SkyFuel™

The Sunrise of Solar Power™

SkyFuel™ & SkyTrough™ Questions and Answers

SkyFuel™ General

Q: What are the products of SkyFuel™?

A: SkyFuel™ designs and manufactures the low-cost, high-performance parabolic trough solar collector assembly called the SkyTrough™ and its critical components such as the ReflecTech® Mirror Film reflectors, the space frame and the SkyTrakker™ control and drive system. SkyFuel™ also provides consulting services to assist project developers in their early project assessment phase to determine feasibility including solar field equipment and site solar resource assessment with solar monitoring stations.

Q: What are the applications for the SkyTrough™?

A: There are two primary uses for the SkyTrough™. First, the SkyTrough™ is ideal for Fuel-Saver™ applications which is a parabolic trough solar field integrated into an existing or new fossil fuel power plant to provide thermal energy to the steam Rankine cycle. This produces the lowest cost solar electricity of any kind. Second, the SkyTrough™ is used for stand-alone solar thermal utility-scale power plants. The key benefit of the SkyTrough™ in addition to its lower cost is its modularity where it can be scaled from small applications (a few megawatt, "MW") to very large scale plants (100 MW+) as the same SkyTrough™ collector is used for all applications.

Q: How may I do business with SkyFuel™?

A: SkyFuel™ is a provider of solar field equipment for parabolic trough solar thermal projects. Our premier product is the SkyTrough™ solar collector assembly that we provide to utilities and project developers. As an equipment supplier, we also sell separately our innovative parabolic trough SkyTrakker™ control and drive system. Please contact our sales office for further information at (505) 293–1023.

Technical Performance

Q: What is the performance of a single SkyTrough™ Solar Collector Assembly?

A: The purpose of the SkyTrough™ solar collector assembly (SCA) is to collect and deliver thermal energy harnessed from the Sun, making it applicable to any system that requires thermal energy including industrial process heat and electricity generation applications. Each SCA has a design rating of 455 kW-th (defined as Gross Thermal Power/Solar Power at 1,000 W/m^2 of direct normal solar radiation and 350° C heat transfer fluid temperature). For electrical generating applications this is equivalent to154 kW-e (at 34 % net thermal-to-electric efficiency). The SCA can be configured in nearly any combination of series or parallel fluid flows which can be optimized based on each project and application.

Q: What is the thermal heat collection capacity for each SkyTrough™ Solar Collector Assembly in BTU (British Thermal Units) per hour?

A: Thermal heat collection capacity for each SkyTrough™ solar collector assembly is 1.5 million BTU's per hour. That is equivalent to each SCA generating 455 kW-thermal.

Q: What is the overall efficiency of a solar plant using SkyTrough™ technology?

A: A typical annual average net solar-to-electric efficiency is 14–15 % for a parabolic trough plant measured at an excellent solar resource area (e.g. Daggett, California) and employing wet cooling.(The peak efficiency, again wet-cooled, is approximately 22–24 %). This annual average efficiency drops to 13–14 % for dry cooling but eliminates water usage of 850 gallons for each MWh-e produced.

Q: What is the operating temperature of the heat transfer fluid achievable with the SkyTrough™?

A: The maximum operating temperature is kept at 391° Celsius (735° Fahrenheit) limited by the Therminol® VP-1 heat transfer fluid. At this temperature steam is typically delivered to the steam turbine at 370° Celsius (698° Fahrenheit) and 100 bar (1450 psi). Many applications do not require the high temperatures used in power generation, and a wide variety of heat transfer fluids exist that are suited for specific temperatures or applications.

Q: Do the parabolic trough plants have energy storage for when the Sun is interrupted or after sunset?

A: Parabolic trough plants provide thermal energy storage capability unlike photovoltaic or wind energy that currently do not incorporate any energy storage due to cost considerations. Parabolic trough plants can deliver thermal energy during periods of solar interruption due to the inherent operational nature of the heat transfer fluid system. Enough thermal energy is stored in the piping, headers and vessels to sustain typically 15–45 minutes of continued operations without sunshine. This duration can be increased at marginal cost by increasing the size of the heat transfer fluid system and corresponding solar field. At the operator's discretion, this stored thermal energy may be used to extend power production into the evening and also be used to maintain minimum heat transfer fluid temperatures on very cold nights. This stored thermal energy is further utilized to minimize the ramps in system output caused by transient interruptions in solar radiation intensity, such as passing cloud cover. This "inherent" thermal energy storage provides valuable power quality characteristics to this otherwise intermittent resource.

Q: What are the dimensions of one SkyTrough™ solar collector assembly?

A: The SkyTrough™ solar collector assembly (SCA) measures 6 meters (19.7 feet) wide by 115 meters (377 feet) long for a total net aperture area of 667 square meters (7,180 square feet). The SCA contains 8 modules with each module having more than twice the aperture area of an equivalent module at the Nevada Solar One plant (the most recently built parabolic trough plant in the United States). The larger aperture width of the

SkyTrough™ facilitates the use of a larger receiver tube, also commonly known as heat collection elements, that are 80 mm in diameter instead of 70 mm. Each SCA needs only one small drive motor (maximum ¾ horse power) to move the entire assembly to track the Sun.

Q: Do you need to clean the SkyTrough™ SCAs and if so, how?

A: The frequency of cleaning the reflectors is determined by the operations team and depends on soiling conditions, the season and power output requirements. Cleaning frequencies of the SkyTrough™ ReflecTech® Mirror Film panels do not differ from glass panels. The amount of water required to wash the reflectors is typically 12–15 gallons per MWh-e. The reflectors on the SkyTrough™ are cleaned by pressure washing with demineralized water from a vehicle equipped with spray bars such as those used for years at the Solar Electric Generating System (SEGS) power plants in California. No abrasive brushes need to be used on the mirror finish. The frequency of cleaning depends on the soiling characteristics of the site, and the value of the electricity produced by additional washing. The SEGS plants in California are generally washed once or twice a week in the summer and once a month or more in the winter.

Q: How robust are the SkyTrough™ collectors in high wind?

A: The SkyTrough™ solar collectors are designed to withstand 84 mph 3 second wind gusts and can operate in 40 mph 3 second wind gusts or 25 mph sustained wind conditions. Furthermore, as the SkyTrough™ uses unbreakable ReflecTech® mirrors made of film instead of glass, the SkyTrough™ SCAs have an added robustness. The SkyTrough™ design has been tested to failure in a controlled environment providing validation data necessary to ensure its ability to bear design wind loads that might be encountered. Furthermore, the SkyTrough™ prototype has experienced nearly design level maximum wind loads at our test facility in Arvada, Colorado, without damage or deformation. NREL and Sandia Labs have conducted wind load analysis that is publically available on the NREL website: www.nrel.gov.

Q: How will the SkyTrough™ be protected by wind, hail storms, stones, dust and pollution?

A: Parabolic trough solar fields using the SkyTrough™ require a wind fence surrounding its perimeter to protect the outer row of parabolic troughs from the highest wind conditions. This wind fence is typically made of chain link fencing with fabric covering. During severe weather events, the collector positions into the stow position (reflectors tilted downward at about 30 deg), which protects them from wind and hail. The SkyTrough™ features aluminum-backed ReflecTech® Mirror Film panels, which eliminates the risk of glass breakage common to most parabolic trough collectors using glass reflectors. Pollution and dust are no issues with regular cleaning.

Q: How far along is SkyFuel™ in the development process of the SkyTrough™?

A: SkyFuel™ deployed its first full scale prototype SkyTrough™ in fall 2008 and immediately began testing the mechanical operation of the SCA, as well as checking the SkyTrakker controls and expanding its capabilities. In March 2009 the solar collector assembly prototype was activated to collect thermal energy to produce heat and

measure performance. In 2009, several solar collector assemblies configured in a heat transfer loop will be deployed in a commercial solar system for validation in a real-world operating environment. SkyFuel™ has worked with its suppliers and independent parties such as Sandia and NREL to verify and validate the robustness and performance of the SkyTrough™ and its subsystems. SkyFuel™ is on track to install its first combined cycle power plant FuelSaver™ system in 2010.

Q: What hardware does SkyFuel™ include in the delivery of SkyTrough™ Solar Collector Assemblies (SCA)?

A: The SkyTrough™ solar collector assemblies include the following components:

1. Receiver Tubes
2. ReflecTech® Mirrors
3. Space frame (Including ribs and receiver supports)
4. Bearings
5. Ball Joints
6. SkyTrakker™ Drive and Control System
7. Collector Support Pylons

Other solar field items such as the heat transfer fluid system, concrete foundations and wind/security fence are typically designed and provided by an engineering and construction firm responsible for this balance of the solar field.

Q: How does the SkyTrough™ track the sun?

A: The SkyTrakker™ computes the sun's position and then uses this to compute the proper tracking angle of the SCA. The SCA is rotated to this angle with the hydraulic drive unit, and its position is verified with an inclinometer. Several times a minute the SCA is adjusted to keep accurate positioning.

Q: What is ReflecTech® Mirror Film?

A: ReflecTech® Mirror Film is a highly reflective, glass-free, polymer-based film for concentrating sunlight in solar energy arrays. It is commercially proven, ultra-lightweight, highly durable, and demonstrated to be stable under ultraviolet (UV) light and moisture. ReflecTech® Mirror Film comes on a roll. 1,500 square feet of mirror film comes in a box 62 inches long by 6 by 8 that weighs about 50 pounds.

Q: How long does ReflecTech® Mirror Film last?

A: ReflecTech® Mirror Film was developed to meet the 20+ year lifetime of a typical solar energy system. Test samples that have been in place for over 5 years (going on 6 years) in the extreme environment of the SEGS power plant in the Mojave Desert, and samples exposed to near 10 year equivalent accelerated testing with magnified UV and water spray show no significant loss in solar-weighted reflectance.

Cost

Q: What is an estimated cost per megawatt to build a commercial size solar plant?

A: SkyFuel is an equipment supplier and its price is competitive and confidential. However, we believe and state that the SkyTrough™ solar collector assembly is the most economically efficient system on the market. Although this might seem more expensive than fossil fuel plants, the operator can rest assured that all fuel costs are free (from the Sun) and will not be subject to future fuel price instability, volatility or availability. After the parabolic power plant has been paid off, after approximately 15 years, it has decades of additional life, when it will produce power at nearly zero cost. (SEGS plants in California have already passed the 25-year mark and are operating at full capacity and efficiency.) As the solar collector assemblies (SCAs) can often constitute close to half of the overall plant cost, additional cost savings can be achieved by using a SkyTrough™ SCA to further reduce the cost of parabolic trough solar plants.

Q: What is the cost for 5 MW power plant?

A: Power plants are economical in sizes of 100 MW or larger. This scale is not due to the solar field, but the economic size of steam power plants. Smaller solar power plants may be built as demonstration plants but would not be able to leverage the same economies of scale as large one and thus, are more expensive. For example, Arizona Public Service built a 1 MW plant for $6,000/kW as a precursor to the larger 64 MW Nevada Solar One power plant that cost $4,250/kW when commissioned in 2007 (calculation based on refinancing package). That is probably indicative of the cost range for something of the 5 MW-electric size system. However, as a FuelSaver™ retro-fit for an existing steam plant, SkyTrough™ solar fields are nearly as cost effective at 5 MW as they are at the 100 MW size.

Q: How does SkyTrough™ achieve cost savings?

A: Parabolic trough systems perform at very high efficiencies. Thus, SkyFuel™ has focused on reducing the cost, while maintaining or slightly improving efficiency, of the solar collector assembly (SCA) parts as well as the labor needed to install, operate and maintain the SCA. The design improvements of the SkyTrough™ implements recommendations from Department of Energy studies (ref. Assessment of Concentrating Solar Power Technology Cost and Performance Forecasts, Sargent and Lundy, 2005) to reduce cost by incorporating technology innovation, such as ReflecTech® mirrors, scaling up the size of the collector, designing for volume production efficiencies, and reducing installation and maintenance costs.

Q: What is the electricity cost produced from a SkyTrough™ solar power plant?

A: The SkyTrough™ solar collector assembly (SCA) will reduce the cost of the solar collector assembly comparable to but lower than the state-of-the-art parabolic trough system, the Nevada Solar One power plant, near Las Vegas, Nevada. Because the parabolic trough solar collector assembly constitutes such a large fraction of the plant cost, using SkyTrough™ SCAs can reduce the price of electricity by about 2 cents per kilowatt-hr in a typical plant.

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Schedule

Q: What is the construction schedule for a large utility scale (multi-megaWatt) plant?

A: The power plant construction schedule is determined by a number of factors but is typically 18–24 months for a large utility-scale solar thermal power plant. These factors include the size of the plant, equipment ordering lead times, permitting and environmental impact studies that can vary significantly from one site to another. The overall project schedule is best answered by the project developer. However, for a solar field using the SkyTrough™, the solar collector assemblies are modular and built with mostly unskilled labor. Therefore, the construction schedule is practically determined on the size and number of shifts that the project developer would want to hire and schedule.

Q: You say rapid field assembly—how fast can one trough be built?

A: Our system is designed for rapid field assembly based on the fewer parts that are involved as well as quick installation and assembly features incorporated into the design. Also, because it can be built on-site, no pre-manufacturing is necessary. All the hardware needed for 3 solar collector assemblies can fit in only 2 standard semi-trucks.

Q: What is the timeframe to construct a complete 5 MW "mini" FuelSaver™ system?

A: The timeframe to construct a "mini" FuelSaver™ project on an existing site that has the necessary land and permits is less than 6 months. A 5 MWe FuelSaver™ project would typically include about 32 SkyTrough™ solar collector assemblies.

Q: When will the SkyTrough™ be available for delivery?

A: SkyFuel™ is currently arranging delivery of its SkyTrough™ solar collector assemblies for FuelSaver™ applications in 2010 and utility-scale plants beginning in 2011.