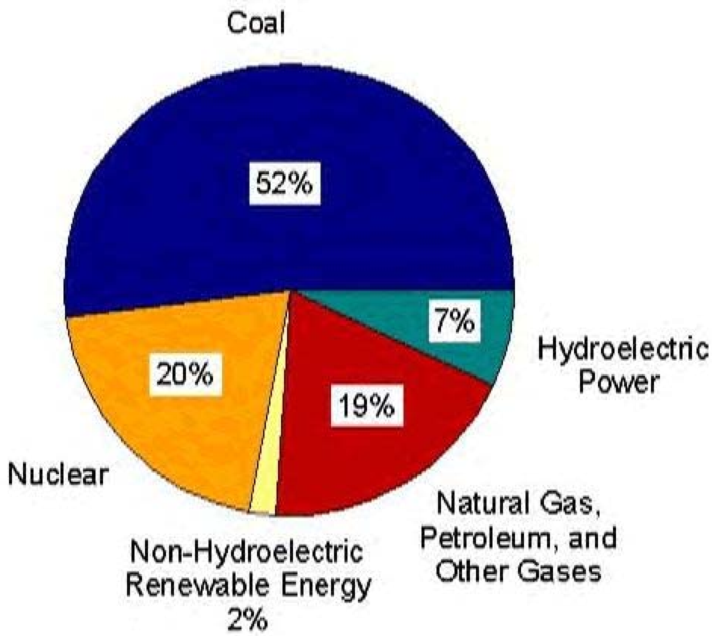

Figure-2. U.S. Electricity Net Generation by Source for 2000

	Solar markets (av of large 5 years)	Solar Price / Competing Energy source
Remote Industrial	17%	0.1-0.5 times
Remote Habitational	22%	0.2-0.8 times
Grid Connected	59%	2-5 times
Consumer Indoor	2%	n/a

Figure-3. Competitive Positioning by each Market Segment

Combined cycle gas turbine	3-5
Wind	4-7
Biomass gasification	7-9
Remote diesel generation	20-40
Solar PV central station	20-30
Solar PV distributed	20-50

Figure-4. Renewable Energy Guideline Electricity Generation Costs Today (cents/kWh)

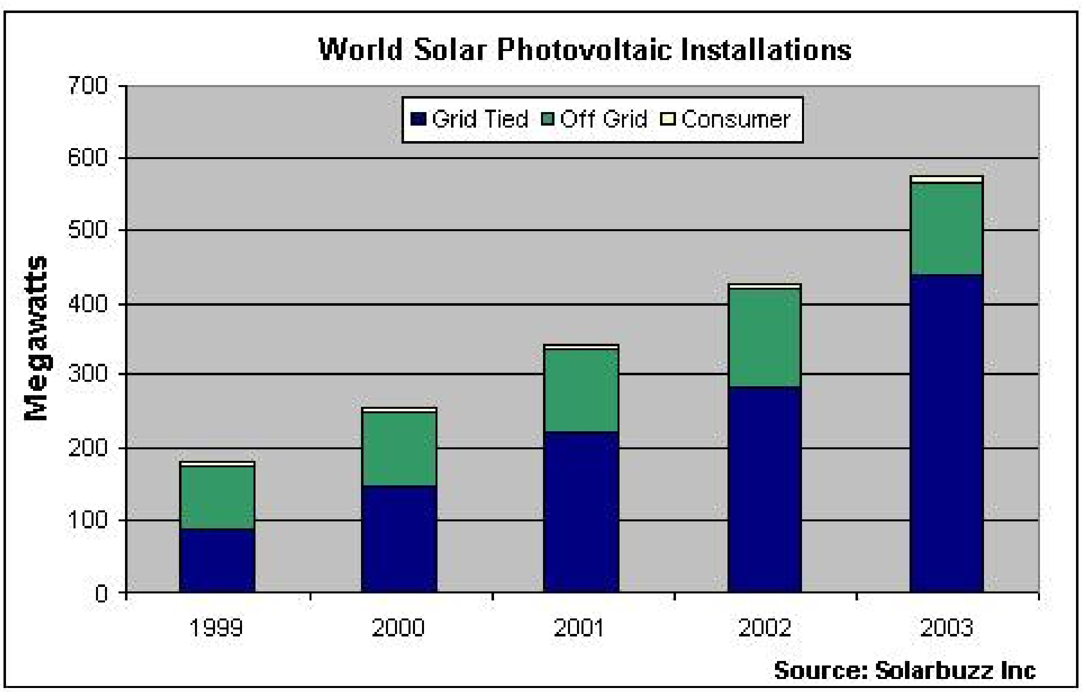

Figure-5. Global Solar Photovoltaic Installations

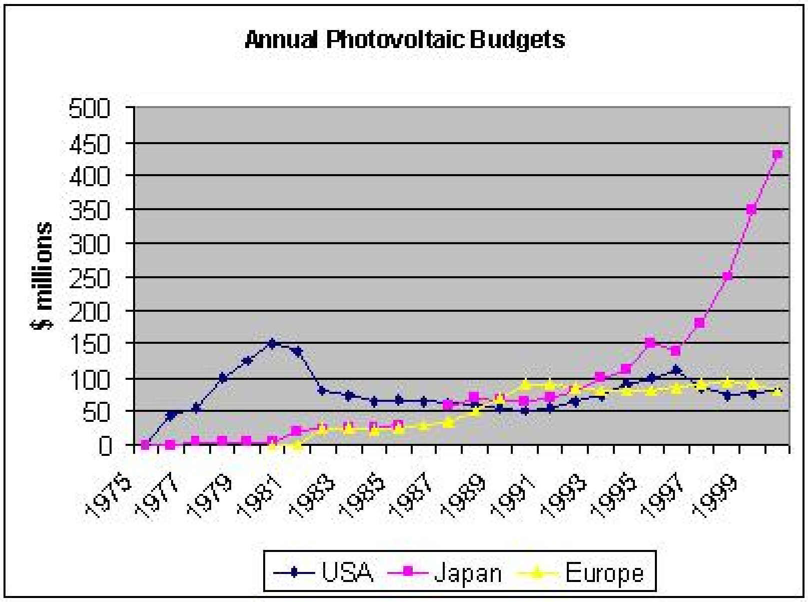

Figure-6. Annual Solar Photovoltaic Budgets

WHEELS & DEALS

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WHEELS & DEALS Cover Story

MTSU WINS WORLD'S FIRST HYDROGEN RACE

Middle Tennessee State University set the World Land Speed record for hydrogen at the World's First Hydrogen Race during Bonneville Speedtrials 1991. The race at the Bonneville Salt Flats in Wendover, Utah was dominated by MTSU. Dr. Cliff Ricketts, who has been working on alternative fuels since 1978, assembled a team consisting of present and past MTSU students. TSC was the major sponsor enabling MTSU to compete along with Clark Maples Realty, Cracker Barrel, Nissan, Union Planters Bank, Farm Credit Services, Farm Bureau Insurance, Bridgestone Tire, A.E. Staley Co., and Traders' Post Inc.

Tom Hennesy, chief executive officer of TSC (Tractor Supply Company), and Cliff Ricketts, a Middle Tennessee State University professor of agriculture, first met in Kansas City at the National FFA Convention.

The ag mechanics class was working on a car powered by hydrogen gas and Ricketts needed corporate support to continue the work. He made his pitch to Hennesy and other TSC executives in Nashville and was able to convince them to contribute to the project.

According to Hennesy, "He convinced me that he and his students were doing some work that is important not only to farmers, but to the entire American public. And if that's not enough, I was impressed by the fact that hydrogen as a fuel has numerous advantages. It doesn't pollute and it's plentiful. I wanted TSC to be involved with this project."

The TSC/MTSU partnership paid off last summer when MTSU set the world land speed record for hydrogen fuel at the Bonneville Salt Flats in Wendover, Utah. The MTSU team first set a record at 85.32 MPG in a Mustang II running on a mixture of gasoline and hydrogen. Then running a 1973 Chevrolet pick up on a mixture of ethanol and hydrogen, they broke their own record with a speed of 108.157 MPH.

According to Hennesy, "This vehicle is a perfect example of Ricketts' practical approach to problems. The engine is from a 1949 International Tractor. It was cheap and it solved a big technical problem."

Detractors had said that backfiring made it nearly impossible to run an engine on hydrogen. But the low torque tractor engine eliminated the backfiring problem.

A hydrostatic transmission connected to the engine converts the low torque to high speeds needed to set records at Bonneville.

Ricketts doesn't claim to be a chemist, physicist, or biologist. "I'm an educator," he explains. Since 1979, Ricketts and his team of past and present students have an impressive record of developing vehicles which run on alternative fuels.

(Continued on page 4)

Figure-7. World Record in Hydrogen Car Race

Figure-8. Solar Raider in 2004

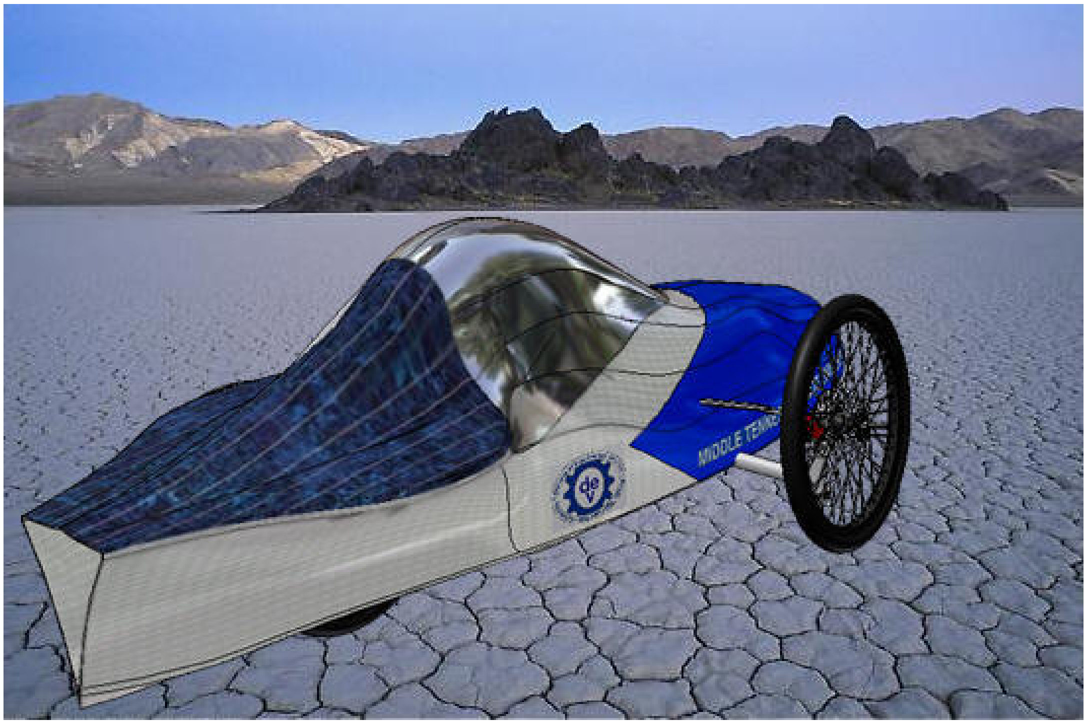

Figure-9. Prototype for New Solar Raider in 2006