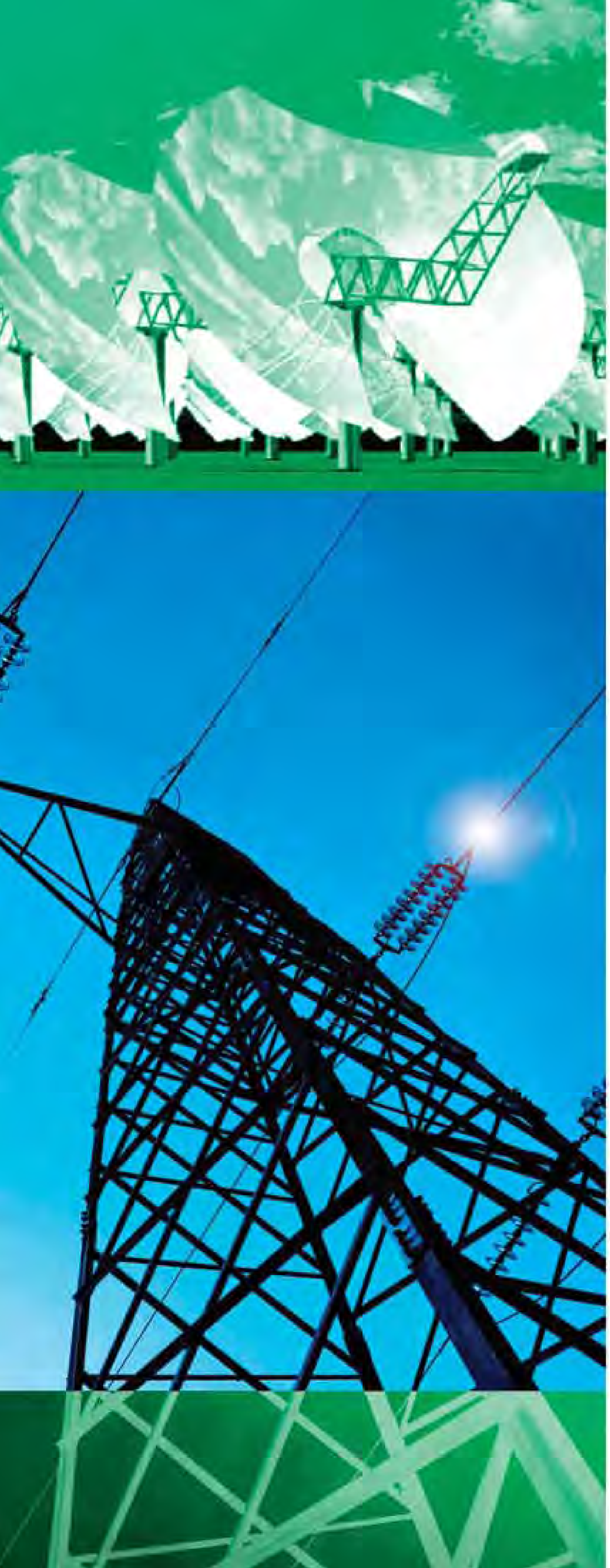
SolarCAT™

A Practical Path to Renewable Energy Independence

Dr. John G. Sperling



The Practical Path was conceived of and articulated by John Sperling, Chairman, SolarCAT, Inc., in collaboration with, Herbert Hayden, President of SolarCAT Inc. and Southwest Solar Technologies, Dr. Jorge Klor de Alva, Senior Vice President, University of Phoenix, Eric Rey, CEO, Arcadia Biosciences, Dr. Joseph Simmons, Professor of Materials Science and Engineering, University of Arizona and John Thiella, Senior Counsel, The Renewable Energy Accountability Project. In drafting this plan, I have drawn on the advice of persons knowledgeable in the many subjects that must be included in designing a practical path to renewable energy independence: electrical utilities, the electric grid, conventional and renewable energy technologies, biofuels, licensing and permitting processes, investment strategies and the necessary enabling legislation that will be needed to make a new energy system possible. Because I and some of those who have aided me in drafting the Practical Path have ownership of companies engaged in the renewable energy industry and patents for critical energy related technologies, we have provided disclosures (See Appendix A) which we hope will allay any concerns that the Practical Path is a self serving proposal. Rather, we believe that the ownership of these companies and the patents that sustain them are crucial to achieving renewable energy independence both in America and in other countries around the world.

Spring 2009

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Introduction[1]

If America is to address the twin problems of energy independence and global warming in a meaningful way, it has to accelerate the construction of renewable energy plants now. Yet public opinion in America has pretty much assumed that we will have to rely on fossil fuels for at least the next 40 years.[2] Predictions that our use of oil will be the same in 2050 as it is today will be true if and only if we willfully cling to skepticism regarding the feasibility of renewable energy that is eagerly promoted by the fossil fuel industries. The only way this skepticism is going to end is to convince the public that current renewable technologies can create a carbon free energy system. Discussions of renewable energy are mostly speculation about future technologies that might come on line 20 or 30 years hence. This is well illustrated by the remarks of Steven Chu, our Energy Secretary, who claims he is totally dedicated to achieving energy independence and ameliorating the devastations of global warming yet believes in the 20/30 time frame. This is well illustrated by his answer to this question by a Newsweek reporter, [3]

> **Reporter's Question:**
>
> "There's wind, solar, geothermal. Which technology will get us out of the fossil-fuel trap?
>
> **Secretary Chu's Answer:**
>
> "Ultimately, it's going to be some form of solar energy. But as to which technology 20 years and 30 years from now will be the dominant one, I don't know. On that time scale, we have to work on carbon capture and storage. Nuclear energy I think has to be part of the portfolio in this century."

Secretary Chu's major argument for the necessity of carbon capture and storage lies in his belief that carbon sequestration (aka "clean coal") is the only way China and India will ever move to a carbon free energy system; this in spite of the fact that both countries possess sufficient sunny and windy areas to support a renewable energy

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[1]See Appendix A for Authorship and Disclosures.

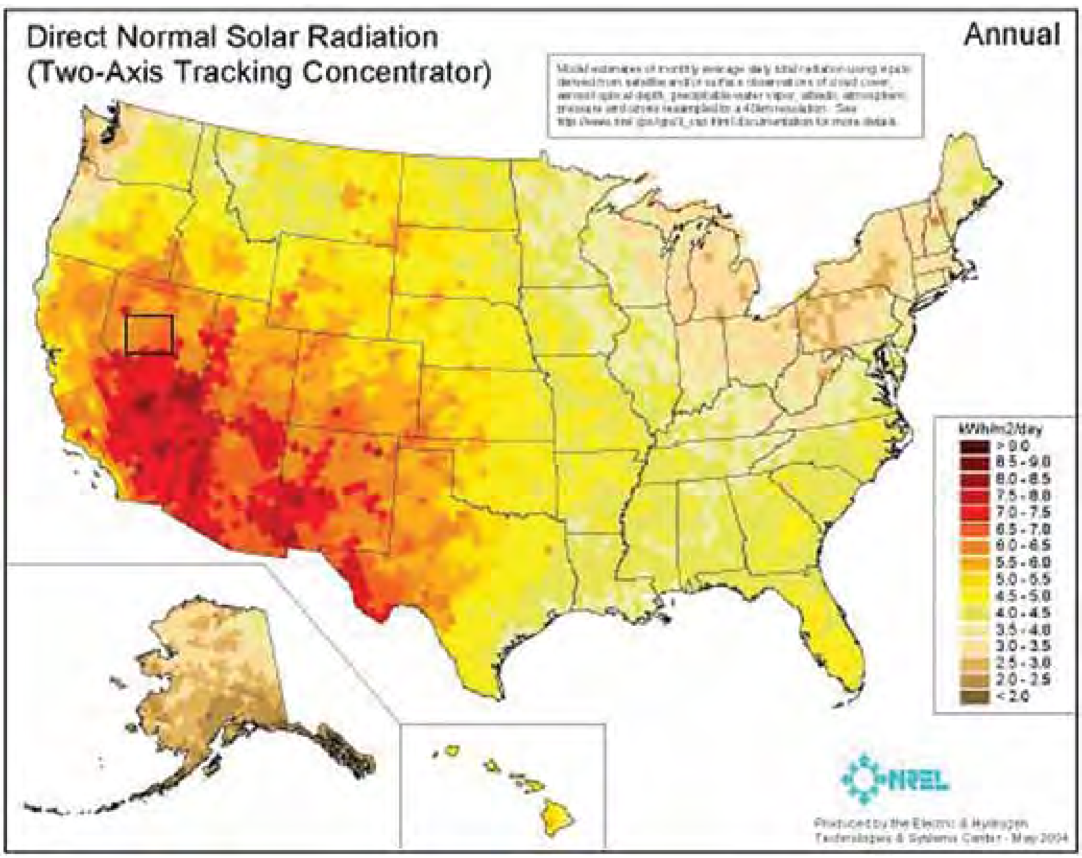
[2]'In its long-term forecast, Exxon says that by 2050, hydrocarbons — including oil, gas, and coal — will account for 80 percent of the world's energy supplies, about the same as today.

"Renewable energy is very real," David J. O'Reilly, the chief executive of Chevron, said in a speech in New York last November. "We need it. It will be an essential part of the future I envision. But it's not realistic to suppose we can replace conventional energy in a timeframe that some suggest." "Oil Companies Loath to Follow Obama's Green Lead," New York Times, 4-8-09

[3]Newsweek, "In the Great Ship Titanic," April, 20, 2009

system. The thought of 20 or 30 more years of fossil fuel energy generation with billons being spent on chasing the mirage of "clean coal," while building dozens of radioactive waste laden nuclear plants is a future too dismal to contemplate. At the core of Secretary Chu's skepticism about the viability of solar technology at utility scale is the problem of intermittency, a characteristic of all renewable energy sources except geothermal. The solution to the intermittency problem is energy storage—that is, a technology that can harvest the various sources of intermittent energy, store that energy and then return it to the gird on an as needed basis. Secretary Chu is correct, storage is the Achilles Heel of renewable energy, but fortunately, viable technology now exists to solve the storage problem. That technology is called **SolarCAT** for "Solar with Compressed Air Technology" and it is shovel ready.

There is a **practical path** to renewable energy independence and this document describes that path. If we take the first few steps along that path, it will soon become apparent that the path leads to a carbon free energy system that will turn skepticism into optimism.



Achieving green energy independence will guarantee America's economic dominance in the 21st century.

Utility Scale Renewable Energy Technologies

Wind, with the Investment Tax Credit (ITC), is the only one of the large scale renewable technologies that is able to deliver energy at a price that is competitive with natural gas. Fortunately solar power will soon be able to do the same. This will be achieved by an innovative concentrated solar power (CSP) system termed "SolarCAT" for Solar Compressed Air Technology.[4] SolarCAT engineers are confident that their technology will be able to deliver peak time power at 10-12 cents per KWh. SolarCAT is the core technology of the Practical Path since it is the only renewable technology that:

- Integrates all other forms of renewable energy so that no energy is lost due to intermittency caused by changing wind or sun conditions or loss of base load geothermal power in times of low demand.
- Stores energy as compressed air for 8 hours, 8 days or 8 weeks.
- Meets the electricity demand curve 24/7.
- Operates with minimal use of water.
- Uses no toxic materials in its fabrication, thus there is no toxic waste problem as is the case with photovoltaic panels.

The challenge America faces in achieving green energy independence is equal to the challenge of Pearl Harbor. Failing to meet that challenge will spell national disaster, meeting it will guarantee America's economic dominance in the 21st century. Thomas Friedman of the New York Times has recently argued that "renewable energy technologies…are going to constitute the next great global industry" and therefore "the country that spawns the most [of these] will enjoy more economic power, strategic advantage and rising standards of living."[5] SolarCAT will be one of those spawns.

Yes, 40 minutes of sunlight produces enough energy to meet the current global energy demand for a year, and either wind,[6] solar or geothermal could supply all of our electricity, but these assertions do not tell us how or how soon. There have been numberless speeches, articles, films, Power Points and books on how America can

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[4] For a discussion on the technology and economics of SolarCAT, see pp. 7-26.

[5] Thomas L. Friedman, "And Then There Was One," New York Times, 9-3-08. "Show Us the Ball," New York Times, 4-8-09.

[6] "There's enough renewable energy to meet energy demand," Wellinghoff said. "There's 500 to 700 gigawatts of developable wind throughout the Midwest, all the way to Texas. There's probably another 200 to 300 gigawatts in Montana and Wyoming that can go West." ENERGY POLICY: No need to build new U.S. coal or nuclear plants — FERC chairman, E&E, April 22, 2009

become energy independent, cut green house gases to a sustainable level, and create a new industrial economy based on renewable energy.[7] All of these plans offer a variety of technologies and actions that are in themselves reasonable solutions, given limitless funding and all of the permitting required to site both the land intensive plants and the transmission lines necessary to carry their power to the grid. However, they do not describe how these technologies can be integrated to deliver power to the grid as needed or how they will store the energy needed to power the system in periods of calm wind or no sun.

None of the current CSP technologies have demonstrated that they can produce energy at market rates and still produce the claimed 16 hour energy storage.[8] Their weaknesses are many. None of the proposed renewable energy solutions has a viable energy storage system. None have a solution for extended periods of overcast after their claimed 16 hours of storage is exhausted, nor do they have a plan to integrate solar with other forms of green energy to produce a flow of electricity that meets the demand curve 24 hours a day and also allows for a seamless transition period from fossil-based to renewable technologies. Finally, none of them discusses the politics of energy or their estimated capital costs which range from $4.5 to $6.6 trillion—a sum that seems far more than the federal government can provide or that investors will be willing to provide, especially when one adds the $500 billion needed to upgrade the grid. The Practical Path challenges their assumption that the government will have to invest billions in new energy technologies. Rather, the necessary 2000 GW of renewable energy plants can be built for some $3 trillion and can be financed by the private sector, however, that money will not be forthcoming unless there is a renewable energy grid . Overcoming the regulatory, environmental, legal and political barriers to that end will call for a level of political skill and courage equal to that of Franklin Delano Roosevelt.

No currently installed form of renewable energy—wind, CSP, PV, geothermal, wave or tidal—can by itself meet the demand curve as efficiently as the fossil based system.

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[7]E.g., A. Gore, "An Inconvenient Truth"; T. Nordhaus and M. Shellenberg's 60 slide Power Point, "A Third Way on Warming"; S.D. Freeman, "Winning Our Energy Independence"; G. Smith, 2007; K. Zweibel, J. Mason and V. Fthenakis, "A Solar Grand Plan," Scientific American, December 2007; Lester Brown, "Plan B 3.0" Earth Policy Institute, 2008; D.R. Mills and R.G. Morgan, "A Solar Powered Economy," Environmental Science, January 2008; Thomas Friedman, "Hot, Flat and Crowded: Why we need a green revolution and how it can renew America," Farrar, Straus and Giroux, 2008.
[8]To date, none of the CSP projects funded by private investors have been completed and many have been abandoned or postponed. That is not going to change in the future, so a renewable technology must be able to produce power at market rates.

Geothermal plants operate 24/7 at a set level and therefore cannot meet changing power demands and the same would be true of ocean thermal. Wind is intermittent and its highest output is at night when demand is lowest, wave power would also be intermittent and solar operates only when the sun is shining. All forms of renewable energy must therefore be matched with other forms of energy in order to meet America's varying demand for electricity. The only way this can be accomplished is through a system that stores energy that can be delivered when needed.

There have been a variety of solutions to the problem of energy storage—dams, flywheels whose inertial energy can spin generators, batteries, hot water, oil and molten salt—but all have serious limitations. The only efficient and financially viable energy storage system that can store almost any amount of energy from any electrical or mechanical source is compressed air. Currently, all of the proposals for compressed air storage systems, primarily for wind, will burn natural gas to extract the energy in the stored compressed air creating a system with 60% of the energy from wind and 40% from fossil fuel. Fortunately, the Practical Path will use solar heat during sunny daytime and biofuel in non-sunlight periods. Natural gas will only be used if biofuel is unavailable. Burning renewable biofuel will create a fully green Wind-Solar-Biofuel-compressed air system.

Confirming Data

To reaffirm the vital importance of an independent renewable energy system here are some confirming data:

- In 2008 the nation's negative balance of trade was $820.8 billion. Of this, 47%, or $386.3 billion, was for the import of foreign oil.[9] If America is once more to achieve a positive balance of trade and pay off its enormous debt to China, it must end oil and gas importation and develop exportable renewable energy technology that can be sold to foreign buyers, especially to China, thus lowering our negative balance of trade, while helping China to end its dependence on coal and oil.

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[9]See: U.S. Census Bureau, U.S. Bureau of Economic Analysis, "News" March 13, 2009, Exhibit 9, Chart 11. See link at: http://www.census.gov/foreign-trade/Press-Release/current_press_release/ft900.pdf

- During 2006, American and Chinese coal fired energy plants emitted 7 billion metric tons of carbon into the atmosphere from fossil fuel emissions.[10] It is a rate that will bring us the Three C's—catastrophic climate chaos, unless CO2 emissions from coal are cut to zero.[11] Only America and China, acting together, can avoid this result. The closure of a 1 gigawatt coal plant, replaced by a wind or solar plant, reduces annual carbon emissions by 6.5 million tons.

- Not only will a renewable energy system do much to solve the global warming problem, it will create millions of new high paying jobs.[12]
  - For example, a grid that will support a renewable energy system would create 7 million construction job years.[13]
  - Given the possibility that no more coal fired plants will be built in the U.S, the closure of a 1 gigawatt coal fired plant would reduce annual carbon emissions by 6.5 million tons at a cost of 177 operations and maintenance jobs.[14]
  - Building renewable energy plants can more than compensate for those job losses. The construction of a 1 gigawatt wind[15] or concentrated solar plant[16] will produce zero post construction carbon emissions and the following number of jobs.
  - Construction job-years per gigawatt:
    - Wind -- 22,000 job-years
    - Solar -- 37,000 job-years

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[10]See: "World Carbon Dioxide Emissions from the Consumption of Coal 1980-2006," U.S. Energy Information Administration. Linked at: http://www.eia.doe.gov/emeu/international/carbondioxide.html

[11]See: "Global Warming, Beyond the Tipping Point," Scientific American, October 2008, quoting climatologist Dr. James Hansen. Linked at: http://www.sciam.com/article.cfm?id=global-warming-beyond-the-co2&page=4

[12]See: "Global Boom in Coal Power – and Emissions," Christian Science Monitor, March 27, 2008. Linked here: ttp://www.csmonitor.com/2007/0322/p01s04-wogi.htm

[13]Because construction jobs are by their nature temporary, they are measured in job years. For example, a two year construction job would create two job years for each job. A recent study released by the technical consulting firm KEMA, projected that an investment of $16 billion in smart grid technology could create directly 280,000 jobs. In January 2007, a study which appeared in Scientific American projected that over $400 billion would be necessary to fully upgrade the nation's grid to allow for a significant build out of solar power. Applying the KEMA projections to jobs created per dollar investment, then such a build out could create an additional 7 million jobs.

[14]According to a study done by the U.S. Energy Information Agency, coal plants were operated with 53 employees per 300 megwatts. See: "Trends in Power Plant Operating Costs, Figure 5," last edited in 1999. Linked at: http://www.eia.doe.gov/oiaf/issues/power_plant.html

[15]See: "Wind Power for Rural Development," National Renewable Energy Laboratory, May 2005, page 13. Linked at: http://www.windpoweringamerica.gov/pdfs/wpa/flowers_windpower_2005.pdf

[16]See: "Economic, Energy and Environmental Benefits of Concentrating Solar Power in California," 5-14, April 2006, Linked at: http://www.nrel.gov/docs/fy06osti/39291.pdf.

- Operations and Maintenance jobs:
  - Wind -- 1,000 permanent jobs[17]
  - Solar -- 1,400 permanent jobs[18]

Two thousand 1 gigawatt renewable energy plants will be required to replace the currently operating coal and gas plants. To replace the oil consumed for transportation will require another 3,000 gigawatts of renewables. Achieving the first goal will entail the replacement of all fossil fuel burning electric plants. The first 2,000 GW of renewable plants can be built over the course of 20 some years and will reduce carbon emissions by 2.5 billion metric tons a year.[19] Building one hundred 1 GW renewable plants each year for 20 years will create approximately 2,500,000 construction jobs each year for a total of 50,000,000 job-years. By the end of the process, it will also have created 2,400,000 permanent operations and maintenance jobs—whether in construction or maintenance, these jobs cannot be outsourced.

These are goals worth working for.

The Grid

If America wants both energy independence and a sustainable level of carbon emissions, its only alternative is a renewable energy system that powers its homes, offices, factories and transportation—autos, trucks, trains and hopefully someday planes and ships. Such a system would have to be secure, robust, redundant and have, at is core, a grid that is conceived of, designed and operated as a single entity. A renewable energy system would require that the grid become, for the first time in its history, a fully integrated national public utility that could absorb the energy generated by thousands of widely distributed mostly rural renewable energy plants. Unless a federal agency is given the power of eminent domain, local and state agencies,

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[17]See: "Wind Energy for Rural Economic Development," National Renewable Energy Laboratory, May 2005, page 8. Linked at: http://www.windpoweringamerica.gov/pdfs/wpa/flowers_windpower_2005.pdf.
[18]See: "Economic, Energy and Environmental Benefits of Concentrating Solar Power in California," 5-14, April 2006, Linked at: http://www.nrel.gov/docs/fy06osti/39291.pdf.
[19]The Department of Energy, Energy Information Agency found that in 1999 the fossil fuel electric generation produced 2,584,779,000 metric tons of CO_2 emissions. See link: http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html.

environmental and property rights associations will tie up the process in regulatory and legal battles that will grind the process to a halt. Unless the grid is consolidated and rationalized as a national utility, America can never achieve renewable energy independence and the ravages of global warming will continue apace. This is one of the greatest challenges that will faces the new Administration and the new Congress. How that challenge is addressed will not only determine the fate of America, it will determine the fate of the world.

Most proposals to create a green and/or an energy independent transportation system have been based on natural gas or hydrogen, each of which would require its own grid. In our opinion, constructing either of these grids would be a colossal waste of money. The same can be said of altering automobile engines to burn either gas or biofuel and then trucking the biofuel across thousands of miles from biofuel plants to tens of thousands of filling stations from the Atlantic to the Pacific. In short, the solution to the problem of green transportation energy independence is to build an electric grid where every home is a filling station and every filling station is a battery recharge and exchange station.

The Wind-SolarCAT-Biofuel System of Energy Independence

The Technology of Renewable Energy Independence

The path to renewable energy independence is a hybrid system of wind, concentrated solar, and biofuel. A key feature of this system will be the use of compressed air technology supplementing and maximizing the efficient use of concentrated solar power, wind, and biofuel in "SolarCAT" plants. In this system the sources of energy production can be broken down approximately as follows: 60% from wind, 30% from solar and 10% from biofuel.[20] By 2012 there will be adequate biofuel to power the first 1 GW SolarCAT plant scheduled to come on line by early 2013. Appendix E offers a description of how biofuel production using sweet sorghum ethanol, then cellulosics and finally algae can supply the needed biofuel from 2012 going forward. Should the demand for SolarCAT plants exceed the supply of sweet sorghum ethanol, then natural gas can be piped to the SolarCAT plants and, in case of real emergency, gas can be shipped to the plants in liquefied form and stored in caverns.[21]

Not only can this system power the nation, it will provide total energy demand as needed and store enough energy to power the nation for a day, a week or a month. This can be achieved by a relatively simple set of technologies of wind, concentrated solar with compressed air storage and biofuel for non-sun periods. When fully constructed the system will generate all of the nation's energy needs well into the future.

A Renewable Energy System in Operation

The core technology of the Practical Path model of wind, SolarCAT and biofuel is SolarCAT. It is the core technology because it uses sun or biofuel to extract the wind energy that is stored in the form of compressed air. Thus it completes a cycle of clean energy. If SolarCAT has to use natural gas in non-sunlight periods, it will still produce 90% clean energy. It also increases the efficiency of all intermittent forms of renewable since any of these forms of energy can power the compressors that stores their energy in the form of compressed air.

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[20]Beginning in 2012 we project that the biofuel needs of the Practical Path can be met by the cultivation of sugar rich sweet sorghum which, because it is grown on non-irrigated marginal land, will not compete for land or water with food crops. By 2012, there would be 1.7 million acres under cultivation and this would ramp up to 29 million acres by 2025. This might appear to be an impossibly large number until one learns that there were 27 million acres of sorghum in 1960. Going forward from 2025, sorghum, cellulose and algae will be able to produce whatever level of biofuel the renewable energy industry can absorb.

[21]As noted on p. 16, America has an estimated 211,085 trillion cubic feet of natural gas which is far more than would be needed to power the SolarCAT system until biofuel production reached the necessary level.

Even with its current shortcomings, wind technology is now the most efficient source of renewable energy and the only constraints on building the needed wind farms are land acquisition, permits, transmission lines and the supply of wind turbine generators.[22] But SolarCAT, by permitting the wind energy currently being lost from intermittency to be shunted to the SolarCAT air compressors, can extract the energy from wind farms with minimal losses.

For reasons to be detailed below, the proposed Wind-SolarCAT-Biofuel combination is the most energy efficient renewable energy system yet proposed. All renewable energy sources will be fed into the grid. As demand drops, the excess power will be shunted to the SolarCAT compressors. By using stored air, SolarCAT can provide a smooth flow of electricity to the grid 24/7. During hours of peak demand—6:00 am to 9:00 pm—SolarCAT will operate mostly on sun, during non-sun hours it will burn biofuel whenever the supply of wind energy drops below the demand level. During periods of low demand (e.g., at night) excess energy from the intermittent and non-load-following forms of renewable energy (primarily wind) will power the compressors that compress the air into storage. During the day when solar provides most of the needed energy, wind energy can be shunted to the compressors. Compressed air storage is the only way the disparate forms of renewable energy can be captured and used with maximum efficiency both to produce power and to create the first truly secure system of national energy security and independence. Furthermore, it will be the most energy efficient system ever devised.

We can assert with a high degree of confidence that the hybrid **Wind-SolarCAT-Biofuel System is a Practical Path to Renewable Energy Independence.** There may be other technologies now under development that would also serve as the heart of a renewable energy system, but to the best of our knowledge they are decades away from building, testing and confirming their efficiency. Such is not the case with the SolarCAT system described below.

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[22]"Wind Energy Could Produce 20 Percent of U.S. Electricity by 2030," DOE Report ("20 Percent Wind Energy by 2030") Analyzes U.S. Wind Resources, Technology Requirements, and Manufacturing, Siting and Transmission Hurdles to Increasing the Use of Clean and Sustainable Wind Power, Office of Public Affairs, Press Release, May 12, 2008; "Wind Energy Bumps Into Power Grid's Limits," New York Times, August 27, 2008.

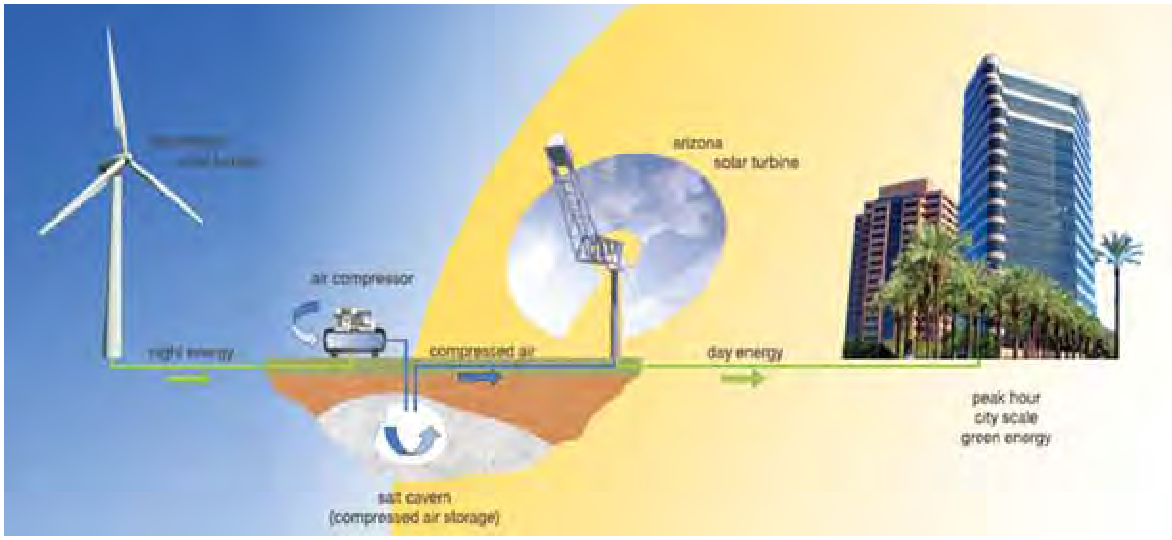
The Elements of the SolarCAT System

The following table on relative solar technology efficiencies provides a major reason SolarCAT is the preferred technology.

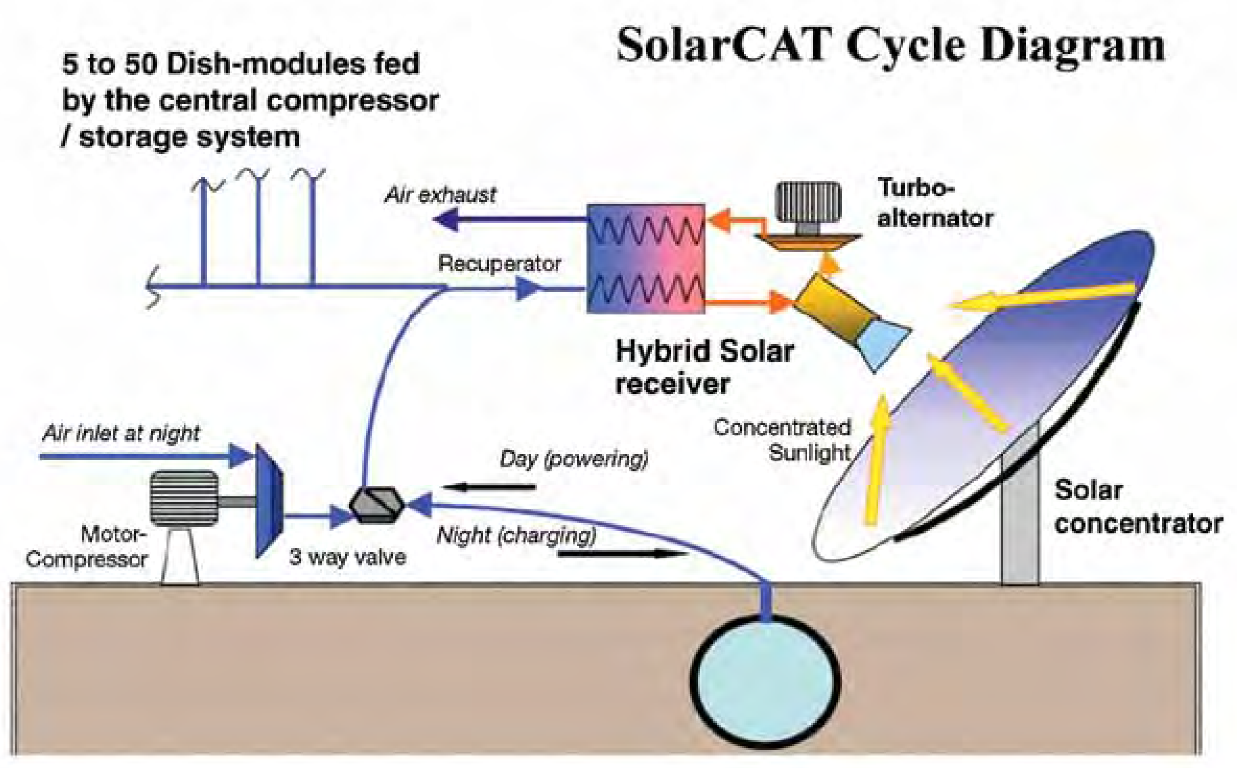
CSP Technology Comparisons

	Trough/CLFR with Stream	***Dish Stirling***	***Power Tower***	***CPV***	***SolarCAT w/Air Storage***
Companies	Abengoa, Acciona, Ausra, SkyFuels	SES, Infinia	BrightSource, eSolar	Amonix, SolFocus	SolarCAT
Cooling	Water cooling, or collant/radiators	coolant/ radiator	water cooling, or coolant/radiators	air cooled	exhaust air at 120F
Work fluids	thermal oil, salt, water, steam	hydrogen	thermal oil, salt, water, steam	none	air
Energy Storage	thermal mass (oil, salt, or water)	non	thermal mass (oil, salt, or wter)	non	compressed air storage of off-peak electricity
Efficiency	10-17%	20-30%	8-18%	15-33%	30-37%
Minimum Unit	60 MW	25 KW	33MW	1KW	200KW
Acres/MW	5	5	5	5-10	1.6

A macro view of the Wind-SolarCAT-Biofuel System



The Elements of SolarCAT



How the SolarCAT System Operates

1) The compressor operates at night, using power from wind and other off-peak renewable electric sources, and stores the air at 200-300 psi.

2) During the peak demands of the day, the stored air is piped to the receiver at the focus of the dish where it is heated to 1700° F. The superheated compressed air drives the two high pressure turbo-alternators, each generating 50 KW.

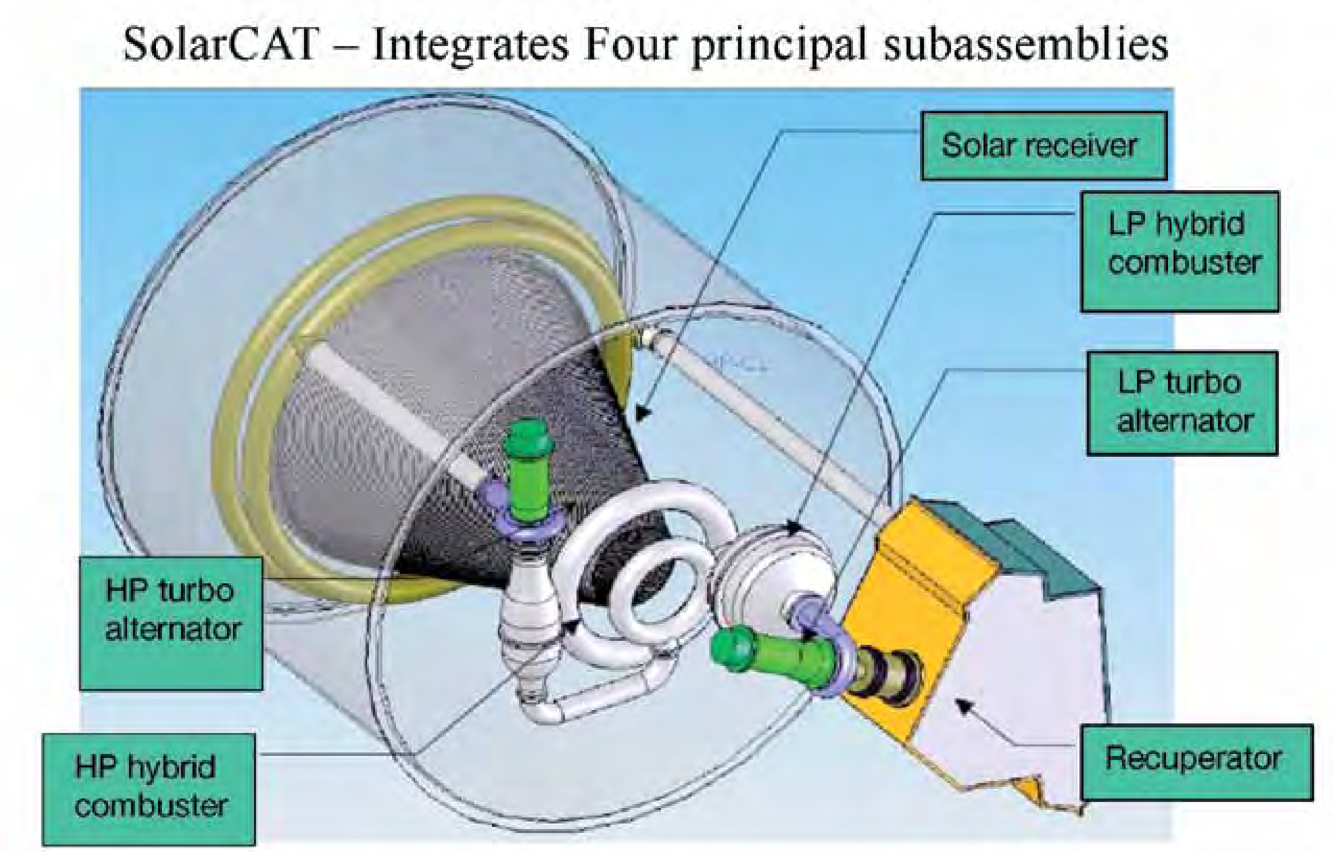
3) The heated air that is exhausted from the high pressure turbo-alternators passes through the recuperator where it pre-heats the incoming air that goes to the receiver.

4) The receiver reheats the air exhausted from the two high-pressure turbo-alternators to 1700°. F. The reheated air at a lower psi drives the two low pressure turbo-alternators, each generating 50 KW and is then ejected from the system.

5) Together the four turbo-alternators generate 200 KW.

During cloudy days or night time, SolarCAT burns either biofuel or gas (brown power) to heat the compressed air. Because it can seamlessly combine sunlight with biofuel or gas, a SolarCAT plant uses multiple resources to produce power that fits the demand curve.

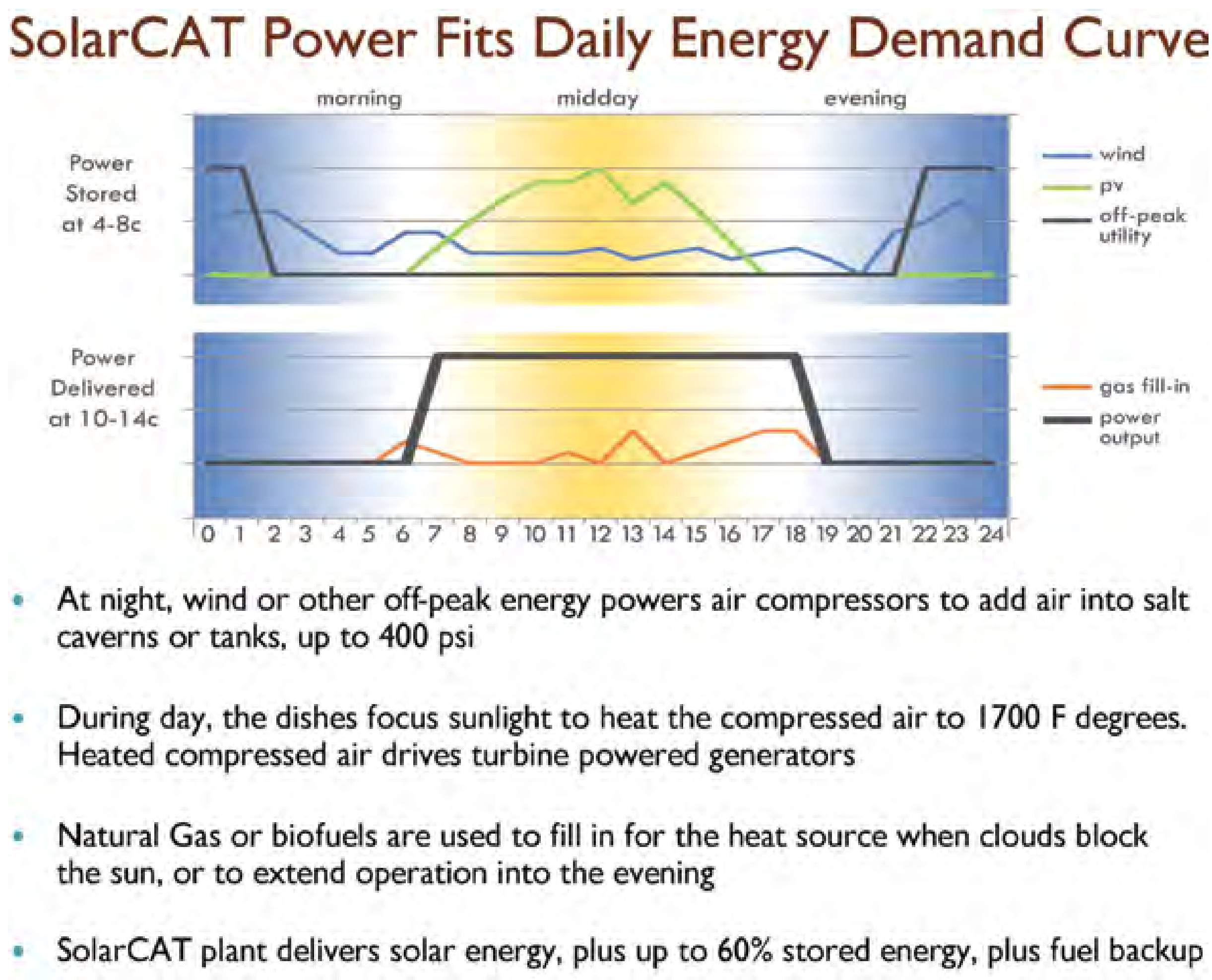
Below is a more detailed view of the way in which electricity is generated by the four principal sub-assemblies—solar receiver, recuperator, combustor and turbo-alternators (two high pressure and two low pressure). (See Appendix C for additional information on each of the SolarCAT units.)



The stored 300-400 psi air flows from the storage cavern to the recuperator where it is preheated by the hot air exhaust from the turbo-alternators. The preheated air flows to the high pressure tubes of the solar receiver where it is heated to 1700° F. The heated air then drives the first turbo-alternator at 1700° F and thence to the second turbo-alternator at decreased psi and temperature. From there it drives the third turbo-alternator and fourth turbo-alternator at the lowest psi and temperature.

The air is exhausted at 120° F, so no water cooling is needed. In non-sunlight conditions, approximately 25% of the time, the combustor burns biofuels or gas to heat the air.

How SolarCAT Power Fits the Energy Demand Curve



For a more comprehensive graph of how SolarCAT meets the demand curve, see Appendix B.

Below is an artist's rendering of a SolarCAT plant with 70 ft. in diameter mirrors.

SolarCAT plants will be so widely distributed geographically between the states and time zones that, averaged over a year, the system will operate an estimated 75% of the daytime hours using sunlight and compressed air. This leaves only 25% of the peak time demand to be met, during non-sunlight hours, through the use of biofuel or some other fuel. For each hour of full-rated operation using sunlight or fuel, each dish unit delivers 200 KWh. The stored compressed air eliminates the compressor load that normally is required in a turbine engine, and this compressed air provides about 120 KW or 60% of the total output. The total 200 KW output is therefore an increase of 67% over the energy used to power the compressors. Therefore, only 10% of the overall energy needs are met by fuel,[23] with the balance met by solar, wind and other renewable sources, directly when possible and otherwise delivered via SolarCAT's air storage capacity.

Once mature economics are established and capital investment and maintenance are amortized over the power produced, the cost of the SolarCAT system in excellent sunny regions is estimated to be about 5 cents/KWh. If the cost of the off-peak energy to power the compressors from wind, geothermal, etc. is 5 cents/KWh, then the total of the two would be about 10 cents/KWh.

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[23]Solar heat supplies 40% of the energy and 25% of that 40%, or 10%, is supplied by biofuel or gas.

To evaluate the cost of the fuel-fired operation, the following must be kept in mind: during full power the amount of heat that is required per hour (from solar or fuel) is about 720,000 Btu/hr. Although natural gas prices will trend steadily upward, in the near term they will vary widely and unpredictably. If we assume the price of gas is $8 per million Btu (about 1000 standard cubic feet), then the gas fired operation would require 0.72 million Btu, or $5.76 per hour, to deliver the 200 KWh. This adds 2.9 cents/KWh to the cost of the energy during non-sunlight hours. We are confident that, with the production enhancing technologies that will be added to current varieties of sweet sorghum, the price of sweet sorghum ethanol per million Btu will be equal to gas. And, in the long-run, gas prices will rise and sweet sorghum and cellulosic ethanol prices will decline. So, during the 12 hours of peak demand, there would be an average of 3 hours of non-sunlight. If the system is burning either sweet sorghum ethanol or gas, the blended cost for the 12 hours would be 10.725 cents/KWh for peak demand electricity.

This is a level of efficiency that produces renewable power at a cost equal to or lower than any competing CSP system, and with much greater versatility by leveraging wind and biofuel. In addition, SolarCAT delivers power that can respond to the demand curve and provides appropriate levels of power storage, reliability and security.

SolarCAT is Non-Toxic, Uses No Water and is Highly Reliable

SolarCAT's electrical generating unit is composed of steel, aluminum, glass, some copper, a small amount of silver and magnets, and power electronics. It uses no water and, except when burning biofuel or natural gas, it operates only on air. No toxic materials are used in its construction and no oil, water or molten salt is used to store energy. By contrast, energy generated by steam turbines whether powered by coal, gas or solar heat use vast amounts of water. Each MW produced by a steam powered system uses over 500 gallons of water per hour. Annual use (500 x 8760 hours) would be about 4,400,000 gallons per year per MW or 4.4 billion gallons per year per GW. The only water used in the Practical Plan is for the production of biofuel. Sweet sorghum is a non-irrigated crop and the only water used is in the process of extracting ethanol from sweet sorghum—about 1,000 gallons per megawatt which is a tiny fraction of the water used in other CSP systems. In the areas of greatest solar capacity, water is scarce and becoming even more so, which makes these steam powered systems increasingly problematic; furthermore, hydro power is also susceptible to water scarcity. The fact that neither wind nor SolarCAT use water to generate electricity is an enormous advantage in a world of quickly shrinking water resources:[24]

> Water scarcity is a significant problem in many parts of the country. Even so, few realize that electricity generation accounts for nearly half of all water withdrawals in the nation, with irrigation coming in second at 34% (USGS 2005). Water is used for cooling of natural gas, coal, and nuclear power plants and is an increasing part of the challenge in developing those resources.
>
> Although a significant portion of the water withdrawn for electricity production is recycled back through the system, approximately 2% to 3% of the water withdrawn is consumed through evaporative losses. Even this small fraction adds up to approximately 1.6 to 1.7 trillion gallons of water consumed for power generation each year.

SolarCAT plants with wind to drive the air compressors probably offer the highest reliability of any electrical generating system. For example, a 1 GW wind farm will have 500 units spread over 40,000 acres while a 1 GW SolarCAT plant has 5,000 units spread over 1,700 acres. It would require an extremely widespread cataclysmic event to shut down either of these. Of course, like any power generating system, the transmission lines leading out of the plant are vulnerable, but the large area systems would have multiple (redundant) points of interconnection to the grid network.

Energy Storage

Energy, warehoused as compressed air, enables the SolarCAT system to store off-peak wind power in order to meet the demand curve whether it is sunny or cloudy, and by doing so increases renewable energy efficiency. The energy from the sun or burned fuel increases the stored energy by 66% and feeds that increased power into the grid at peak demand. This energy is a blend of about 60% stored energy and 40% thermal energy. Other CSP systems that store energy as hot water, oil or molten salt lose energy through heat transfer. However, with SolarCAT there is no heat transfer loss because energy is stored as compressed air at ambient temperatures. Another source of SolarCAT efficiency lies in the fact that, unlike hot water, oil or molten salt, each of which must be stored in highly insulated vessels at high pressures and temperatures, air at ambient temperature can be stored in a variety of places: exhausted gas or oil wells, mined caverns such as salt or potash, aquifers, or even mine shafts lined and sealed against leakage. The salt caverns either existing or to be mined are the ideal

[24] Hutson, Susan S., et al., Estimated Use of Water in the United Sates in 2000, US Geological Survey, USGS Circular 1268, February 2005.

storage sites. They can be sized to store enough compressed air to operate a SolarCAT plant for 8 hours, 8 days or even longer. In non-sunlight times, SolarCAT is powered by biofuel or natural gas, with the 60% of energy from air storage minimizing the fuel required. Salt caverns are also ideal for storing biofuel or gas fuel.

Because the SolarCAT system solves the storage problem, it functions as an aggregator and resource-integration tool that increases the efficiency of any source of intermittent or off-peak energy. For example, energy output is constant in geothermal and large biomass plants that operate 24/7 whatever the demand so they produce excess power in periods of low demand. The intermittency of power from wind, ocean wave, tidal plants or PV can lead to periods of both inadequate and excess power. So, all forms of renewable energy must have storage to extract the needed level of power. SolarCAT with air storage maximizes their efficiencies by storing their excess energy and delivering it when demand is highest. (For a fuller discussion of salt cavern storage see Appendix D)

Compressed Air and Biofuel Storage Offers True Energy Security

Energy security is of increasing concern to both the Department of Energy and the utility industry. As the current system moves increasingly to natural gas, we become hostage to a new set of players and new sources of competition for that gas.[25]

> Energy security concerns for the electric industry will likely increase in the foreseeable future as natural gas continues to be a leading source of new generation supply. With declining domestic natural gas sources, future natural gas supplies are expected to come in the form of LNG imported on tanker ships. U.S. imports of LNG could quadruple by 2030 (EIA 2007). Almost 60% of uncommitted natural gas reserves are in Iran, Qatar, and Russia. These countries, along with others in the Middle East, are expected to be major suppliers to the global LNG market. Actions by those sources can disrupt international energy markets and thus have indirect adverse effects on our economy. Additional risks arise from competition for these resources caused by the growing energy demands of China, India, and other developing nations.

Fortunately, America's estimated reserves of natural gas are far larger than would be needed to power the SolarCAT system whenever there is a shortage of biofuel. These natural gas reserves will be greatly extended by integration with renewables using SolarCAT. Salt cavern storage of compressed air plus storage of biofuel and natural gas back up, offers a level of energy security never before possible. There are salt

[25] "20% Wind Energy by 2030," U.S. Department of Energy, May 2008, p. 18.

deposits and other air storage options in many parts of the Sun Belt. Both Texas and Arizona, the home of SolarCAT, are blessed with major salt deposits and other geological formations that are large enough to provide air storage capacity for months of energy for the nation.

It would be difficult to design a more secure energy storage system than compressed air in underground formations some 1,000 feet or more below the surface. Only a geological event could breach its integrity and, were that to happen, the result would be no more than leakage of air. Because there is no oxygen in any fuel-storing cavern, were one of these to be bombed the risk of combustion would be manageable and, given the caverns would be in remote areas, the possible damage limited. Thus, compared to the levels of concentration in coal, gas and oil plants, but particularly nuclear plants, SolarCAT plants are far less vulnerable and hazardous.

Although not as secure as salt caverns, the surface elements of wind and SolarCAT are the least vulnerable of any of the other forms of electrical energy generation. Geothermal plants are vulnerable to the same degree as coal and gas plants, meanwhile dams for hydropower are easy targets that are also affected by variations in rainfall, and when destroyed they take years to rebuild. Large scale PV and CSP are concentrated and the generating units of the steam-turbine forms of CSP are as concentrated as coal and gas plants. Even though a wind generator could be knocked over with a small explosive charge, it would take some doing to fell 500 of them in a 1 GW wind farm covering 40,000 acres. It would take ten times such an effort to knock down the 5,000 SolarCAT units spread over 1,700 acres in a 1 GW plant. In sum, a wind-SolarCAT-biofuel system with gas backup will be the safest energy generating system yet designed.

Wind-SolarCAT-Biofuel Can Create an Energy Secure America

A renewable power system can generate the estimated 5000 GW needed to power America. Properly scaled, this integrated wind-SolarCAT-biofuel system can supply the renewable energy needed to power American buildings, business processes, manufacturing, and transportation. Except for air and sea transportation and other highly specialized uses, the nation would run on electricity. Electricity would drive the machines needed for mining, manufacturing, building construction, maintenance, heating and cooling, ground transport of any kind and all domestic uses. In fact, it would power everything that does not require liquid fuel. Eventually biofuels will not only supply SolarCAT but also air and sea transportation and other functions demanding liquid fuel.

Assuming the continued availability of night time wind and geothermal for the air storage, these sources will provide 60% of total energy. The sun will provide 30% and biofuel 10%. The amount of biofuel needed to provide 30 days of the fuel heat energy (i.e. assuming fuel is needed for all of the estimated 3400 peak hours per year because the sun is obscured), is about 14 billion gallons. Storage of the 14 billion gallons of biofuel would take about 125 average sized caverns,[26] which is a small addition to the 10,000 caverns required for air storage. Therefore the storage volume for biofuel in the most extreme case of non-sunlight, though clearly a large undertaking, is a comparatively small part of the overall plan.

The Capacity of Renewable Power, Today and In the Future

In 2007, nuclear, hydropower and other forms of renewables generated 27.7% of non carbon producing energy, with renewable resources such as geothermal, solar, and wind providing 2.5% of this total.[27] To replace the 72.3% of the electricity generated by fossil fuel will require about 2000 GW of renewables. Building the wind and SolarCAT plants to produce those 2000 GW is a huge undertaking, but it can be done.

Now that the ITC has been renewed there is still to be added a carbon tax or cap and trade that would force fossil fuel users to internalize their environmental impact costs. Once that is in place, and assuming the reform of the grid keeps pace with the production of renewables, then wind and SolarCAT are capable of ramping up production of electricity, at market rates, to reach 2000 GW in 20 years. As previously stated, wind is a mature technology that will attract all the billions it can absorb and SolarCAT, now the most efficient form of concentrated solar technology, will also attract all the billions it needs. With no financial constraints, the speed with which wind and SolarCAT plants can be built depends on land acquisition, permitting, the availability of raw materials and the speed with which the various components can be manufactured and assembled. All the components of SolarCAT technology can be purchased off the shelf or manufactured by SolarCAT, including the receivers, turbines, combustors and recuperators. Though wind turbines, only recently produced by such companies as GE, are now in short supply worldwide, wind energy production will continue to increase, using standard industrial capability.

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[26]The current petroleum strategic reserve is 30 billion gallons. Storage of this size would provide biofuel for nearly 2 months of continuous lack of sunlight, when combined with air storage of the non-solar renewable sources.

[27]"A Solar Grand Plan," Scientific American, December 2007.

Assuming that other forms of renewables can produce the power needed to meet the annual increase in demand, the question is, "Can the Wind-SolarCAT-Biofuel system produce sufficient GWs for the electrical system plus enough additional GWs for all forms of transportation?" Given a renewable friendly grid and removal of the previously described barriers—political, regulatory and legal—the answer is "YES"- with no constraints on access to capital, land, labor and raw materials. Although no one is quite sure as to the total energy needed to power America, it has been estimated that the current electrical system requires 2000 GW and transportation another 3000 GW for a total of 5000 GW to operate a totally renewable system. In a system of 50% wind and 50% solar, the first 1000 GW of SolarCAT plants could be built by 2030 and the second 1000 GW by 2040. But it all depends on the national commitment to achieving renewable energy independence. Assuming the first 1 GW SolarCAT plant is nearing completion by 2013, most of the logistics will have been worked out. At that point, the number of 1 GW plants that can be built each year depends on the key variables listed above and, given all of the other renewable energy technologies now coming on stream, another 1000 GW of renewables might be in place in the same time frame.

Building the Wind-SolarCAT-Biofuel System

Because building and operating the Wind-SolarCAT-Biofuel system will require major changes in the forms of transportation, mining and manufacturing, the initiative will have a multitude of opponents, led by coal, oil, gas and utility companies. Industry opposition might be followed by labor unions, whose members mine the coal, drill for the oil and gas, and build, maintain and operate the coal, gas and oil fired plants. Beyond them might be the rail companies that haul the coal, and the multitude of companies that supply the raw and finished materials for the fossil based energy system.

To these overt opponents one would have to add the covert opponents: the bureaucrats in the thousands of federal, state and local agencies that issue the permits to build the renewable power plants and open the rights of way for the transmission lines to carry the power from rural renewable power plants to urban centers. Because renewable power plants will be spread over an area ten or maybe a hundred times larger than the current compact coal, oil, gas and nuclear power plants, the permitting process will be greatly enlarged thereby bringing forth a myriad of environmental groups committed to the protection of untold numbers of plant and animal species and the territories needed for their survival. Nonetheless, no matter how powerful the opposition of all these disparate groups will be, their influence pales against the overwhelming national security interest in making America truly energy independent, once and for all.

Today, more than ever in our history, the press of urgency is upon our leaders.

With Iraq War spending now toping $574 billion and estimated by Nobel Prize winning economist Joseph E. Stiglitz to ultimately cost $3 trillion and with the added $850 billion plus Congress has appropriated for economic stimulation, energy dependence is draining our nation's wealth while making the American economy a permanent hostage to unstable and often hostile foreign regimes.

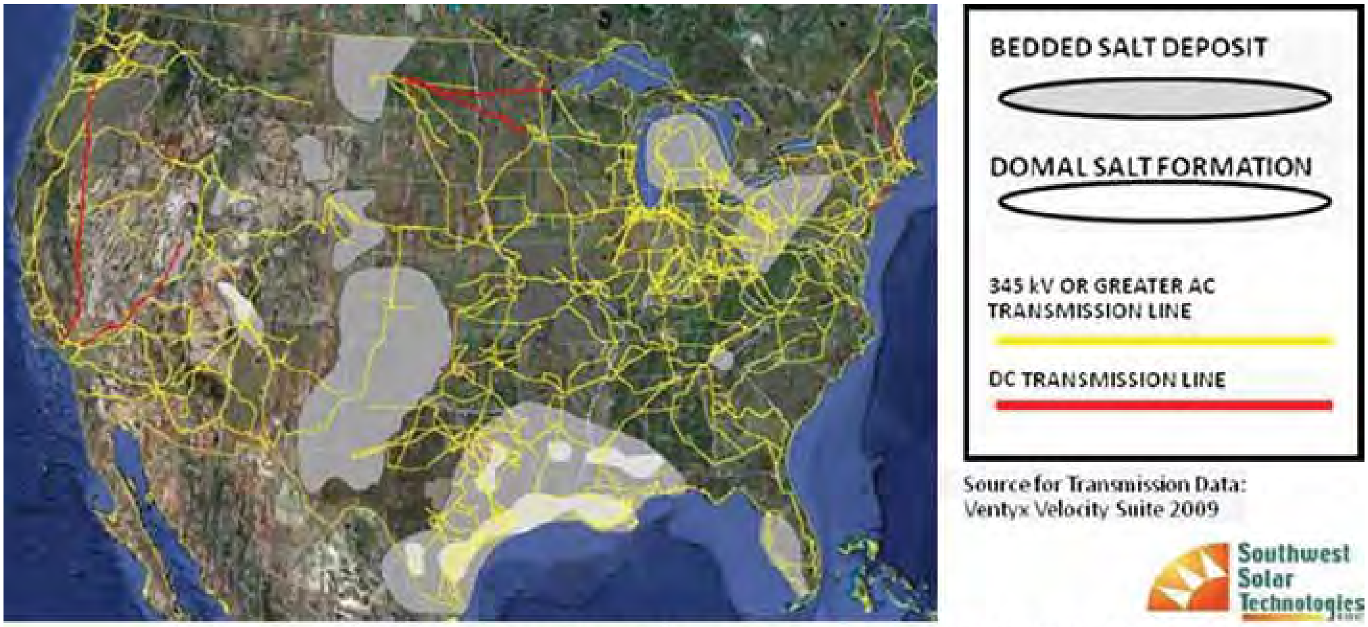
How long would it take to create a renewable power system? Answer: long enough for the body politic to generate the popular will sufficient to transform opposition into support, and denial into action.

Siting the System

At about 2.5 sq. miles per 1 GW, the 1000 GW of SolarCAT requires 2500 sq. miles (a 50 by 50 mile square) and the 1000 GW of wind another 26,000 sq. miles (a 160 by 160 mile square). The amount of cavern space needed for the compressed air storage plus the relatively tiny amount for biofuel storage would all fit comfortably under the area needed for the SolarCAT plants. Mining these caverns may be the largest undertaking of the **Practical Path to Renewable Energy Independence**, but it would provide the efficient energy storage capability needed to make renewable energy practical on a national scale.

The amount of cavern space required is related to the operating air pressure, and the hours of stored-air operation. CAES (compressed air energy storage) systems that use fossil-fuel turbine technology typically are designed to operate with 600 to 1200 psi air storage. However, higher efficiency can be achieved using lower pressures, from 250 to 400 psi, which is the psi selected for SolarCAT. For 1.0 GW of SolarCAT capacity operating for 12 hours per day requires about 160 million cubic feet of cavern volume. The 1000 GW as projected would require 160 billion cubic feet of storage. This number would be multiplied by the days needed for energy security. The average size of caverns used in the US Strategic Petroleum Reserve is 420 million gallons, or about 56 million cubic feet. Only about 2,500 caverns of such size would be needed for the entire national electric system and as technology improves, the total amount of cavern volume needed will be reduced. For such large caverns, suitable large domal salt formations exist in Texas and Louisiana, but elsewhere shallow bedded salt deposits are more common and there, a much greater number of caverns of smaller volume can be constructed. New Mexico, Arizona, and Utah have large bedded salt formations, along with very good solar and, in some cases, wind resources.

To expand the options beyond salt sites, work is underway to identify other alternatives such as depleted gas and oil wells, and underground mining methods that can be used on salt as well as on other types of geology. Fortunately for America, salt caverns are the most efficient and safest form of storage, and bedded salt formations of varying quality and depth are known to exist beneath many thousands of square miles of land in the U.S. southwest. To develop these salt caverns it will also be necessary to engage the considerable abilities of the mining and geo-tech industry, academics and the U.S. Departments of Energy and Defense, whose understanding of underground



NATIONAL ELECTRICAL GRID AND SALT STORAGE RESOURCE MAP salt formations will also be needed. But none of this expertise can be used unless permitting authorities make sufficient area available for salt cavern development.

SolarCAT plants and caverns can be placed strategically from Florida through the other southern states to Texas and then through New Mexico, Arizona and on to California. This would ensure the ability to meet the demand curve as it moves from the Atlantic to the Pacific. As many plants as possible will be sited over the salt formations in West Texas, New Mexico, Arizona and California because these sites are situated in areas of intense solar and wind energy. Furthermore, in many of these areas the salt deposits are so large they can be mined to store any amount of air, biofuel/oil/gas needed to insure the level of reliability and integrity to be mandated by the federal body that will manage the grid.

So configured, the Wind-SolarCAT-Biofuel system can provide a smooth flow of power across the time zones. Eastern SolarCAT plants would begin operation at 6:00 am while the plants in California would operate until 6:00 pm. In so doing, wind and SolarCAT would supply power during the 17 hours of high demand. The 9 hours of low demand[28] would be covered by other forms of renewable power—wind, hydro and geothermal. SolarCAT compressors can always absorb any energy above current demand and SolarCAT plants can provide peaking power from sun, biofuel or gas. Thus, SolarCAT plants can function as a load leveler for the National Grid and can insure that renewable energy resources follow the demand curve 24 hours a day.

Because wind plants perform no leveling function, and all wind energy not absorbed by the grid flows to the SolarCAT air compressors, they can be located anywhere suitable for wind. And, the prime wind areas—the eastern mountain chain from New England to West Virginia, the Great Lakes, the Plains States, the Rocky Mountains, the Sierras and the Pacific coast from Canada south to Northern California—are so vast that siting almost any number of wind plants is possible.

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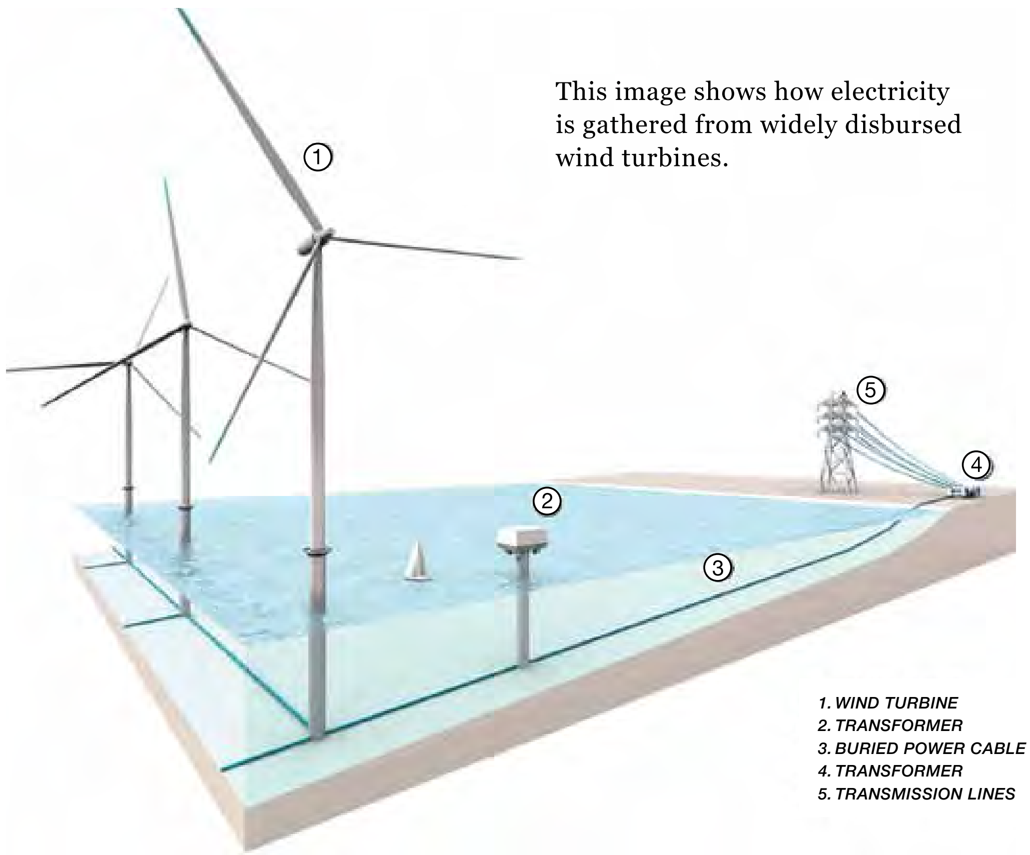
[28]In the Eastern time zone the 9 hours would be from 9:00 pm to 6:00 am; in Central, 8:00 pm to 5:00 am; in Mountain, 7:00 pm to 4:00 am and in Pacific, 6:00 pm to 3:00 am.



This image shows how electricity is gathered from widely disbursed wind turbines.

As land sitings become more difficult, wind plants will need to be moved off-shore (even high-altitude airborne wind plants have been proposed). The image below shows the likely look and feel of such off-shore units.

FINANCING THE SYSTEM

The cost of a 1 GW wind plant is approximately $2 billion and that of a 1 GW SolarCAT plant is approximately $1 billion. Therefore, 1000 GW of wind plants would have a capital cost of approximately $2000 billion and 1000 GW of SolarCAT plants would be another $1000 billion, for a total of $3 trillion. Adding enough power to run our transportation system would double this cost to $6 trillion. Based on published estimates for other systems, this would be the least expensive renewable energy system yet developed. As has been stated above, if the Congress and President create a national grid that can be privately funded, there will be funding for as many wind and SolarCAT plants as there is demand for renewable power.

Wind energy is already an attractive investment and coupled with SolarCAT it will be even more attractive. SolarCAT is an attractive investment because it buys cheap off-peak energy to power its air compressors and sells most of its energy during periods of high demand. In nighttime off-peak hours winds are at their maximum and the price of their energy is at a minimum. SolarCAT uses that reality as an opportunity for energy arbitrage—it buys cheap energy at night at 4-6 cents per kilowatt, increases that energy by 66% using solar and sells it at peak demand for 10-15 cents, depending on the local market. Simplicity of construction and operation, energy storage and arbitrage are the reasons SolarCAT can produce energy at the lowest cost of any of the renewable energy systems explored to date.

Is the System Ready To Be Deployed?

Wind power generation is a mature technology and the most efficient source of renewable energy and, when integrated with SolarCAT technology, it will no longer suffer from the problem of intermittency. The only constraints on building the needed wind farms are land acquisition in the areas that have viable wind resources, followed by permits, transmission lines and the supply of wind turbine generators. SolarCAT technology is as previously stated, "shovel ready" with construction now underway for a 1 MW test installation at the Riverpoint Research Park in Phoenix[29] with permitting and land acquisition nearing completion for a 100 MW plant at the West Phoenix suburb of El Mirage and a 1000 MW plant in Northern Arizona near the town of Holbrook. (Appendix B provides timelines and details for these three projects.) It is expected that the construction of these facilities will proceed rapidly because all of the elements of the SolarCAT technology have been proven in other systems. For example, the SolarCAT turbo-alternators are a combination of automotive-scale turbocharger and high speed alternators such as those used for electrical power in jet aircraft—all of its components are off-the-shelf or easily manufactured. No commodity used in SolarCAT has limiting supply constraints; the major materials—standard grade steel, aluminum, glass and copper—are all available. Each component is relatively simple in design and its manufacture can be expanded to meet almost any level of demand. Field demonstration of the new commercial SolarCAT system using these same concepts will be completed by the fall of 2009. As for air storage, salt caverns for air storage have been in operation since 1991.

Establishing the infrastructure for the production of the components that make up a SolarCAT unit[30]—mirrored dish, two axis tracker, solar receiver, recuperator, turbo-alternator and combustor—began in the fourth quarter of 2008 and initial commercial production will begin in the fourth quarter of 2009. Assuming all permitting has been completed, engineers estimate that it will take up to 18 months to construct the first 1 GW SolarCAT plant and mine the needed salt caverns.[31] Once manufacturing

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[29]Riverpoint Solar Research Park is operated by a consortium of business, academic institutions, and public entities. The original members of the consortium are University of Phoenix, University of Arizona's Solar Research Center, University of Colorado, City of Phoenix, the Arizona and U.S. Geological Surveys, Tucson Electric Power, Southwest Solar Technology and Arcadia Biosciences.
[30]See Appendix A for a fuller description of these components.
[31]Currently caverns are mined with water, a process that requires 18 months and many billion gallons of water to mine a cavern large enough for a month of air/biofuel/gas storage. SolarCAT will mine the caverns with boring machines that will use no water and will complete the mining in a year.

of the needed components of SolarCAT reach a production level equivalent to high production manufacturing plants, it is reasonable to assert that a 1.0 GW SolarCAT plant with caverns can be constructed in a year and up to fifty or more could be under construction at any one time.

One of the great advantages of wind and of SolarCAT in comparison with other forms of CSP is the speed at which they can deliver power. For example, a 1 GW plant using any of the other CSP technologies must be fully completed before it produces electricity. By contrast, wind and SolarCAT can produce power as soon as they have reached sufficient capacity to deliver the minimum acceptable to a utility, probably less than 50 MW; the amount of power will steadily increase as the remaining 950 MW of a 1 GW plant comes on line.

Assuming that SolarCAT and wind companies can develop a growth plan by 2012, it should be possible to construct fifty 1 GW plants a year of both wind and SolarCAT. By 2032 there would be 1000 GW each of wind and SolarCAT. From 2032 forward, annual construction of fifty 1 GW of wind plants and fifty 1 GW of SolarCAT plants would allow America to achieve complete renewable energy independence by 2040. That such a time line is reasonable can be seen from a May 2008 report by the U.S. Department of Energy. The report presents an in-depth analysis of the potential for wind in the U.S. and outlines a potential scenario to boost wind supply electric generation from its current production of 16.8 GW to 304 GW by 2030.[32]

[32]Prepared by the U.S. Department of Energy and a broad cross section of stakeholders across industry, government, and three of DOE's national laboratories - the National Renewable Energy Laboratory in Golden, CO; Lawrence Berkeley National Laboratory in Berkeley, CA; and Sandia National Laboratory in Albuquerque, NM.

Conclusion

It is not beyond reality to propose that the nation begin the process of making wind coupled with SolarCAT and biofuel the core of the national energy system. Whether the energy SolarCAT uses to compress the air is green or black, it increases energy output by 66% above the storage energy input. Even when burning gas or oil in dark hours, it produces energy more efficiently than do gas, oil or coal with carbon capture. In addition, salt caverns filled with air, gas, oil or biofuels provide the safest energy storage available. If this Practical Path were followed, America could move seamlessly from our current fossil fuel power system to a renewable power system that would provide an unlimited supply of cheap power. America could double or treble its energy usage without stressing the system. An almost inexhaustible supply of cheap energy would do more than anything else to raise millions of poor Americans out of poverty. It would also spark an avalanche of innovation in every activity—bioscience, renewable energy, electronics, transportation, communication, construction, manufacturing, to name only the obvious. It would dramatically raise the living standards of all Americans and place America at the forefront of the movement to save the earth. If America will take the lead, the world will follow.

Appendix A

Authorship and Disclosures

The Practical Path was conceived of and articulated by John Sperling, Chairman, SolarCAT, Inc., in collaboration with, Herbert Hayden, President of SolarCAT Inc. and Southwest Solar Technologies, Dr. Jorge Klor de Alva, Senior Vice President, University of Phoenix, Eric Rey, CEO, Arcadia Biosciences, Dr. Joseph Simmons, Professor of Materials Science and Engineering, University of Arizona and John Thiella, Senior Counsel, The Renewable Energy Accountability Project. In drafting this plan, we have drawn on the advice of persons knowledgeable in the many subjects that must be included in designing a practical path to renewable energy independence: electrical utilities, the electric grid, conventional and renewable energy technologies, biofuels, licensing and permitting processes, investment strategies and the necessary enabling legislation that will be needed make a new energy system possible.

SolarCAT (solar with compressed air technology) is the core of the Practical Path to Renewable Energy Independence and, in our opinion, essential to the achievement of renewable energy independence. “SolarCAT” is a concentrated solar power (CSP) technology developed by SolarCAT, Inc., an Arizona company in which John Sperling has a controlling interest and Herbert Hayden has a substantial interest. John Sperling also has a controlling interest in and Eric Rey has a substantial interest in Arcadia Biociences, Inc. Arcadia Biosciences is a company that holds some of the patents on the technologies described in Appendix F on US Domestic Biofuel Supply Opportunity.

Although the Practical Path focuses on renewable energy for America, SolarCAT, Inc. hopes to achieve similar renewable energy systems world wide. SolarCAT and Arcadia technologies will be made available world wide thereby encouraging the building of the maximum number of SolarCAT plants needed to create renewable energy systems. Thus, a question sure to be asked is this: Since SolarCAT, Inc. expresses the desire to reach world renewable energy independence and carbon zero in the shortest possible time, why doesn’t it make the SolarCAT and the accompanying Arcadia patents available to the world at no cost? Answer: The only way to attract the investments to build the needed wind and SolarCAT plants and produce the needed biofuels, is to provide patent protection to the investors in these entities. Without that protection, no plants will be built.

In order to maximize the number of SolarCAT plants, SolarCAT, Inc. will grant patent rights world wide wherever there is patent protection. Given there is no adequate patent protection in much of the developing world, SolarCAT could protect investor’s interests by following the path currently being pursued by Arcadia Biosciences in China. Arcadia has proposed to the Chinese government that it will grant patent rights to its nitrogen uptake efficiency (NUE) gene at no cost, in return for which China will give Arcadia 50% of the certified emission reduction (CER) credits it receives under the Clean Development Mechanism or subsequent carbon credit system. Arcadia can then sell these credits on the Cap and Trade market. Arcadia investors will thus be compensated for lost patent royalties.

Concerning John Sperling’s personal interests, all monies earned from either SolarCAT or Arcadia will be reinvested in improving SolarCAT and Arcadia technologies or paid into the John Sperling Foundation, a non-profit entity dedicated to the advancement of education, science and enlightened socioeconomic policies.

Appendix B

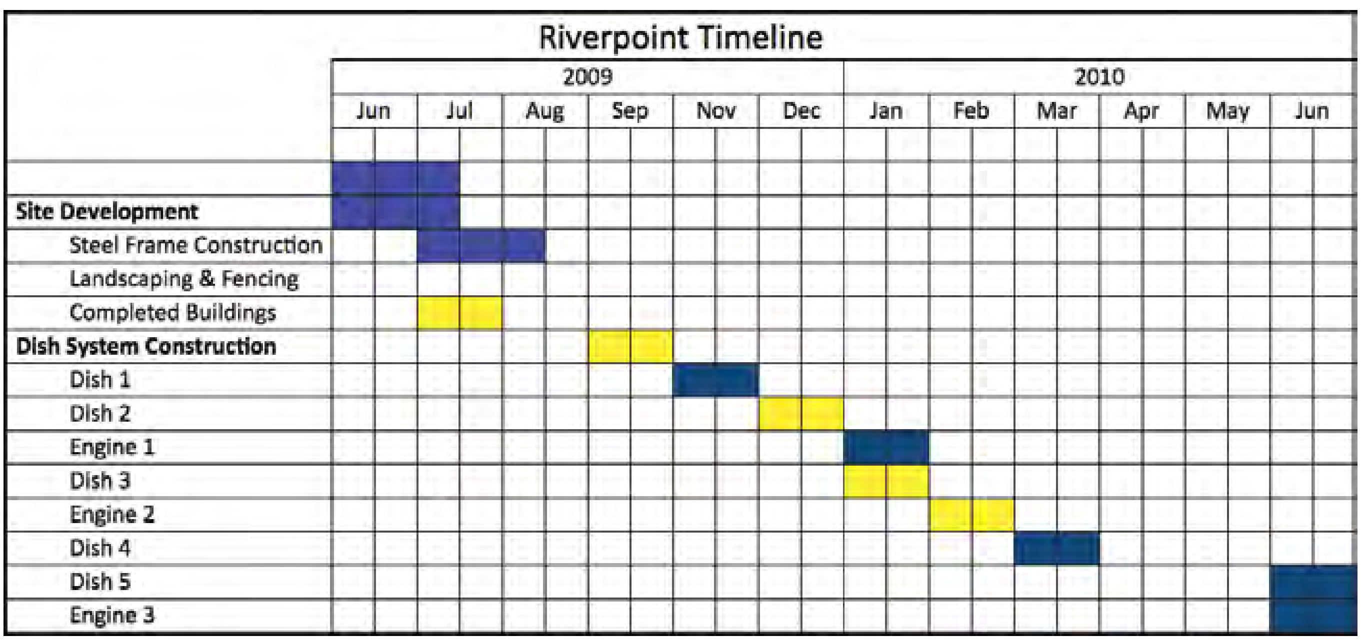
SolarCAT Plant Construction Schedule

Riverpoint

In May 2009, Southwest Solar Technologies (SST) will begin construction of the first series of SolarCAT plants ranging from 1 megawatt to 1 gigawatt. The 1 megawatt plant will be located at the Riverpoint Solar Research and Development Park being developed by a consortium composed of Southwest Solar Technology, the City of Phoenix, the University of Phoenix, the University of Arizona, the University of Colorado, Tucson Electric Power, Arcadia Biosciences, the Arizona and U.S. Geological Surveys and the U.S. Department of Energy[33]. Riverpoint Solar Park is located on a 25 acre plot adjacent to I-10 near Sky Harbor Intl. Airport. SST leased the land from the AZ Dept. of Transportation and is installing the infrastructure access roads, water, power, etc. The first mirrored dish will be in place by the 4th of July.

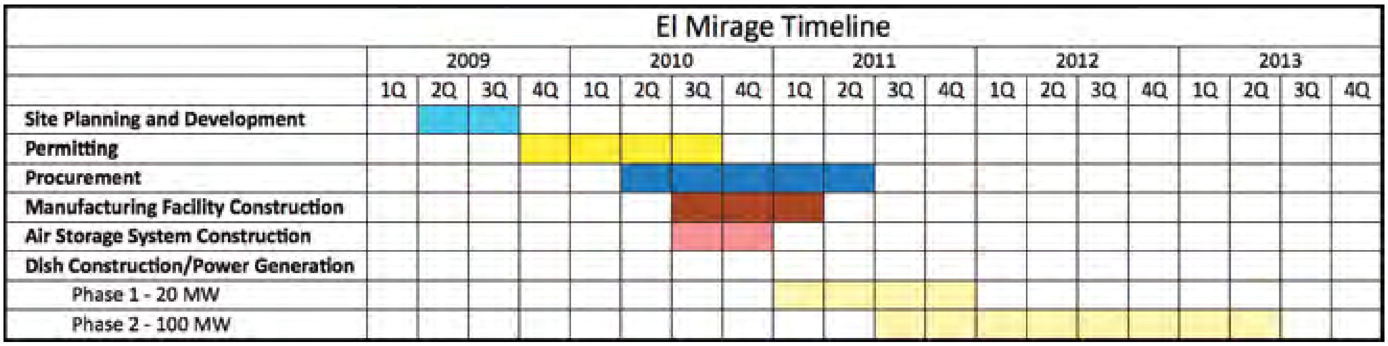
[33]January 16, 2009, the U.S. Department of Energy (DOE) announced today that it has made three new technical assistance awards under the Solar America Showcases project, which is run by the Solar Energy Technologies Program. These awards provide technical assistance from solar energy experts to high-visibility, large-scale solar installations. Southwest Solar Technology was one of the three.

The partners in the Solar Research Park will be testing, measuring and researching integrated solar energy systems. The system being tested is the 1 MW SolarCAT plant. Each element of the SolarCAT system will be tested for efficiency and indicated improvements will be incorporated in each succeeding installation. Because SolarCAT is modular, continuous improvement can be made without any of the components being incompatible. The Park will also do research on concentrated photovoltaic (CPV), flat plate PV, and integrated energy storage, using underground and above-ground compressed air, thermal energy, batteries and super-capacitors, desalinization and biofuel from sweet sorghum, cellulosics and algae. All of these systems will be monitored and controlled. The land will be used to grow biofuels plants and algae. Water will be harvested and recycled. The Park will contain a complex of solar buildings to be used as a Visitor Center, a Conference Center and research laboratories and offices. The major goal of the activities of the Consortium is the development and testing of systems integration under real operating conditions. University researchers will set up instruments to monitor function and component performance in daily supply/demand cycles under real weather conditions. Testing will focus on component and system reaction time, capacity, economics and compatibility. The Park will be the first in the World and unique in the United States. Its greatest value will come from the ability to witness and measure the operation of the technology and to evaluate the economics of the integrated system. Below is the timeline for the SolarCAT installation at Riverpoint.



El Mirage

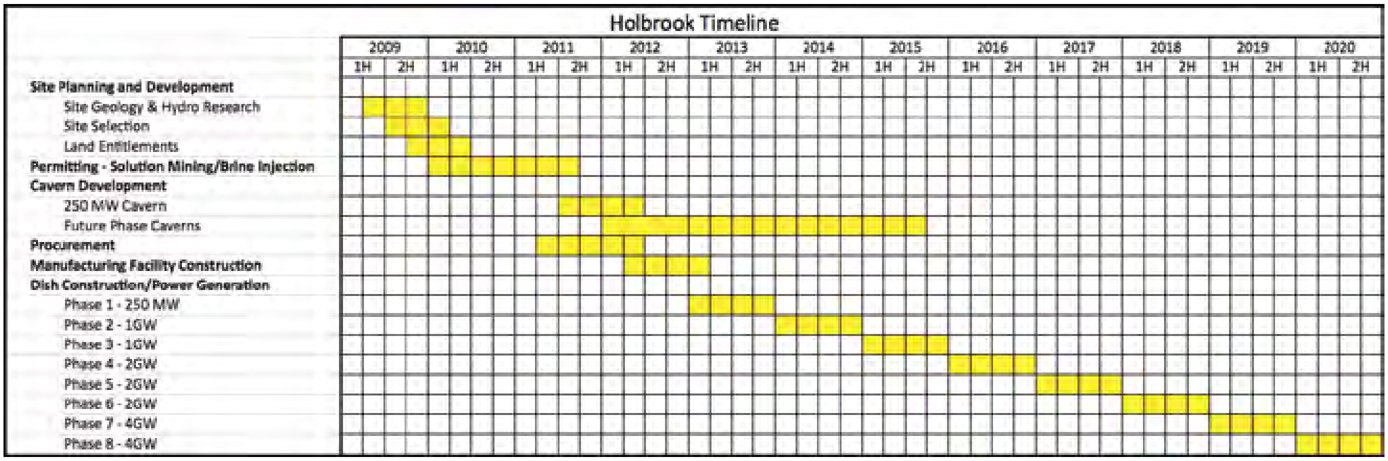
The land for the El Mirage SolarCAT plant is 20 miles west of Phoenix near Luke Air Force Base and adjacent to a Morton salt cavern capable of storing sufficient air for a 100 MW plant. As the timeline below indicates, site and permit planning has already begun and the first 20 MWs will come on line in the first quarter of 2011 with the final build out scheduled for the second quarter 2013. Below is the timeline for El Mirage.

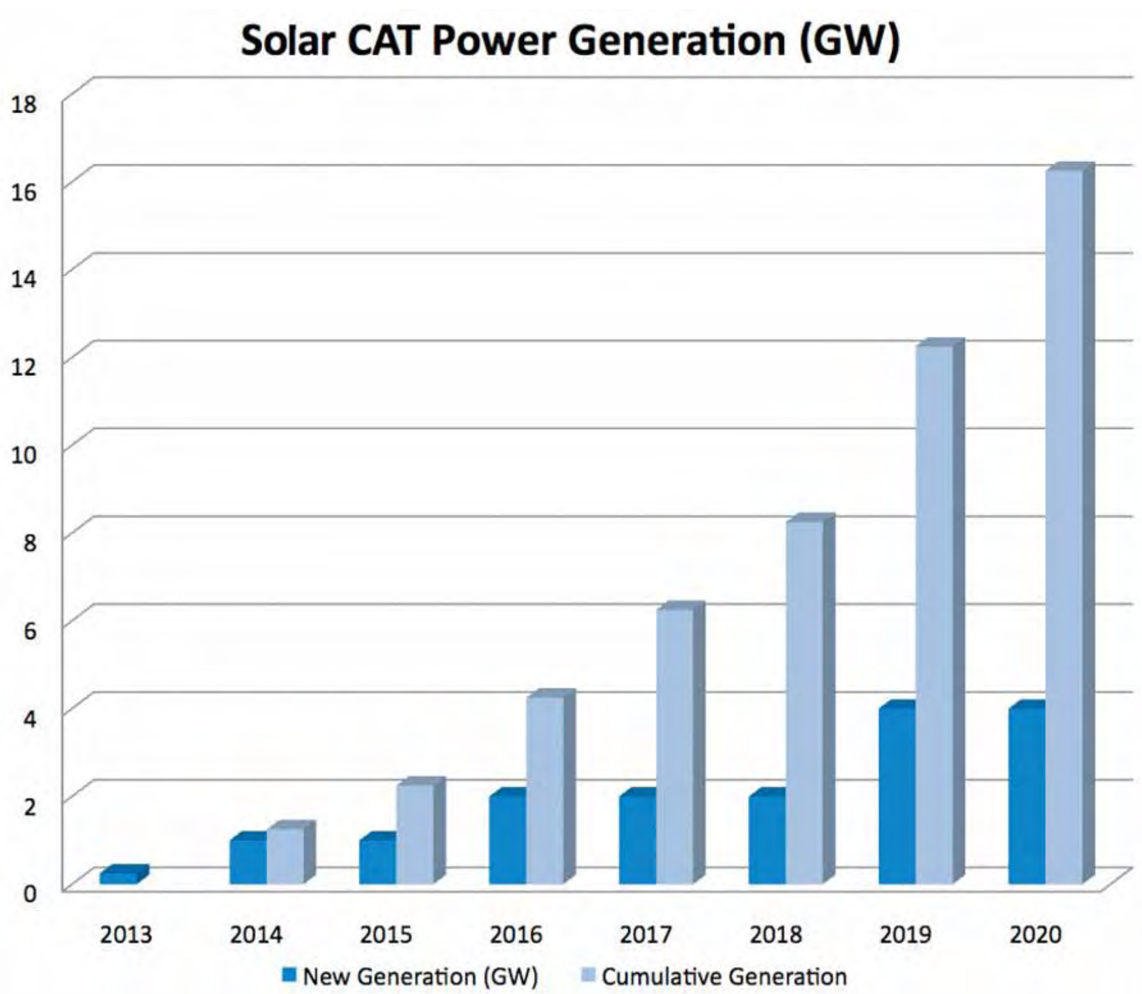


Holbrook

By the fourth quarter of 2009, SolarCAT will have secured land options and begun the permitting activity needed to begin construction of a 1 GW plant above the vast imbedded salt deposits near Holbrook, Arizona. Installing the SolarCAT equipment will present only ordinary problems but mining the salt caverns at reasonable cost is of greater magnitude. However, assistance from the geology departments of two universities plus the Arizona and U.S. Geological Surveys and the U.S. Department of Energy insures that it will be done. Until the mining technology is decided on it is not possible to give a firm date for completion of the Holbrook project.

However, Holbrook should be well into construction in 2012 with possible completion of the first 1 GW in 2014. When Holbrook completes the first 250 MW in 2013, it will be possible to begin the construction of as many 1 GW-scale plants at whatever speed permitting and financing make possible. The next page top is the Holbrook timeline.


Holbrook Timeline
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
1H
2H
Site Planning and Development
Site Geology & Hydro Research
Site Selection
Land Entitlements
Permitting - Solution Mining/Brine Injection
Cavern Development
250 MW Cavern
Future Phase Caverns
Procurement
Manufacturing Facility Construction
Dish Construction/Power Generation
Phase 1 - 250 MW
Phase 2 - 1GW
Phase 3 - 1GW
Phase 4 - 2GW
Phase 5 - 2GW
Phase 6 - 2GW
Phase 7 - 4GW
Phase 8 - 4GW


Solar CAT Power Generation (GW)
18
16
14
12
10
8
6
4
2
0
2013
2014
2015
2016
2017
2018
2019
2020
New Generation (GW)
Cumulative Generation

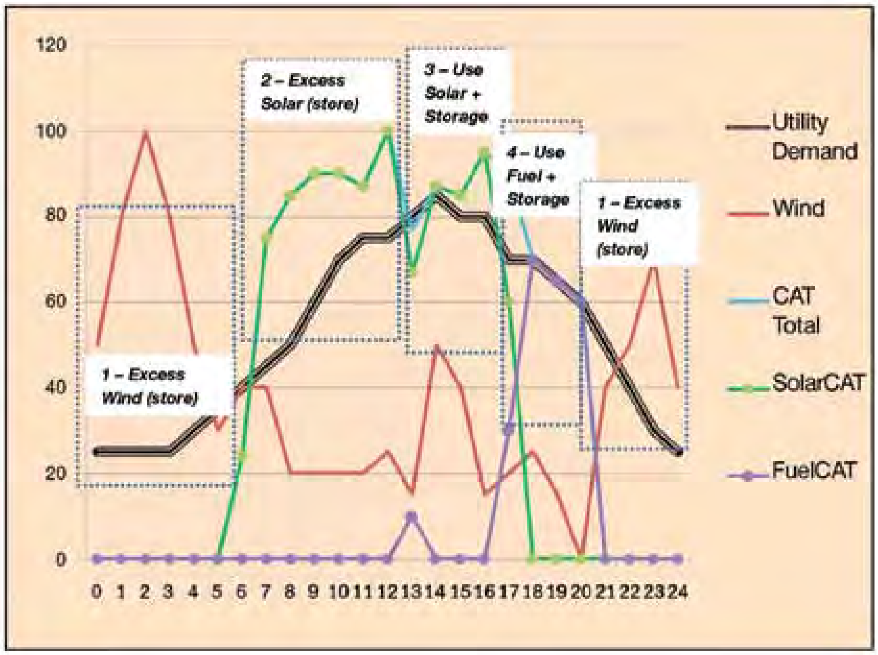
Appendix C

How SolarCAT Meets the Demand Curve

Four Modes of SolarCAT Operation

- **Operating Modes:**
  1. Store excess wind
  2. Store excess solar
  3. Use storage plus solar
  4. Use storage plus fuel

- **Modes can be combined:**
  1. Output may add all at peak: Solar + Fuel + Storage + Wind
  2. Storage accepts any off-peak: Wind, Solar, also PV and Utility



Appendix D

SolarCAT Unit Description

- Mirrored dish: Mirrors are placed on a 70 ft. diameter concave structure, focused on the solar receiver. The dish rests on an aluminum scaffold which in turn rests on a two axis steel tracker. The mirrors have a useful life of 20-30 years.

- Two axis tracker: The tracker is made of steel and sits on a steel shaft that is anchored in a reinforced concrete base. It allows the dish to follow the sun from sun up to sun down at any angle on the horizon. The tracker can also move the dish into safe mode when winds reach a critical level. The useful life of the tracker is indefinite.

- Solar receiver: The solar receiver is a cone composed of steel tubes for heating the air. Air circulating in the tubes is heated to 1700° F. The solar receiver has a useful life of 40,000 hours or more.

- Recuperator: The recuperator is a rectangular metal heat exchanger that captures the exhaust heat from the turbo-generators and pre-heats the 300-400 psi air that has entered the system at ambient temperature. The recuperator has an indefinite useful life.

- Turbo-alternator: The turbo-alternators are the size of a turbo-charger typical for automotive and truck engines. They are driven by hot air, are made of steel with air bearings and operate at 120,000 rpm, made possible by their small size. After the power is extracted, from the compressed air, the air is exhausted from the system at 120° F. The turbo-alternator has an indefinite useful life.

- Combustor: The combustor is placed just before the turbo-alternator, for fuel to be added as needed. The combustor burns fuel to heat the air during cloudy days or other times when there is no sunlight. The useful life of the combustor is indefinite.

- Compressed air cavern: The typical salt cavern is a 1,500 ft. deep, 50,000,000 cubic ft. cavern, mined from a salt deposit. A cavern of this size can store 1000's of megawatt hours of energy in compressed air. The air is fed to the solar field dishes through a system of steel and plastic pipes.

Together, the solar receiver, the recuperator, combustor and turbo-alternators compose an engine that weighs about 3,000 pounds, in a size similar to a refrigerator. To receive the concentrated sunlight each engine is located on a 40 ft. boom attached to the dish tracker. Five SolarCAT units can generate 1 MW, and 5,000 units can produce 1 GW. About 3 units are installed per acre, so only about 2.5 square miles is needed for each 1 GW. This area is also sufficient for the caverns that store the compressed air, biofuel or gas.

Appendix E

Salt Cavern Compressed Air Storage Data

Cavern space is needed for the compressed air storage capacity. The operating pressure assumed for the SolarCAT air storage is 300-400 psi. This is a fairly low pressure compared to other CAES systems, but it provides better efficiency than would be possible with higher pressures. For the 1000 GW of SolarCAT capacity, and 12 hours per day of operation, about 160 billion cubic feet of cavern volume is needed.

Large caverns can be about 100,000,000 cubic ft. However, such large caverns can be 1500 feet vertically, and are typically only possible in the large "domal" salt formations such as in Texas and Louisiana. More salt formations exist in more shallow "bedded" salt formations, such as exist in New Mexico, Arizona, and many other areas. Other geological formations such as limestone or even hard rock underground mines also can be used for air storage.

"Bedded" formations can be used for the purpose of a conservative estimate. A field of salt caverns would consist of numerous smaller caverns, about 15,000,000 ft^3 in volume, which would only be about 300 ft in height and width. Energy storage for the whole nation would require about 10,000 caverns of this size. About 100 square miles of surface area would be needed to allow for structural spacing or a square about 10 miles on each side. This field could be increased five fold to allow for sufficient storage to capture the lowest cost weekend off peak power that could compress sufficient air to run the system for a week.

Caverns require about a fourth of the land area needed for SolarCAT plants, and so can be located within the same area. Bedded salt formations of varying quality and depth are known to exist beneath many thousands of square miles of land in the US southwest. Permitting authorities must make sufficient area available for salt cavern development and to develop these salt caverns it also will be necessary to apply the considerable abilities of the mining and geo-tech industry, academics, U.S. Department of Energy and U.S. Department of Defense, whose understanding of underground salt formations will also be needed.

Appendix F

US Domestic Biofuel Supply Opportunity

Sweet Sorghum the Preferred Crop

Why is sweet sorghum ethanol the preferred biofuel? Sweet sorghum ethanol production, in comparison to that of other oil crops, has the smallest land and carbon footprint, the least impact on food prices and because it can be grown in proximity to SolarCAT plants its ethanol can be piped rather than trucked to the plants.

Land Footprint

After adjusting for the higher energy content of biodiesel relative to ethanol, sourcing biofuel from biodiesel would increase the land requirement by at least 400%. To service the biofuel needs of the Practical Path using biodiesel from canola would require at least 120 million acres and if biodiesel from soybean were used the land requirement would increase to 150 million acres. Given that the current global acreage of canola is about 70 million acres, biodiesel from either of these sources is clearly not an option.

Biofuel yield in gallons/acre/year from:

- Ethanol from sweet sorghum: 700 (possibly 875 in the future)
- Biodiesel from soybeans: 66-80
- Biodiesel from canola: 90-115

Carbon Footprint

Sweet sorghum ethanol today has about 50% lower GHG (Greenhouse gas) emissions than biodiesel.

Estimates of lifecycle carbon footprint in grams CO_2e/megajoule from:

- Cellulosic ethanol: 7
- Sweet sorghum ethanol: 18
- Soybean biodiesel: 38
- Natural gas: 62

Food vs. Fuel

Because biodiesel is derived from oil it needs an oilseed as a starting point. The major oilseed crop options globally are palm, soybean, canola, coconut, sunflower, safflower, and castor. The seed oils derived from these crops are one of the most concentrated sources of calories in nature, which is why these oils are prized as a food source. Therefore, each time that biodiesel is made (other than from castor seed oil) the market is making a "food or fuel" choice.

While castor produces high non-food oil yields, the by-product meal that remains contains ricin, the most toxic protein in nature, which is poisonous if injected, inhaled or ingested and is therefore an ongoing bioterrorism threat. Consequently, there would be zero support for proposing 100 million acres of ricin-producing castor in the U.S.

The "food or fuel" choice means that dedicating 100 million acres to the production of any of the other biofuel crops would drive a huge increase in the cost of food. However, this is not relevant to sweet sorghum, unless one wishes to argue that sugar juice is a "food" that the world needs more of.

Biofuel Crop Proximity to SolarCAT Plants

There is no significant production of soybean or canola in the southwest of the U.S., where most SolarCAT plants will be located. Although there is a limited production of sunflower and safflower, in each case this adds up to only thousands to tens of thousands of acres, not millions. Indeed, the global production of safflower is only about 1 million acres. And oil crops are relatively intensive users of water, a scarce resource in the Southwest. In contrast, sweet sorghum can be grown widely throughout the U.S., including much of the Southwest, and it has an inherently low water requirement.

Fuel Storage

However, because biodiesel contains significantly more energy per gallon (120,000 BTU) than ethanol (75,000 BTU), the other key advantage of biodiesel is that less fuel storage would be required.

Biofuel Transportation

The US now produces about 6.5 billion gallons of ethanol per year. 75% of this is transported by railcar and the remaining 25% by tanker truck. The 13.5 billion gallons that were produced globally in 2007 were transported by all means, including via pipeline. The significance of this volume has led several rail systems and trucking companies to announce major investments to increase transportation capacity. With regard to pipeline transportation, significant R&D investments are being made. There are now commercially operating pipelines in South America and recently one was built in Florida. Below are typical costs for fuel movement via key modes.

Cents/gallon per 1000 miles	
Pipeline	1.5-2.5
Barge	4-5
Train	7.5-12.5
Truck	30-40

We believe that the sweet sorghum ethanol required by SolarCAT would quickly reach a level that would permit an ethanol plant to be located in a cost-effective manner in the vicinity of 4 GW SolarCAT plants. Installing a pipeline to the plants would then be economically feasible and its cost would be low enough to offset the advantages provided by the higher energy content of biodiesel (including its need for less storage space than sweet sorghum ethanol). Furthermore, in the long term, as is discussed below, the plan is for SolarCAT to use cellulosic ethanol which is the best answer to the biofuel calculation in terms of energy content, cost, carbon footprint, and impact on food cost.

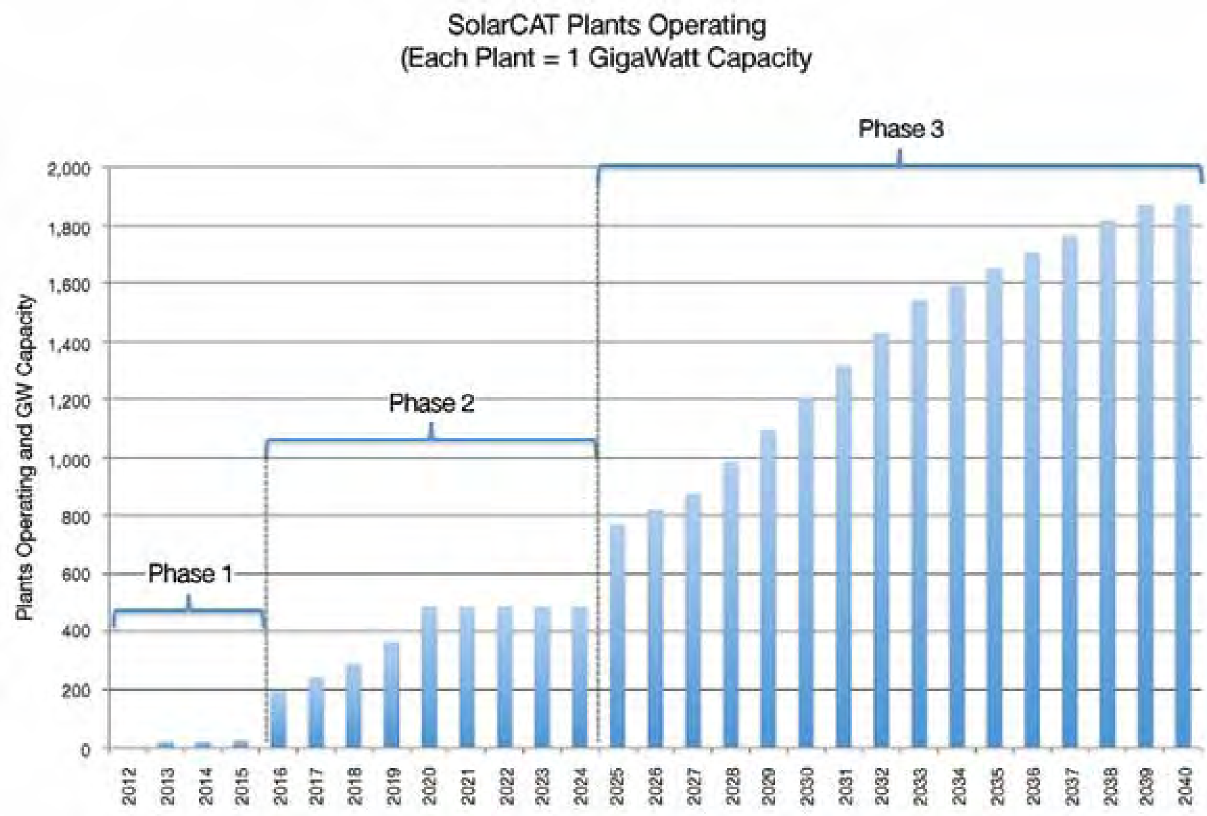
SolarCAT Biofuel Requirements

In the Practical Path, biofuels will provide approximately 10% of the energy used to produce electricity, with 60% of the remaining energy coming from wind and 30% from solar. The SolarCAT electrical generation plan is to bring the initial 1.0 GW production plant on-line in late 2011 or early 2012. Beginning in 2013, additional 1.0 GW plants will be built each year at a rate determined in large part by the availability of biofuel. Assuming adequate availability, this rate of expansion will result in 1,800 plants and 1,800 GW of generation capacity by 2040.

The Practical Path's demand for biofuel is based on the following calculations. Each 1.0 GW plant consists of 5,000 individual SolarCAT dishes, each of which will utilize energy from biofuel for a total of 1,000 hours each year, at a consumption rate of 6.6 gallons per hour. The resulting biofuel energy requirement ranges from 52 million gallons in 2013, to 97 billion gallons in 2040. Meeting the biofuel requirement in 2040 will require approximately 29 million acres of land dedicated to producing biofuel crops. As is detailed below, we divided the projected production of biofuels from the present to 2040 into three phases, each based on the availability of land and water and on the improvement in the characteristics of sweet sorghum expected to be achieved through the application of demonstrated biotechnologies.

The number of SolarCAT plants operating per year is shown in the following graph. If requirements dictate bringing SolarCAT plants on-line more quickly during any given time period, any shortage in sweet sorghum biofuel could be met by sourcing alternative biofuels or natural gas.

The graph shows that, except for short periods, the biofuel production meets or exceeds the Practical Path's demand for biofuel.



After surveying the various crop sources for biofuel we chose sweet sorghum as the preferred crop based on the characteristics listed above and the following criteria:

- Energy independence: Use only biofuel crops grown in the United States.

- Lowest possible greenhouse gas emissions: From the outset of the implementation of this plan the lifecycle greenhouse gas emissions from sweet sorghum biofuel will be lower than the lifecycle emissions for the lowest-emitting conventional fuel source, natural gas. Through the successive phases of the plan, the biofuel lifecycle greenhouse gas emissions will be further reduced to reach minimal levels.

- Lowest possible use of water.

- Greatest utilization of unused and marginal land.

- Lowest impact on the food supply: Minimal use of crop materials and land that can be utilized for food production.

- Smallest environmental footprint: Most efficient use of crop production inputs.

- Lowest possible cost: Achievement of the required biofuel energy supply at a competitive cost.

Carbon Footprint

Reducing greenhouse gas emissions, relative to conventional electrical generation, is an obvious and achievable goal of the SolarCAT system. This goal is not limited to generation of electricity through the use of wind and solar energy; it is also an explicit goal for the use of fuel-based energy during non-solar periods. The carbon footprint of sweet sorghum as grown today is among the lowest of any biofuel plant. With the addition of crop production efficiency technologies in Phase 2 of this plan, and cellulosic ethanol technology in Phase 3, the carbon footprint for biofuel from sweet sorghum drops to almost zero.

The biofuel utilized under this plan will, in each of Phases 1-3, produce lower lifecycle greenhouse gas emissions than the lowest-emitting conventional fossil fuel, natural gas. As the stages under this plan progress, the lifecycle greenhouse gas emissions will progressively decrease, reaching levels approaching zero in the third (cellulosic ethanol) phase.

While the lifecycle greenhouse gas emissions of fossil fuels are well characterized, there remains considerable debate about the lifecycle emissions from various biofuels. Determination of the lifecycle emissions from a biofuel must take into account not only the details of crop production (where the use of nitrogen fertilizer is the single greatest driver of emissions), but must also consider the post-harvest processing of the crop to make ethanol and, in particular, the source of processing energy (electricity from coal-fired power plants, nuclear, hydro, etc.).

Nonetheless, there is consensus that certain biofuels have lifecycle greenhouse gas emissions that are lower than the emissions from natural gas, the lowest-emitting fossil fuel. Through incorporation of cellulosic technology as described in this Appendix, lifecycle carbon emissions from sweet sorghum will be further reduced to approximately 7 grams per megajoule; that is 89% lower than for natural gas and 94% lower than coal. With significant potential for further improvements in processing, sweet sorghum with cellulosic technology offers the opportunity to approach zero net carbon emissions. The carbon impact of major energy sources is shown in the following chart.[34]

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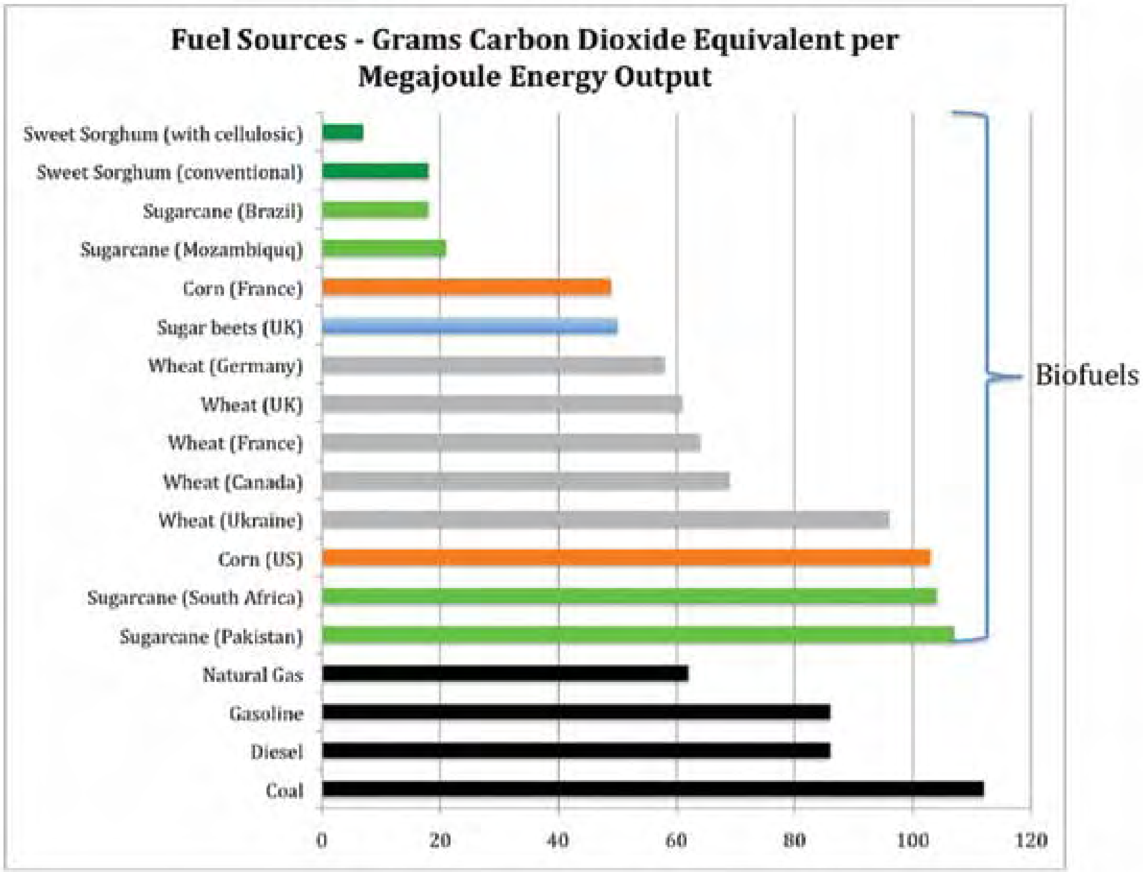
[34] Adapted from http://www.dft.gov.uk/pgr/roads/environment/rtfo/govrecrfa.pdf, utilizing data from EBAMM 1.1.



Water and Land Considerations

Water

Fresh water is a critical and increasingly scarce resource, and a key concern in electrical generation and crop production. In 2000, the U.S. used about 408 billion gallons of water per day. While fresh surface-water withdrawals varied less than 2 percent between 1985 and 2000, fresh ground-water withdrawals increased by 14 percent in the same time period.[35] The following figure illustrates the changes in U.S. water withdrawals and types of use from 1985 to 2000.

In addition to the obvious increase in total fresh water withdrawals over time, it is important to note that in 1965 fresh water withdrawals for thermoelectric power generation exceeded those for agricultural irrigation for the first time. In 2000,

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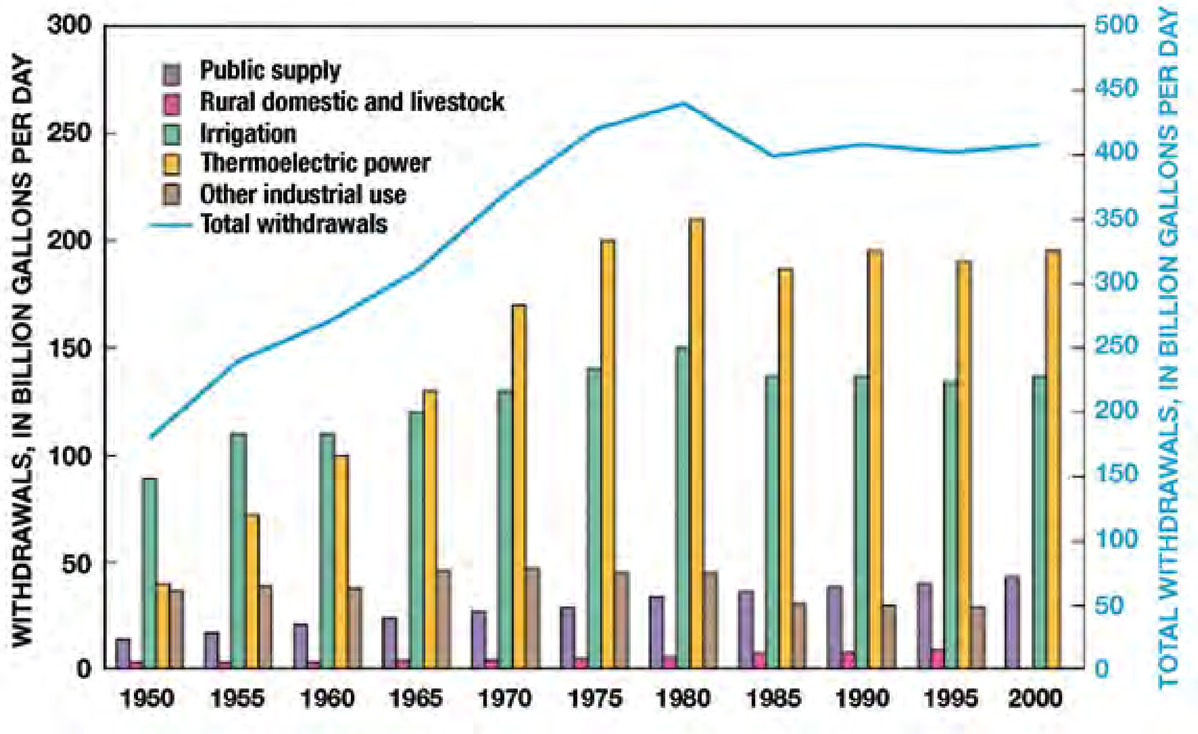
[35]Hutson, Susan S., et al., Estimated Use of Water in the United Sates in 2000, US Geological Survey, USGS Circular 1268, February 2005.

approximately 48% of all fresh-water and saline-water withdrawals in the US were used for thermoelectric power generation, and current solar thermal technology using steam turbines will use approximately the same as coal and gas plants.



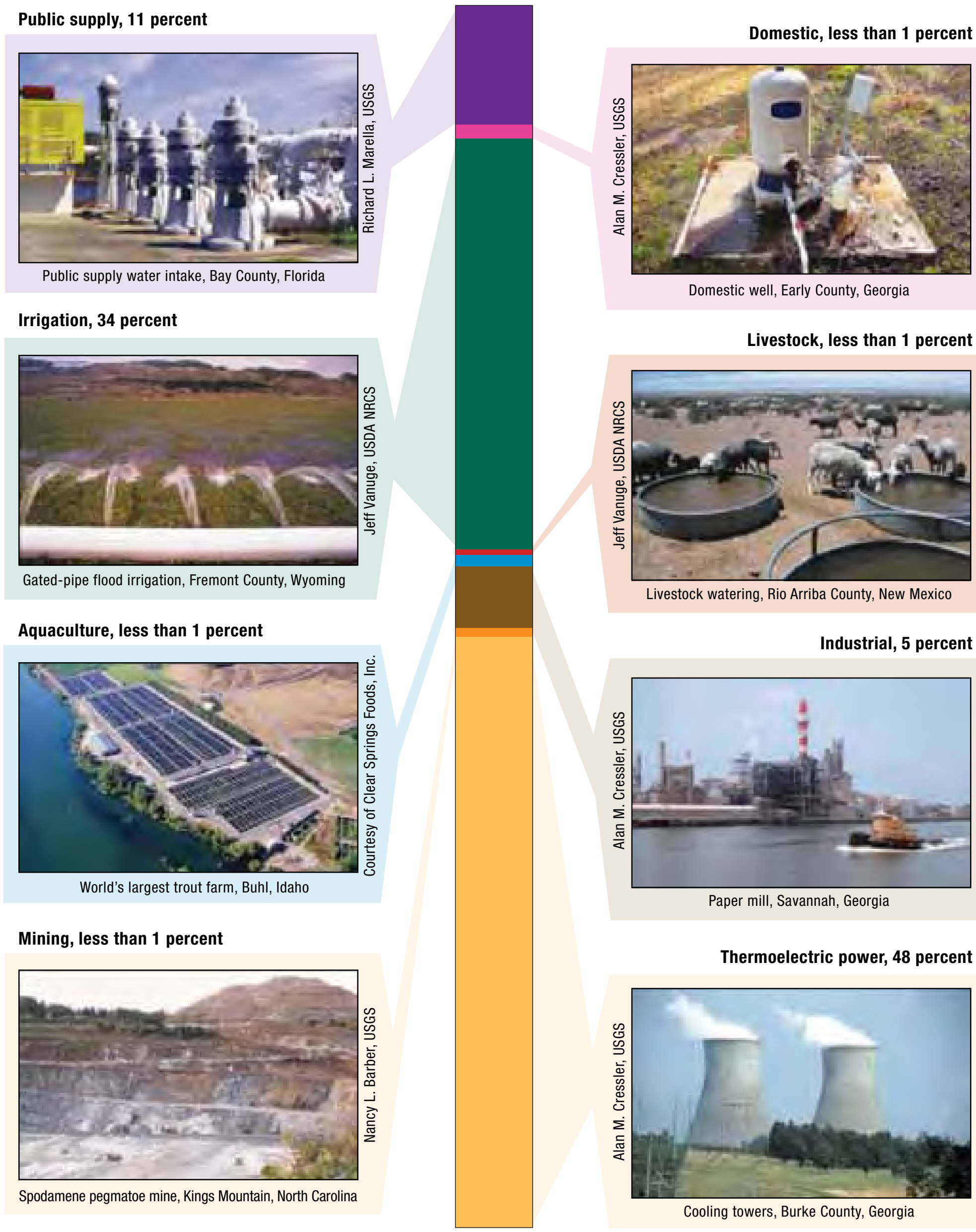
Agricultural irrigation accounted for approximately 34% of all water withdrawals. Together, thermal power and agriculture comprised about 52% of fresh surface-water withdrawals and about 96% of saline-water withdrawals. The current composition of total water withdrawals in the U.S. is described in the following graphic chart.

Of the water used for thermoelectric power generation, 91% was used in power plants with "once-through" cooling systems, meaning that the water is used once and then discarded. "Closed–loop" systems (which re-use cooling water) accounted for just 9% of total withdrawals.[36]

Current methods of electrical power generation are clearly water-intensive. In 2000, total electrical generation in the US was 3.8 billion megawatts,[37] and this required 71.3

[36]IBID., Thermoelectric.
[37]US Energy Information Administration, Summary Statistics for the United States, the Electrical Power Annual, October 22, 2007.

trillion gallons (325,821 acre feet) of cooling water. This means that each megawatt of power produced requires, on average, 18,800 gallons of water and each gigawatt



[38]

requires 18,800,000 gallons. Replacing coal and gas plants with solar thermal plants using steam turbines would not lower, and might even raise, water consumption per megawatt.

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[38]Hutson, Susan S., et al ., Estimated Use of Water in the United States 2000, US Geological Survey USGS Circular 1268, February 2005, Figure 1.

One of the key objectives of the Practical Path's biofuel production plan is to develop a sweet sorghum biofuel crop with water requirements significantly lower than would be required by solar thermal plants using steam turbines. Technologies exist today that enable the development of Water Use Efficient (WUE) crops. Some of these technologies have been demonstrated to result in crops that achieve conventional yields using 50-70% less water than conventional crops. Additional technologies have been demonstrated that enable crops to utilize saline water instead of fresh water. In combination, these technologies provide the promise of developing dedicated sweet sorghum crops that consume very little fresh water and allow us to move away from the highly water intensive form of electrical generation.

Land

US Land and Biofuel Production Potential

The United States has vast land resources that, if utilized wisely, provide the opportunity to produce large amounts of biofuel and thereby contribute to sustainable and environmentally acceptable energy independence. Agricultural land in the United States totals approximately 455 million acres, of which 349 million acres are currently used to produce crops. Currently, 39 million acres are idle (including Conservation Reserve Program), and 67 million acres are classified as pasture.[39] The total land base in the US is 2,263 million acres, of which approximately 50% has the potential for biomass production.[40] To meet or exceed the biofuel requirements under the SolarCAT electrical generation plan, peak dedicated biofuel crop acres under this plan will be 29 million acres, of which 27 million acres (26% of current combined idle and pasture lands) will be land that is now under-utilized but will be brought into production specifically for biofuels.

During Phase 2 of the plan, dedicated biofuel production area reaches 29 million acres (8.3% of current U.S. crop acres and 2.6% of total potential U.S. acres). In Phase 3 of the plan, dedicated biofuel crop area remains at 29 million acres, and increases in

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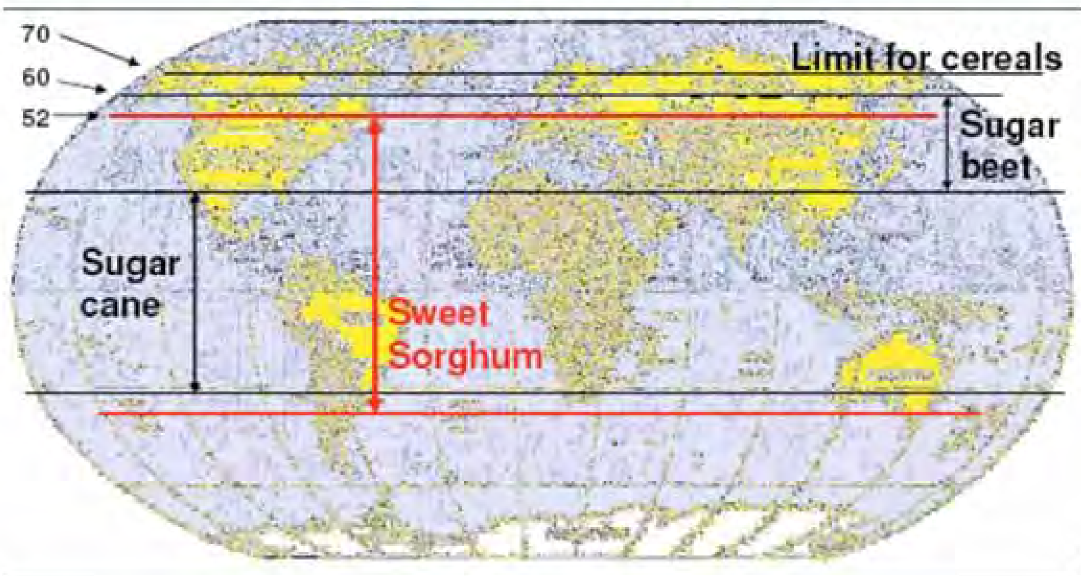
[39]USDA-NRCS (US Department of Agriculture – National Resource Conservation Service). 2003a. "National Resources Inventory: 2001 Annual NRI." http://www.nrcs.usda.gov/technical/land/nri01/nri01lu.html

[40]"Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply," US Department of Energy, DOE/GO-102005-2135, ORNL/TM-2005/66, 2005.

biofuel volume are achieved by utilizing residue from multiple crops for production of ethanol from cellulose.

Sweet sorghum can be grown throughout the U.S. and the world. Sorghum requires less nutrients and dramatically less water than corn or sugarcane. Production of sorghum has been adapted to tropical and sub-arid climates, resulting in a much broader range of potential production, including the entire U.S.



[41]

Sweet sorghum is naturally adapted to production on marginal lands so it is less likely to displace food crops, a significant issue in the consideration of biofuel crops. As a biofuel source, ethanol made from sweet sorghum contains 8 units of energy for each unit of energy used to produce and process the crop. This is more than four times the net energy balance of ethanol made from corn in the U.S. and a water use improvement of 16% over corn based ethanol.

[41]Low Cost Production of Bioethanol from Sweet Sorghum, European Biomass Industry Association.

Biofuel Costs

Due to the current energy-intensive nature of agricultural crop production, costs for biofuels from conventional crops are highly influenced by energy complex costs. Such energy costs are reflected throughout the production and processing cycle for biofuels, and include the cost of farm machinery operation, fertilizer inputs, pumping of irrigation water, and heating of feedstocks during ethanol production.

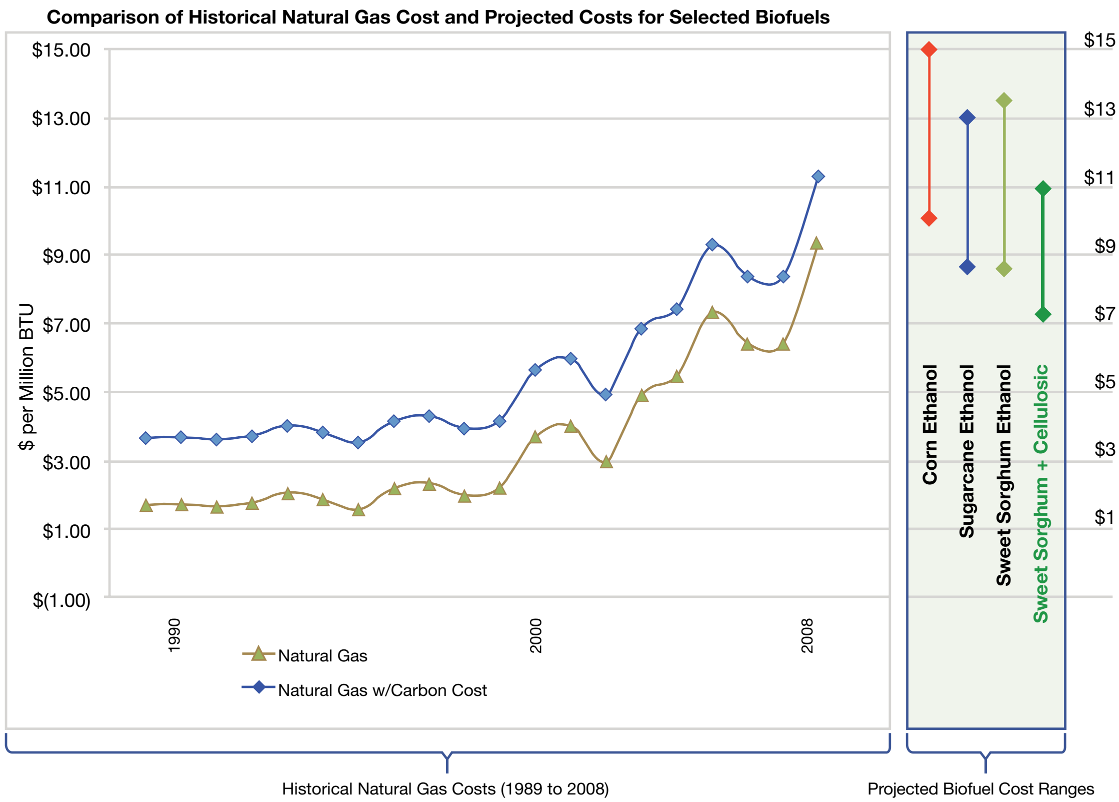
One of the overall technical objectives of this sweet sorghum biofuel production plan is to break several of the key links between energy input and agricultural crop output.

Doing so will not only decrease the cost of biofuels, it will also increase the net energy value (energy content of biofuel relative to energy input) and decrease the carbon footprint of biofuels.

One of the primary energy and cost inputs to crop and biofuel production is nitrogen fertilizer, which drives yield increases. Because nitrogen fertilizer is highly dependent upon natural gas as an input material, and because natural gas prices have increased dramatically over the past several years, nitrogen fertilizer use has become an even more significant component of biofuel production costs. When evaluating the carbon footprint of biofuels, nitrogen fertilizer (via resulting nitrous oxide emissions) is typically the single largest component of total greenhouse gas emissions. The technical goal of developing a dedicated biofuel sweet sorghum crop that is nitrogen use efficient and requires 50% less nitrogen fertilizer will dramatically decrease both biofuel costs and greenhouse gas emissions.

The following chart compares historical costs per million BTU ($/Million BTU) for natural gas and compares this to projected price ranges for various biofuels. The natural gas price history also shows the cost of natural gas if carbon emissions are taken into account (at a market price of $30 per metric ton). The cost ranges for the biofuels shown are based on our own and published estimates. The lower ends of the cost ranges for biofuels reflect cost improvements that we believe are possible through the application of technology to develop more efficient dedicated biofuel crops. Of the biofuels listed, we believe that sweet sorghum ethanol and sweet sorghum including cellulosic ethanol provide one of the keys to sustainable U.S. energy independence.

When efficiently produced, ethanol from sweet sorghum in the medium term, and cellulose in the long term, will provide fuels with a cost basis that is equal or superior to natural gas, and a carbon footprint that is minimal.



As illustrated in the chart, the cost of natural gas has increased steadily since the late 1990s. Industry analysts project that price increases are likely to continue in the future. The chart shows that natural gas pricing in the U.S. averaged approximately $9.30 per million BTU in 2008. If the carbon emissions from natural gas are considered, the carbon-loaded cost of natural gas in 2008 can be estimated at slightly more than $11.00 per million BTU. In comparison, the shaded box above shows estimated cost ranges for key biofuels. Ethanol from corn in the U.S., for example, has an estimated cost range of $10-$15 per million BTU, making it more expensive than the 2008 average cost of natural gas. Sweet sorghum, using current varieties and production methods has an estimated cost range of about $9-$13 per million BTU, making it approximately equivalent in cost to natural gas in the best case. Sweet sorghum integrating crop productivity and ethanol technologies is projected to result in a cost range of about $7-$11 per million BTU, putting it clearly lower than the cost of natural gas today.

The Three Phases of the Practical Plan for Biofuel

Phase 1 (2012-2015)

In the first phase of the plan, growing sweet sorghum for biofuel replaces 2.5% of the current 6.8 million acres of grain sorghum production acreage in the U.S. This production will result in 114 million gallons of biofuel, more than sufficient to operate a single SolarCAT 1 GW installation (which requires 52 million gallons annually). Phase 1 ramps-up production and supplies biofuel for the first 28 SolarCAT 1 GW installations planned to be in operation by 2015.

By the end of Phase 1, biofuel production from sweet sorghum is 1.5 billion gallons and requires 1.7 million acres of sweet sorghum crop.

Phase 2 (2016 – 2024)

The defining element of Phase 2 of this biofuel plan is the development of improved sweet sorghum varieties that can be produced on marginal lands with low inputs of fertilizer and fresh water.

Sweet sorghum is already tolerant of a range of relatively adverse production conditions and will be further improved, as detailed below, through the incorporation of multiple new traits that will increase the efficiency and reduce the environmental impact of biofuel production.

Nitrogen Use Efficiency: Nitrogen fertilizer is the key energy input and primary source of greenhouse gas emissions from crop production. Nitrogen Use Efficiency (NUE) technology has been developed that enables crops to produce high yields while using approximately 50% less nitrogen fertilizer than conventional crops. For biofuel crops, this means that the energy input required for crop production is lower, and the net energy value of the resulting biofuel is much higher. Because agriculture globally is the second largest industrial source of greenhouse gas emissions, and because nitrogen is the primary contributor to these emissions, biofuel produced from NUE sweet sorghum will have a substantially lower carbon footprint than conventional fuel or biofuel from conventional crops.[42]

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[42]NUE technology has been developed by Arcadia Biosciences, Inc., demonstrated in the field in multiple crops, and has been licensed to numerous seed companies for deployment in major agricultural crops. Application of Arcadia's NUE technology to sweet sorghum is underway. See link at: http://www.arcadiabiosciences.com/nitrogen.php

Water Use Efficiency (WUE) and Drought Tolerance. Fresh water is a key input to crop production and one of the world's most limited and precious resources. WUE and drought tolerance technologies for crops exist today and are being added to a number of crop species, including sweet sorghum.[43] WUE and drought tolerant sweet sorghum will minimize water requirements and improve the environmental impact of biofuel production.

Salt Tolerance. Salt tolerance technology has also been developed for crops and demonstrated in early field trials.[44] Salt tolerance technology can work synergistically with WUE and drought tolerance technologies to allow brackish water and marginal land to be utilized for biofuel crop production. This will further decrease the impact of biofuel crop production on natural resources and the environment.

Through the incorporation of these and other agricultural productivity traits, sweet sorghum production can be expanded to include millions of acres of marginal land. Currently, the sorghum production area in the U.S. is approximately 6.8 million acres. Under this plan, sorghum acreage will be expanded to 29 million acres, with most or all of the increased acreage coming from the more than 100 million acres of idle and pasture land in the U.S. U.S. sorghum production peaked at 27 million acres in about 1960 so projected land use in this biofuel plan is quite reasonable.

Within Phase 2 of this plan, total energy output from biofuel production increases to 25.3 billion gallons by 2020. This is sufficient to meet the biofuel requirements of the 485 SolarCAT plants in operation in 2024.

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[43]Water Use Efficiency (WUE) technology has been developed by multiple research organizations, including the University of California, Davis (UCD). Arcadia Biosciences, Inc., has obtained exclusive rights to WUE technology from UCD and has demonstrated the viability of this technology in field trials. Application of WUE technology to sweet sorghum is planned to begin in 2009.
[44]Salt Tolerance technology for plants has been developed by Arcadia Biosciences, Inc. and demonstrated in field trials with multiple crops. Application of Salt Tolerance technology to sweet sorghum is planned to begin in 2009.

Phase 3 (2025 – 2040)

Phase 3 of the plan builds on the earlier phases through the implementation of technologies that enable the production of ethanol from cellulose. There is a high degree of confidence that by 2025, if not sooner, these technologies will have been improved to the point that they lead to very large supplies of biofuel with high net energy, low environmental footprint, and low cost. Such technologies and processes are under development now, and a few have been tested at pilot scale.

This plan focuses on one particular technology that enables the production of critical cellulase enzymes (enzymes responsible for conversion of cellulose into fermentable sugars) directly within plant cell walls. Through a unique technology, the cellulases remain inactive until plant material reaches a "triggering" temperature during processing, at which time they become active. The approach overcomes the key cost-limiting step of adding expensive cellulase enzymes during processing. Because cellulosic ethanol production utilizes residual plant material—stalks and leaves—rather than harvested seed, the impact on food crop production is negligible.

Phase 3 of the plan will utilize cellulosic ethanol produced from sweet sorghum as well as three other key crops: wheat, sugarcane, and corn. The plan assumes that only a portion of the available residual biomass (which is typically plowed back into the soil) from each crop is utilized for biofuel production: 75% of sweet sorghum, 66% of wheat, 50% of sugarcane, and 66% of corn. As a practical matter, when it becomes possible to extract incremental value by selling crop residue for biofuel production, most acreage of these and other crops is likely to be put to such use, simply based on the goal of farmers to increase crop revenue.

Biofuel energy production at the beginning of Phase 3 (2025) is 40 billion gallons, meeting the biofuel needs of the 770 SolarCAT plants operating at that time. The biofuel volume under Phase 3 increases to 97 billion gallons by 2040, enabling the operation of up to 1,872 SolarCAT plants.

SolarCAT

A Practical Path to Renewable Energy Independence

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