A clean energy company

INTERVENTION

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E-00000A-01-0630
E-01933A-02-0069
E-01933A-98-0471

February 25, 2002

Arizona Corporation Commission
1200 W Washington
Phoenix, AZ 85007

RE: Docket # E-00000A-02-0051

To Whom It May Concern:

Please find enclosed, ten copies of motion to intervene and comments made by Stirling Energy Systems in regards to the Electric Competition Rules.

If you have any questions or require additional information, please do not hesitate to contact the office.

Sincerely,

Lori Glover
Director of Industry Affairs

Enclosures

Arizona Corporation Commission
DOCKETED
FEB 2 5 2002

DOCKETED BY

BEFORE THE ARIZONA CORPORATION COMMISSION

In re Generic Docket for Electric Restructuring	))))	Docket No. E-00000A-02-0051

MOTION TO INTERVENE AND RESPONSE TO COMMISSION QUESTIONS ON BEHALF OF STIRLING ENERGY SYSTEMS

On January 14, 2001, Chairman Mundell issued a letter to fellow Commissioners regarding the status of electric restructuring in the State of Arizona. In this letter and in subsequent letters issued by the Chairman and Commissioners Spitzer and Irvin dated January 22, January 29, and February 8, the Commission has requested responses to numerous questions posed regarding the development of electric restructuring in the State.

Stirling Energy Systems (SES) is a renewable energy company based in Phoenix, Arizona. SES develops energy projects using a variety of renewable energy sources. In Arizona, SES is particularly interested in developing projects using its proprietary Dish Stirling System, which concentrates sunlight to generate power.

Due to the nature of its business and as a potential developer of renewable electric energy projects in the State of Arizona, SES has an interest in the status of the electric restructuring rules in the State.

WHEREFORE, pursuant to Commission order requiring intervention and comment by February 25, 2002, SES respectfully requests to be allowed to intervene in the above-referenced docket. SES also requests that it be allowed to submit the attached responses to the questions posed.

This 22nd day of February, 2002, by

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Response of Stirling Energy Systems

Introduction

Stirling Energy Systems ("SES") is a renewable energy company, developing both solar and wind projects in the U.S. and worldwide. Due to the vast solar resources in the Southwest, in Arizona SES is focusing on solar power, using its proprietary Dish Stirling concentrating solar power system. SES is based in Phoenix, and is thus particularly interested in developing Arizona's solar resource. SES is taking this opportunity to respond to questions posed by the Commissioners regarding deregulation as these issues relate to the development of renewable energy in the State.

To begin such a discussion, it is important to remember the intent of deregulation regarding the role of renewable energy. Prior to the opportunity presented by deregulation, very little renewable energy was developed in Arizona although the Commission supported such development. Recognizing the importance of solar energy to the future of the Southwest, the Commission established a Staff Subcommittee to analyze the existing solar portfolio standard in 1997 in order to incorporate renewables into deregulation. According to the Subcommittee, the purpose of the solar requirement was to "foster advances in technology, encourage economies of scale in manufacturing, and gain greater experience with applying solar resources." SES believes that these goals are not and will not be met under the current scheme.

Between enactment of the original standard, the revised standard and now, the only solar that has been developed in Arizona is small amounts of photovoltaic cells and small-scale testing of certain concentrating solar power technologies. This is far from what the Commission seemed to envision. The Solar Subcommittee suggested the following objectives for the solar portfolio standard:

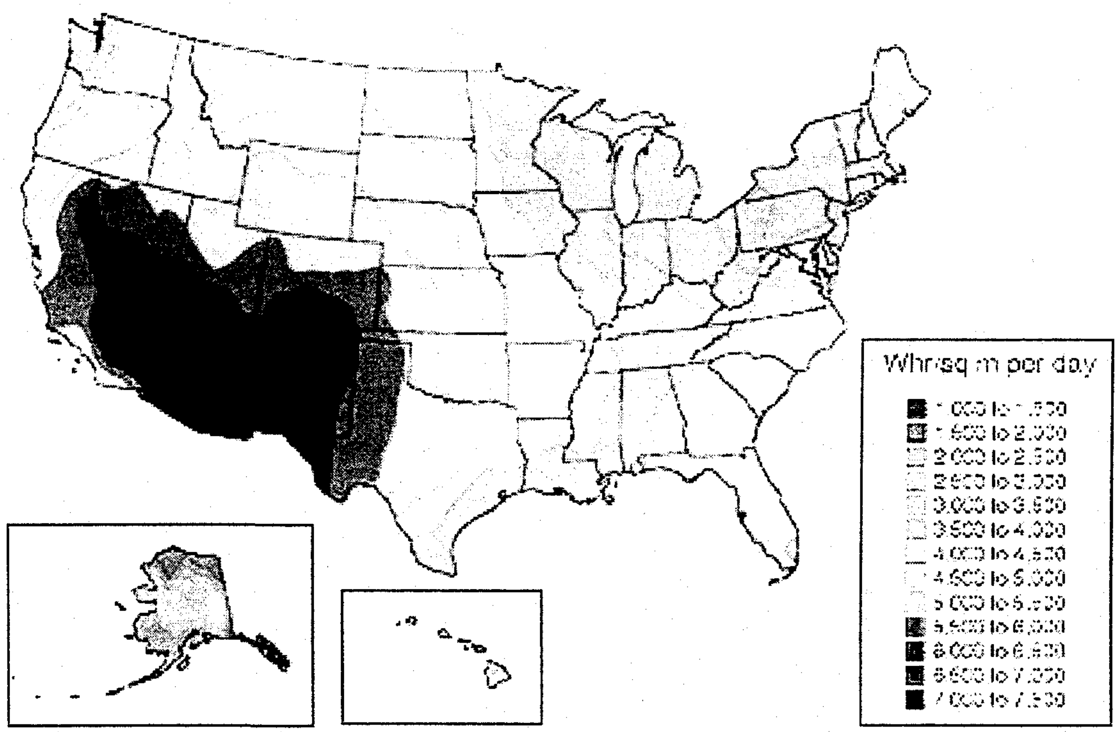
1. Encourage the use of solar electric technologies to increase the fuel diversity in the electricity generation mix.
2. Increase utility and electric service provider expertise and experience in the procurement, installation, and operation of solar electric systems or in the purchase and transmission of solar electricity from other sources.
3. Encourage new solar electric technologies as a reasonable percentage of competitive retail electric sales that is significantly less than the annual growth of demand for electricity.
4. Contribute to the commercialization of solar electric technologies, which will decrease the cost of solar electricity to Arizona customers in the future.
5. Contribute to economic benefits throughout Arizona.
6. Encourage environmental benefits.
7. Encourage a market-based solar electric industry.
8. Increase public information/awareness of solar electricity.
9. Reach an acceptable cost/benefit point.
10. Encourage solar development, rather than payment for non-compliance.

If Arizona wishes to reach many or all of these goals, it must move forward more aggressively. According to the U.S. National Renewable Energy Laboratory (NREL), "[d]uring the next decade, worldwide demand for electricity is expected to create markets for new concentrating solar power systems. U.S. government experts speculate that by the year 2020, more than 20 gigawatts of concentrating solar power systems could be installed throughout the world." As companies such as SES move forward, they will begin giving preference to other markets that more vigorously support solar power, moving business and manufacturing to these markets, and taking other steps that will deny Arizona the full benefits to be obtained from becoming a premier solar provider in the U.S.

The Benefits of Pursuing Solar Power

According to U.S. Department of Energy (DOE), "[t]he Southwestern United States potentially offers the best development opportunity for concentrating solar power technologies in the world," as shown on the map below.

The Solar Resource for Concentrating Solar Power



Arizona could benefit substantially by being the first state to develop this resource. Currently, the California Power Authority is recommending substantially increased use of renewables, the State of Nevada has issued its first round of utility RPF's under the State's new renewable portfolio standard, New Mexico is developing its renewable portfolio regulations and exploring renewable development, and Texas is investing in substantial amounts of renewable power (primarily wind at this time). In addition. CSP projects are currently being developed in India, Egypt, Morocco, Spain, and Mexico, and being explored in Greece, South Africa, and other countries.

Accompanying the Subcommittee Report were two independent reports discussing costs and benefits of solar technology. The first report, by Pacific Energy Group for the Commission (the PEG Report), estimated the cost to increase solar capacity to 250 to 330 MWs to range from $250 to $1,150 million, with a resulting rate increase of $0.0002 to $0.0013 per kWh. The Report noted this to be a very small rate effect. The Report also noted that this activity would directly create 600 jobs by 2010, $200 million in wages, salaries and state income tax revenue through 2020, and would avoid 12 million tons of CO_2 emissions, 32 thousand tons of SO_x emissions, and 38 thousand tons of NO_x emissions through 2020. The second report, by Economic Research Associates for the Department of Commerce (the ERA Report), concluded "[f]urthermore, if Arizona is able to develop a renewables manufacturing industry capable of producing 50 MW by 2010 – to meet in-state renewable electricity generating needs and take advantage of growing export opportunities – the market potential will be $115 million in 2010 and generate 1,100 new jobs in that year." Arizona is experiencing few of these expected benefits.

Although Arizona had made strides in energy efficiency and conservation, it has made little progress in developing renewable energy. Even for PV, NREL data shows that Arizona, although now ranked second, will soon fall to fourth or fifth amongst the states for installed PV. The ERA Report noted that further pursuit of energy efficiency along with renewable energy technology represented "a critical economic development strategy for Arizona." To create the benefits, the report concluded the investment in electric generating renewables would need to be $700 million (in 1996 dollars) between 1998 and 2010. This investment is not being made.

A review of Arizona's solar programs shows a focus on PV, and that primarily for residential use. The one exception is Tucson Electric Power, which recently exceeded 1 MW of installed PV generation at its Springville Generating Station. Nonetheless, aside from voluntary participation by utility customers and tax incentives for small PV systems, there are currently no incentives for the development of large-scale solar power.

Development and expansion of the Southwest's renewable energy industries should be pursued aggressively and as soon as possible, or risk losing the associated benefits of such a course of action to its neighboring states. This is especially true for concentrating solar power technologies, of which Dish Stirling is one.

Concentrating Solar Power, a Different Kind of Solar Power

Concentrating solar power ("CSP") is different from the better-known photovoltaic ("PV") technology. PV concerts sunlight directly to electricity with small systems typically ranging in size from a few millivolts to 1-2 kilowatts. Although the cost of PV-based energy production has declined dramatically over the past 10 years, it is still in the $6 per watt range and, further, is market constrained by production capacity shortage. CSP technologies, on the other hand, use reflective materials such as mirrors to concentrate sunlight onto a receiver, which, in turn, powers a generator. These technologies, which include dish systems, power towers, and parabolic troughs, are cheaper than PV and can produce power in volumes of 100s of MWs to put directly into the grid.

In addition to the benefits of solar power already discussed, benefits of CSP include:

- Sunlight is normally the only fuel required, preventing susceptibility to fuel-price fluctuation.

- The operating costs are very low, partially because of the use of sunlight as fuel.
- The price is levelized, avoiding inflationary factors.
- The benefits are not only to the air quality, but also to the rest of the environment, partially because no other fuel is used. In addition, these technologies normally have no other adverse environmental consequences. For example, the SES technology uses just over 4 gallons of water per MWh of electricity produced, much less than most other types of electricity production.
- Siting issues often related to coal, nuclear, and natural gas plants don't apply to CSP technologies because plant sites can be remote locations, in arid land that is otherwise underutilized.
- These technologies offer pollution credit trading possibilities.
- By adopting CSP technologies, Arizona will enhance its "green" image enhancement.
- Arizona will also be in the position to obtain preferential pricing and order positioning from SES and possibly the other technologies.

If Arizona does not act soon, many of the potential benefits will be lost.

The U.S. DOE formed a partnership between NREL and Sandia National Laboratories – SunLab – to develop CSP technologies. According to SunLab, CSP technologies "have the potential to provide the world with tens of thousand of megawatts of clean, renewable, cost-competitive power beginning in the next few years." Although having the ability to be used off-grid to produce as little as 25 kilowatts of power, CSP technologies can also be grid-connected and provide 100s of MW of power. In fact, according to SunLab, CSP technologies "currently offer the lowest-cost solar electricity for large-scale power generation (10 MW and above)."

For more information on the potential of the Dish Stirling concentrating solar power system, please see the enclosed Attachment 1.

<u>The Effect of Deregulation on the Renewable Industry</u>

In it first decision incorporating a solar portfolio into electric deregulation, Decision No. 62506 issued May 4, 2000, the Commission said that "[b]ecause the environmentally friendly resources (especially solar resources), are significantly more expensive than other resources for the foreseeable future. there is a direct conflict with the objective of lower rates resulting from competition. In addition. there is a conflict between customer choice and mandated environmentally friendly resources." These concerns still exist today; however, such concerns should not prevent the development of solar power in Arizona.

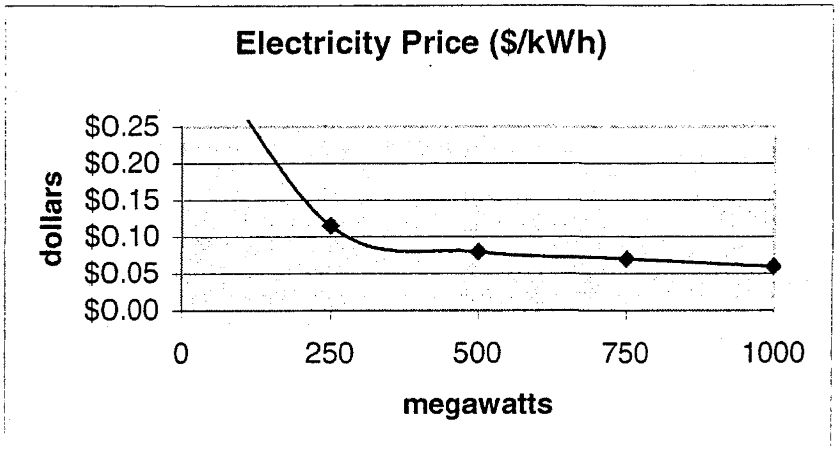
Deregulation has opened electric generation markets and made possible true development of solar power in Arizona as recommended by the Commission many years ago and now mandated through the Renewable Portfolio Standard; nonetheless. deregulation has done nothing to actually further this purpose. SES believes that Arizona should develop solar energy concurrently with but separate from deregulation. Deregulation is a matter complex and vast enough of its own right that renewable energy questions become subsumed. Further, the primary goals of choice and lowest possible cost electricity, although compatible with the development of solar power, are, in the short term, prohibitive of a flourishing solar industry in the State.

At this time customers cannot easily choose green power. Although a consumer may participate in some green power programs with the utilities at this time, there is insufficient renewable energy available, and none available at truly competitive prices to make this a true choice. In the long term as solar is developed in Arizona, the larger amounts available along with the lower costs of solar power will allow a green choice to be a true choice. In the near future, however, cost is preventing the development of this market.

As is true of many renewable energy systems, the primary cost for a Dish Stirling system is the initial capital cost. Thus, the manufacturing cost is directly reflective on the price of power produced. As SES begins to produce its system in large volumes, the price will drop dramatically due to economies of scale. This has been seen with other renewable energy technology: wind moved from 80 cents down to 4-6 cents per kWh and PV has gone from $2.00 to 30-40 cents per kWh. SunLab notes that although current cost for concentrating solar power is 9-12 cents per kWh, future technology advancements will allow the cost to drop to 4-5 cents per kWh in the next decade.

While initial capital costs of a renewable plant are somewhat higher than a fossil-fueled plant, operating expenses are lower through the economic life of the project. This means that, for certain commercially available renewable technologies, the present value of a renewable plant project equals or exceeds that of a fossil-fueled plant. Even without factoring the value of external economic environmental factors, renewable source projects can deliver competitively priced retail and wholesale electricity.

The installed cost is a direct function of manufacturing volume. SES expects manufacturing costs to decrease dramatically as volume of output increases. At a production rate of 2,000 units per year, the capital cost of one unit is $2,500 - $3,000 per installed kW. At a production rate of 12,000 per year however, the capital cost is expected to be in the $1,200 per installed kWh range. SES is also aggressively pursuing cost reduction and design improvements for its Dish System. As production levels are increased and manufacturing costs are decreased, SES expects the price to drop, resulting in a projected levelized energy cost of approximately $0.06 cents. This is depicted graphically at the top of the next page.



The price of power sold by a renewable source project, such as a utility-scale dish Stirling electricity generation project, can remain nearly level in constant dollars over the economic life of the project (assume 30 years). Price levelization is possible because:

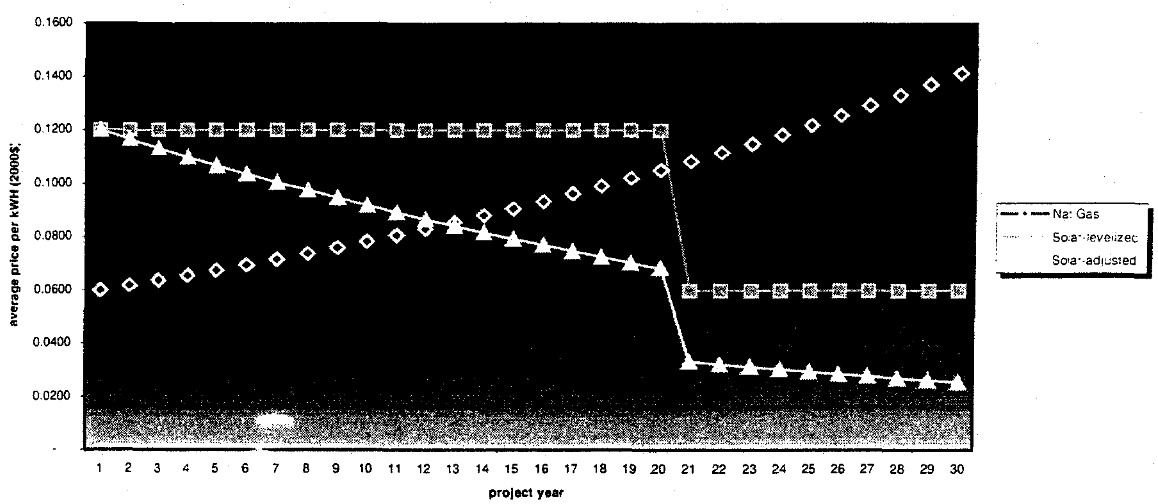
- Only a small fraction of the annual project expenses are subject to variability due to inflation (e.g. repayment of the initial cost of equipment design, procurement and construction; financing cost, operation and maintenance labor, consumables and equipment).
- Expenses subject to inflation will vary by general inflation deflators such as the Producer Price Index (e.g. operation and maintenance labor, consumables and equipment replacement)

By comparison, fossil-fueled electricity generation plants (such as natural gas, the most common choice in 2001) have a far greater portion of annual operating expenses subject to inflation variability. The largest component of price volatility is the fuel conversion costs. The price of the output of a fossil-fueled plant is subject to far greater possible volatility, transferring price risk to consumers or forcing municipal retail suppliers to operate at a significant loss.

While initial capital costs of a renewable plant are somewhat higher than a fossil-fueled plant, operating expenses are lower through the economic life of the project.

This means that, for certain commercially available renewable technologies, the present value of a renewable plant project equals or exceeds that of a fossil-fueled plant. Even without factoring the value of external economic environmental factors, renewable source projects can deliver competitively priced retail and wholesale electricity and attractive yield to investors in those projects.

Natural Gas Inflation Adjusted Electricity Prices vs. Levelized Solar (30 yr.)



A solar mandate is essentially separate, although not incompatible, from the goals of deregulation. After initial assistance from the Commission, the State will see a variety of benefits from developing a solar industry in Arizona, including greater choice, lower prices, other economic benefits, and vast environmental advantages.

Conclusion

SES applauds the Commission for its support of renewable technologies in the past; however, SES respectfully suggests that the Commission must do more to allow these technologies, especially solar, to truly develop.

Attachment 1
Commercialization of the SES Technology

The SES Dish Stirling Technology

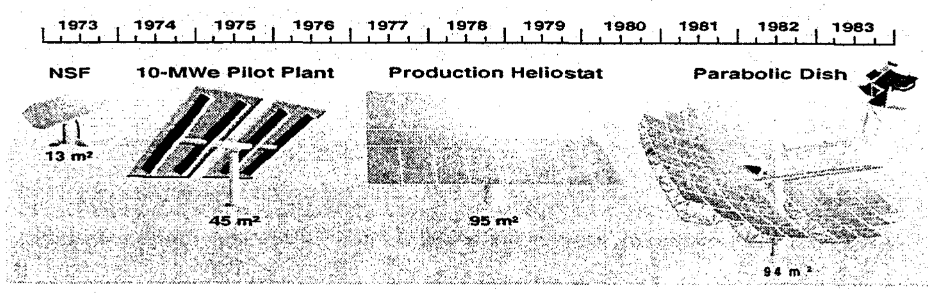
The SES Dish Stirling system is composed of two major components: the solar concentrator and the power conversion unit (PCU).

The solar concentrator. The large parabolic concentrator is fabricated in a factory (rather than on site) to ensure proper quality and alignment. It is designed in five subassembly units for ease of transport and installation on site. The 89 mirror facets are attached to the frame by three-point adjusting mounts at specific points on the subassemblies. When final alignment adjustments are made at the factory, the facets are locked into place before the system is shipped so as to eliminate the need for adjusting mirror facets at the site. The subassembly design permits units to be transported to an installation site by truck.

Site preparation involves sinking a cement base with an imbedded pedestal to support the dish, with the subassemblies unloaded, bolted together and affixed to the pedestal by two workmen in about four hours. No crane is required. Two small motors, an azimuth drive and an elevation drive, are attached to the pedestal and programmed to swivel the dish on two axes, following the sun's progress across the sky during the day.

At the end of the day, the system controller commands the concentrator to tilt down into a "night-stow" position, with the engine at ground level. Each morning, the system wakes up, putting it in position to greet the sun, rather like a robotic sunflower. The system is built to withstand winds of up to 100 mph, but as a precaution, the system controller automatically "tilts up" when winds reach about 35 mph. The concentrator achieves its lowest profile in this position, thereby preventing strong wind loads to cause damage to structural components. In addition, in the event of a malfunction, the Fast Slew System automatically moves the sun's focused beam two feet off the receiver of the PCU, thereby avoiding damage to any parts of the system.

Solar Concentrator History



Over $100 million invested by McDonnell Douglas/DOE

The power conversion unit ("PCU"). The engine's cylinder block incorporates four sealed cylinder assemblies (pistons, piston rods, and connecting rods domes) along with coolers, regenerators and heater heads. Concentrated solar energy heats up self-contained gas in the PCU, causing the gas to expand into the cylinders. Inside the cylinders, the pressure from the expansion pushes the piston assembly toward the crankshaft while at the same time gas from an adjacent chamber that has been cooled is contracting, pulling the piston assembly. So, there is a double "push – pull" action on the piston assembly. The movement of the piston assembly creates linear motion, which is converted into the familiar rotational movement of the crankshaft. This rotational movement is then converted into electricity by the generator, which is attached to the unit. There is a 90-degree timing separation between adjacent cylinders and the working gas is exchanged repeatedly back and forth between the same adjacent cylinders. This cycle is repeated over and over as the engine runs at a steady rate of 1,800 rpm (a low-stress, long duty-life regimen for a conventional gasoline engine).

The working gas used by the engine is pressurized hydrogen, stored in the same kind of steel tanks used in welding and other conventional industrial applications. The gas is cycled repeatedly so the same gas continues to work indefinitely, though routine maintenance includes recharging the hydrogen tanks once or twice each year.

Unlike familiar auto or truck engines, Stirling engines do not rely upon internal combustion to drive the pistons and rotate a crankshaft. In fact, there is no combustion at all. Power is generated by heat transfer from the concentrated solar rays to the working gas in the engine's heater head, which converts the heat energy into mechanical motion. This power runs the electric generator, which produces electricity with an output of 480 Volts and 60 Hertz, so it is already power-conditioned by the generator's interface. The generator of each unit in a utility-scale project is connected by underground wire to a small substation where the power can be transformed into a higher voltage for more efficient transmission across the grid.

Technology History

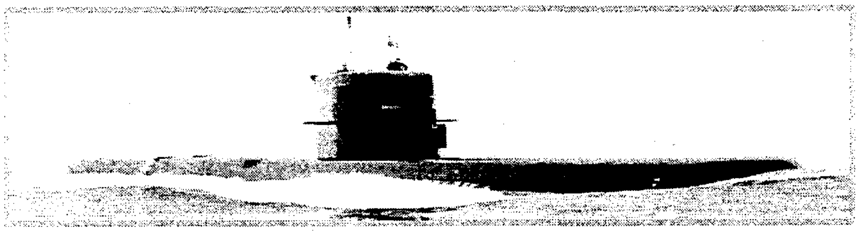
Development of the Kockum's Stirling engine began in the early 1970s when United Stirling AB (USAB) of Malmo, Sweden started the design of a "4-95" kinematic Stirling engine. In the late 1970s and early 1980s, USAB, under contract from the Jet Propulsion Laboratory (JPL) and the U.S. Department of Energy (DOE), designed, fabricated, and tested "solarized" versions of the USAB 4-95 Stirling engine at the Georgia Tech Advanced Component Test Facility (ACTF) and at the JPL Solar Test Facility at Edwards Air Force Base. Because the system demonstrated excellent performance, a DOE program was initiated with Advanco Corp. in which a USAB 4-95 Stirling Power Conversion Unit (PCU) was integrated with the Vanguard concentrator. This system demonstrated very high efficiency and established records for conversion efficiency of direct normal solar insolation to electricity.

In the early 1980s, McDonnell Douglas (now Boeing) and USAB formed a joint venture to commercialize a dish Stirling system based on the 4-95 PCU and a McDonnell Douglas-designed solar concentrator. Systems were installed at the McDonnell Douglas test site in Huntington Beach, CA and several utility test sites. Testing at these sites continued through late 1988.

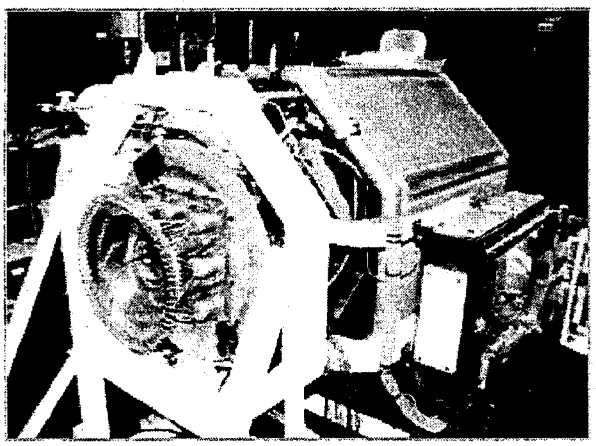
Attachment 1
Commercialization of the SES Technology

SES was formed in 1996 with the objective of acquiring, developing and commercializing the production of electrical energy from the sun using Dish-Stirling Point-Focusing Distributed Receiver (PFDR) technology. SES has acquired the intellectual and technology rights to the McDonnell Douglas (MDA) concentrator and the license to manufacture the USAB (now Kockums) 4-95 Stirling engine-based PCU.

Kockums Stirling Engine Development
for Non-nuclear Submarines



$250M invested over 30 years
$15M to solarize engine



Commercialization

Since April 1998, SES has been moving toward commercial production of its Dish Stirling System through the DECC Program (Dish Engine Critical Components), a cost-share program between Boeing, SES, and Sandia/DOE to incorporate design enhancements to the Stirling engine and other components of the PCU to increase performance and decrease operation and maintenance costs. Phase I of this DECC program cost approximately $945,000, of which Sandia Labs contributed 52% and SES contributed the remaining 48%.

The Contract set out an ambitious six-point multi-task work program including both bench-testing and on-sun testing of Stirling engine-based PCUs. Phase I was successfully completed in August 1999 and resulted in significant engineering refinements, which SES is incorporating in the current dish Stirling system. It was particularly significant that the McDonnell-Douglas systems, which were constructed in the mid-80's, remained on-sun during the interval and were merely refurbished for the DECC testing project, performed at the same rates as they had fifteen years or so earlier. This serves to demonstrate the endurance capability and longevity of the system.

Phase II began in October 1999, using the two dish Stirling modules from Phase I and two additional 4-95 Stirling engines. Phase II is a $6.2 million project (cost-shared between SES and Sandia with SES provided about 62% of the total cost). This contract is aimed at system integration, incorporating additional bench tests and on-sun tests of Stirling engine PCUs, grid tests and a business and marketing component. The work program will continue through 2002 with building of two new generation systems this year.

Ready for Commercial Production

Detailed technology reviews of the SES Dish Stirling System were delivered in April 2001, at the proceedings of Solar Forum 2001, by the project manager for the Sandia National Laboratories and representatives of Boeing, Kockums, and SES. The reports presented data documenting the operation and service requirements of the SES dish Stirling energy system. Among other things, they reported:

- Since April 1998, SES Stirling engines (PCUs) accumulated over 10,400 hours of on-sun operating time and logged more than 11,800 hours of bench test operations.
- System availability was better than 94% during periods of insolation over 300 W/m^2, even taking into account "off-sun" events related to the testing program.

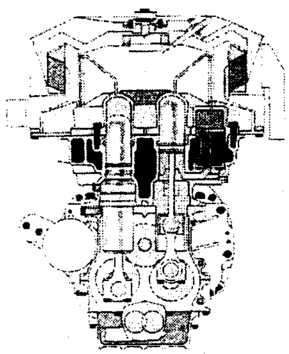
The report concluded that "based upon the performance of the systems … there appear to be no serious obstacles to the commercialization of this technology."

To this day, the SES Solar Technology holds the World's Record (29.4%) for sun-to-electricity efficiency. The technology has also demonstrated long life and excellent reliability with systems over 17 years old and still operating like new. The system is modular, scalable, and environmentally safe.

In November of 2001, a peer review of this program and other concentrating solar programs (CSP) programs was conducted. On December 7, 2001, the Panel forwarded its results to the Department of Energy concluding that "[w]ith proper funding the DOE CSP program can play an important role in catalyzing further CSP technology advances, which will further improve CSP economies and market penetration. Ultimately, CSP technologies could contribute significantly to the U.S. supply of electricity from domestic resources. In the short term, CSP could make a difference for the US by adding diversity and security to our energy supplies, particularly in the high-grade areas of the Southwest."

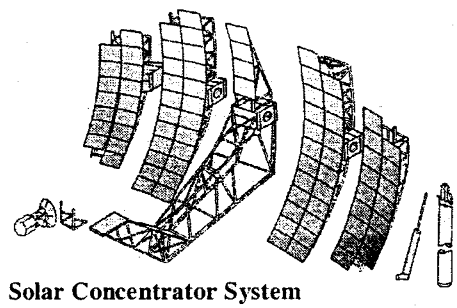
Simultaneously, the Department of Energy is separately developing a program to construct 1,000 MW of CSP facilities under direction from Congress. In addition, there is currently a bill pending in Congress to promote renewable energy.

The SES Dish Stirling System Offers High Availability, High Efficiency and High Reliability.



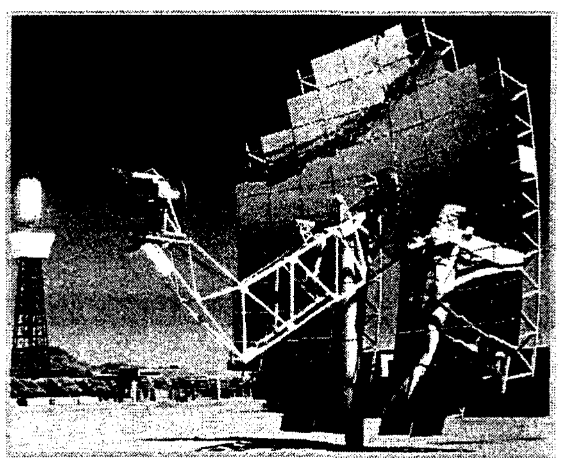
4-95 Stirling PCU
- 40% efficiency
- Rated power of 25kW at 1800 RPM

Induction Generator
- 94.5% efficiency
- 3-phase/480 volt AC
- Cost effective



Solar Concentrator System
- 11 meter diameter
- Balanced concentrator design
- 94.1 m2 aperture area
- 2 axis tracking system

Direct Impingement Receiver
- Proven design
- 89.7% efficiency



5 Major Subassemblies
- Modular structure
- Ship by truck
- 4-hour assembly

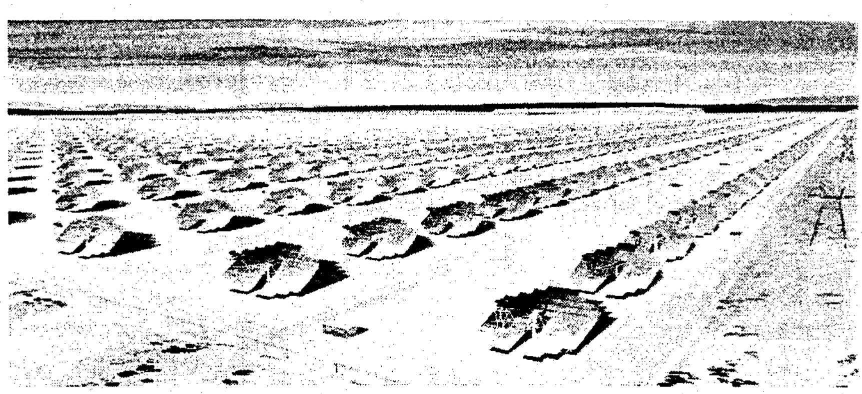
Mirror Facets
- 82 per Concentrator
  1 m x 1.5 m
- Reflectivity 92 to 94%

Azimuth & Elevation Drives
- Off the shelf hardware
- Counter balanced

Single Post Support
- Inexpensive
- Small footprint

Typical Plant Layout

- 10 MW = 400 Gensets
- Land required: Approx. 40 acres
- 1% solar shading



Attachment 1
Commercialization of the SES Technology

The Stirling technology offers many additional advantages unique to its technology:

1. Stirling's renewable technologies are robust, reliable and competitive with conventional technology. The Dish Stirling System is proven technology with a 17-year operational track record, over 25,000 hours of on-sun time, and world's efficiency record in producing grid-quality electricity (95-98% availability of daytime electrical power).

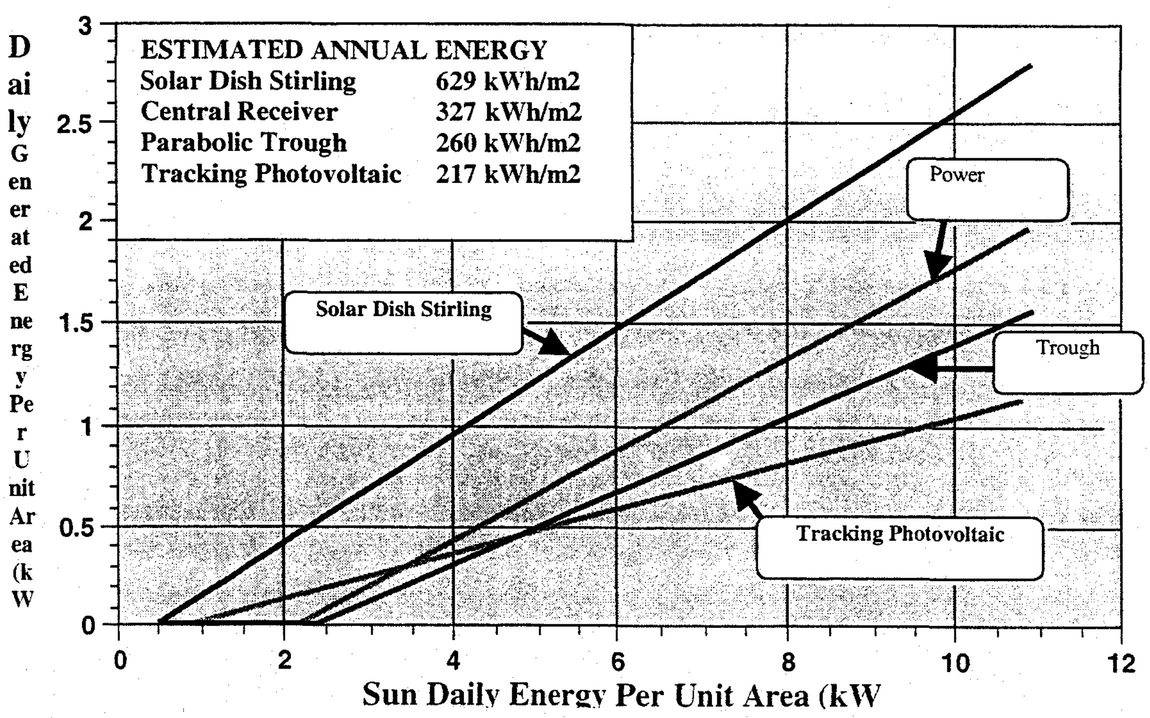
2. The Systems can be rapidly deployed through mass production and are scalable to meet growing market demand.

3. Dish Stirling solar technology is environmentally pristine, with zero environmental emissions or other adverse effects. Particularly important is the fact that a Dish Stirling System uses just over 4 gallons of water per MWh or electricity produced, much less then most other types of electricity generation on dramatically less then the other CSP technologies.

Efficiency Advantages

In addition to Dish Stirling Systems, there are three other types of CSP technology: 1) parabolic trough systems; 2) central receiver or "power tower" plants; and 3) concentrating PV systems.

Solar Dish Stirling – Most Efficient



Source: Southern California Edison and Sandia National Laboratories

Attachment 1
Commercialization of the SES Technology

In side-by-side testing of all four concentrating solar technologies over a period of several years, data from Southern California Edison shows the Dish Stirling System to be, by far, the most efficient. This efficiency, coupled with the lower potential product cost of the Dish Stirling System in mass production quantities, leads management to believe that SES will be highly competitive. In addition, SES has much longer field data time than competitive technologies.

Simple Operation and Maintenance

In preparation for production, McDonnell Douglas (now Boeing) has conducted detailed manufacturing studies with high volume manufacturing consultants. McDonnell Douglas was also the design integrator of the DOE Solar One plant located near Barstow, California and obtained valuable manufacturing and installation experience with the 1,818 Solar One heliostats comprising that plant. Boeing also has years of experience in the operation of this type of solar plants.

The SES Stirling Dish system is designed for a life of 30 years and includes provisions to facilitate operation and maintenance activities. It operates automatically and does not require operator monitoring or hands-on attention. The test site system has operated for years in the automatic mode, where the system goes "on-sun," in the morning, produces power all day, and goes to night stow after sunset, all without operator intervention. If a problem occurs, the system automatically goes off-sun, returning to a night stow position and printing out a description of the problem for maintenance personnel. After the problem is resolved, the maintenance person returns the system to automatic operation. The control system has a built-in diagnostic and status check to isolate any problems. The central System Controller (SC) also prints diagnostic information indicating any need for maintenance.

For a solar-only Dish Stirling power plant, maintenance functions typically are scheduled during the hours when the plant is already off-line. Thus, the plant can take full advantage of daytime solar insolation periods. The primary solar concentrator maintenance activity is reflector washing, typically performed once a month in the dormant hours between sunset and sunrise. With respect to the Stirling PCU, primary maintenance occurs every 5,000 or 6,000 hours of operation.

The system is designed in modules that are easily replaced in the field. When a problem occurs and is isolated to a particular module, the module is replaced and the faulty module is returned to a maintenance facility for repair. As an example, the electronic control unit is housed in a separate enclosure, with electrical interface provided by quick disconnect connectors. The control unit can be disconnected, removed, replaced, and reconnected in less than a minute, The 25,000 hours of "on-sun" operation accumulated by a number of units since the mid-1980's provides a significant database from which to calculate system O&M costs.

Attachment 1
Commercialization of the SES Technology

Long-Life with Limited Performance Degradation

The Dish Stirling System is inherently superior to photovoltaic systems in that its performance does not inevitably degrade with time. Unlike other solar concentrator systems, the SES Dish design shows no significant age-related loss of mirror reflectivity, an essential functional parameter of the system. Mirror panels manufactured 16 to 17 years ago have been continuously exposed to the environment and repeatedly cleaned throughout that period and, remarkably, they still meet the original performance requirements.

With respect to the Stirling engine, any long-term (6000 operating hours) seal wear degradation is eliminated by periodic replacement. Experience shows that the original performance of the engine is fully recovered by this process. Historically, the receiver heat transfer surfaces (which are made up of Inconel tubes) accumulate a thin layer of oxidation over a period of several hundred hours of solar operation. Rather than degrading receiver performance, this gradual change increases the solar absorbency of the surface, thereby increasing the amount of heat transferred from the tubes and into the working gas that operates the engine.

Modular and Scalable

Unlike many of the other technologies, the SES Systems are modular and scalable. A Dish Stirling plant can range anywhere in size from 25 kW to 100s of MWs depending upon the requirement. In addition, Dish Stirling Systems are adaptable to mass manufacturing, dramatically reducing the costs.

Environmentally Pristine

The SES technology is environmentally pristine. It has zero air emissions. In addition, it offers other environmental advantages:

- *Minimal Water Usage.* The only water used in a Dish Stirling power plant is that used for periodically washing the mirrors - only approximately **4.4 gallons per MWh of energy produced**. The water used in the washing solution is de-ionized, and it is mixed with a non-toxic compound that has been approved for use in California, even in circumstances where the runoff from the solar concentrator is directly over an aquifer. This water and the antifreeze solution will be the only wastewater.

- *No Hazardous Materials.* With the exception of the antifreeze used in the cooling system and the small amount of oil lubricant used in the Stirling engine, there are no toxic chemicals. Hydrogen gas is used as a working fluid in the Stirling engine, and it is sealed inside the engine. Although small amounts of the hydrogen will escape from the engine over time, hydrogen is a non-toxic substance that will diffuse rapidly into the atmosphere.

- *Land Requirements*. A Dish Stirling plant utilizes approximately one acre per 9-10 Systems, plus a small additional amount of land for the office and control room, perimeter security areas, substation, equipment maintenance and storage areas, and parking, as needed. Other solar technologies utilize more land per kWh. Each Dish Stirling System has a relatively small "footprint" that is made by a single pedestal that is about 18 inches in diameter. In addition, a plant can easily be sited in areas where land is underutilized, far from urban areas.

- *Aesthetics & Noise*. Stirling-cycle engines do not utilize a process of internal combustion, and are thus remarkably quiet during their operation, emitting less than 66 dB at full load. Dish Stirling installations would typically be placed in remote areas so that even the minimal amount of noise that is generated by the systems is not expected to pose any problems with respect to humans or wildlife in the area.

- *Biological Resources*. The installation of an SES Dish Stirling system is comparable to the planting of a tree. The primary impact to the area will be the shade provided by the solar concentrator system. As a result, no special permits from the Department of Fish and Game streambed Alteration Agreement or EPS's 404 permit, U.S. Fish and Wildlife Section 7 or Section 10 permits are expected.

- *Cultural/Paleontological/Geological Resources*. The SES Dish system has a single post support structure that is only about 18 inches in diameter, and this support structure is usually installed so that about 15 to 20 feet of the structure is located below the surface, depending on the soil structure.

- *Traffic/Transportation.* With the exception of tourist traffic, the SES Dish Stirling Power Plant is not expected to have any significant impact on local traffic and transportation.

Strategic Alliances

Several important teaming relationships with strategic partners augment the SES management team and staff, providing significant engineering, technical, and project development support.

- **Kockums, AB,** a Swedish company which manufacturers submarines for the Swedish, Japanese, and Australian navies, has invested over $250 million over a 30-year period developing the Stirling engine. Kockums granted SES both exclusive and non-exclusive licenses to manufacture, distribute and market the engine worldwide.
- **NASA-Glenn Laboratories** has been involved in Stirling engine research and development for the past 15 years, and provides technical advice to SES.
- **U.S. Department of Energy (DOE)** provides additional research and development support of the Dish Stirling System under an ongoing government contract.
- **The Boeing Company** is a teaming partner with SES and the U.S. DOE. McDonnell Douglas (now Boeing) developed the SES solar concentrator during the early 1980s, spending $50 million.

Attachment 1
Commercialization of the SES Technology

- **Christenson Electric**, based in the Pacific Northwest, is a $100 million electrical contractor specializing in large-scale electrical installations. Christenson is becoming a premier contractor for the construction and installation of wind systems. In addition, Christenson is working on SES to install its solar facilities.
- **Vestas**, a Danish company that is the largest and most experienced wind system manufacturer in the world, signed an Equipment Acquisition Agreement with SES in 2000. As part of that agreement, Vestas provides both the equipment and operation and maintenance engineering support to SES.