STATE OF CALIFORNIA

Energy Resources Conservation
And Development Commission

In the Matter of: **Application for Certification for the Hidden Hills Solar Electric Generating System**	**Docket No. 11-AFC-2**

California Energy Commission
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ENERGY COMMISSION STAFF'S REBUTTAL TESTIMONY

In accordance with the Commission's Order, tn 69434, the Energy Commission staff files its Optional Rebuttal Testimony Related to Avian Impacts from Solar Flux, which is attached.

Dated: February 15, 2013

Respectfully submitted,

/S/

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Biological Staff Optional Rebuttal Testimony Related to Avian Impacts from Solar Flux and Applicant's Solar Flux Exposure Experiments

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Pursuant to the Presiding Member's Order of February 8, 2013, staff has prepared rebuttal testimony in response to the applicant's information on avian impacts from solar flux. This testimony addresses, but is not limited to the information presented at the public workshop on February 11, 2013, regarding solar flux experiments conducted on behalf of the applicant at its Solar Energy Development Center (SEDC) in Dimona, Israel, in July 2012. The information is described in the Applicant's Exh. 44, Responses to Data Requests Set 3, Att. DR 201, Potential for Solar Flux Impacts to Avian Species, Nov. 21, 2012. This testimony supplements and incorporates staff's Final Staff Assessment and prior rebuttal testimony filed herein.

1. **Question**: Does the experimental evidence demonstrate the existence of a safe exposure threshold at 50 kW/m^2?

   Answer: No. The exposures of specimens at flux densities in excess of 50 kW/m^2 provided evidence of clear adverse effects observable with the naked eye. This included evidence of complete carbonization of feathers as seen in photographs. This effect necessarily means that portions of the outer feathers reached a temperature of at least 400°C, the temperature necessary to carbonize keratin, the compound of which feathers are made. This carbonization is the end result of complete destruction of keratin through thermal decomposition. Carbon is what is left after all other atoms making up the protein are removed through bond scission. Furthermore, thermo-gravimetric analyses of keratin provide strong evidence of bond scission, significant changes in molecular structure, and melting at temperatures between 160°C and 400°C. Beta keratin molecules form the natural polymeric structure responsible for the feathers exceptional strength and flexibility. Changes caused by bond scission leading to denaturing of keratin molecules within the feather alone would result in destruction of cross-linking between protein strands that are central to the exceptional strength of the beta keratin molecule. Thus, these effects would cause reduction in strength, flexibility, and functional capability, and compromise the overall integrity of feathers (Wasko 2010, Cameron 2003). Consequently, even if feathers are not visibly carbonized (i.e., "singed", charred or burned), they would be damaged to the point of reduced functionality. (See Final Staff Assessment, Appendix BIO1, pp. 8-10,)

2. **Question**: Why is a flux exposure level of 50 kW/m^2 too high an exposure level to protect against adverse effects?

   Answer: The experimental results (i.e., photos of bird specimens exposed) display evidence of clear adverse effects at or above 50 kW/m^2 observable with the naked eye. This experimental evidence indicates a level of feather damage exceeding what staff considers a Lowest Observed Adverse Effect Level (LOAEL) at 50 kW/m^2.

Most birds exposed to this level of flux would be expected to suffer adverse effects. Thus, this is not a protective exposure level (i.e. a threshold).

As described above, many types of adverse effects would be expected to occur at lower temperatures (i.e. lower flux exposures). These effects could not be observed with the naked eye. This is precisely the reason that LOAELs are typically divided by an uncertainty factor of up to 10 to approximate a No Observed Adverse Effects Level (NOAEL) in establishing threshold or safe exposure criteria (U.S. EPA 2012) (Cal EPA 1993)). In fact, the Cal EPA Department of Toxic Substances Control recommends that when converting an acute LOAEL to a chronic NOAEL for vertebrates, an Uncertainty Factor (UF) of 10 be applied and when adjusting from a chronic LOAEL to a chronic NOAEL a UF of 5 be applied.

If the experimental results from exposure of about 50 kW/m^2 are divided by 10, the resultant approximate NOAEL is 5 kW/m^2 which is essentially equivalent to staff's estimated threshold based on a NOAEL derived from results of thermo gravimetric analyses that are far more sensitive, far less subjective, more accurate, and more reliable than the visual observations made during the Applicant's experiments with dead specimens exposed to discrete flux levels for short durations.

3. **Question**: Do the experimental results predict effects under plausible, realistic exposure scenarios?

   Answer: The experiments provide little data relevant to plausible, realistic exposures.

   The experimental results apply to an exposure scenario that is so implausible as to make the results irrelevant to any determination of a safe exposure threshold under actual flight conditions.

   The results essentially hypothesize an exposure where a volume of air space exists that is a uniform flux density of 50 kW/m^2 into which a bird would enter from ambient conditions. This space does not exist according to the applicant's flux density maps. This space would also be of a dimension that it would result in an elapsed time of 30 seconds to traverse at a speed of 14 meters per second (420 meters). In fact, a flux density of 50 kW/m^2 exists only along a very thin isopleth line. On one side of this line the flux density is 49 kW/m^2 and on the other side the flux density is 51 kW/m^2, and so on from ambient at the outer edge to very high levels at the facility's receiver. Unless a bird happened to precisely follow the isopleth (a very narrow line on a mapping of flux where all points on the line are at a specific intensity) line, it would encounter higher or lower exposure. Thus, staff took the approach of estimating exposure along plausible hypothetical flight paths interpolating between the isopleths provided by the applicant (See Final Staff Assessment, Appendix BIO2),

4. **Question**: Does the experiment provide clear evidence of adverse effects on flight feathers?

   Answer: Yes. The experimental evidence demonstrates that the flight feathers on the specimens exposed to flux densities at or above 50 kW/m^2 suffered nearly complete carbonization on the portions that were blackened. This was further demonstrated by the pieces of blackened feathers that had fallen off into the trays holding the specimens. Mr. Santolo, who conducted the experiments, also stated that the blackened areas were parts of the feather that readily fell off the specimens if disturbed. The evidence of near complete carbonization of parts of the feather strongly suggests that less pronounced effects, such as denaturing and melting, could have occurred before carbonization and on other areas of the feathers without becoming detectable with the naked eye.

5. **Question**: Does the design of the experiments support the conclusion that no significant adverse effect is manifest at exposure below 50 kW/m^2 rather than staff's estimated safe exposure level?

   Answer: No. The experiment's design failed to incorporate basic accepted principles of expected dose response relationships that are essential to establishing safe exposure thresholds. The experiments do not adequately reflect the expected dose response associated with dynamic radiant exposure. In this context, the dose response relationship is a product of intensity times the duration of exposure, in a dynamic flight path correlated with feather damage. Even if overt carbonization were the end point of interest, which it is not, it is clear that exposures of lower intensity would require longer duration of exposure to produce the same level of damage as heat from flux exposure would be continually lost due to convective transfer and other mechanisms. This renders all of the data collected at lower flux exposure levels on inanimate specimens exposed to a given flux level nearly meaningless, as it should not be expected that adverse effects be manifest in damage that is observable with the naked eye.

   Plausible exposure scenarios would include increased exposure as flight path progressed to higher flux densities up to 500 kW/m^2. Exposure of a bird moving in the flux field to one specific level of exposure and remaining at that exposure level for 30 seconds, similar to the exposure in the experiments is not plausible.

6. **Question**: Does staff agree with the applicant's primary conclusions drawn from its experiments at its SEDC facility (SFS Study) (see Applicant's Exh. 44, Responses to Data Requests Set 3, Att. DR 201, Potential for Solar Flux Impacts to Avian Species, Nov. 21, 2012), that no adverse effect on avian fauna occurs from solar flux exposure below 50 kW/m^2 for 30 seconds?

   Answer: No. The experiments do not provide clear evidence of the asserted threshold and, in fact, provide evidence to the contrary for several reasons.

The applicant asserts that the level of damage (as shown in, among other things, photographic evidence from the experiments) would not be sufficient to impair flight and can thus be considered evidence of a safe exposure threshold. The duration of exposure of specimens tested was in many cases less than 30 seconds. Based on typical flight speeds, birds can be expected to be exposed to flux levels above (and sometimes well above) ambient conditions for much longer than 30 seconds. The size (volume of air space) of the flux field would result in many plausible exposures far in excess of those reflected in the experiments.

The inability to control rotation of the specimens resulting from twisting of the rope from which the specimens were suspended during flux exposure allowed rotation of an unknown number of specimens' bodies. This could have caused the evidence of carbonization observed on both the front and back of at least one specimen. The result of such movement may have reduced the actual exposure to less than the experiment run time (e.g., 15 rather than 30 seconds on feathers that showed evidence of carbonization). In short, the actual duration of exposure that led to carbonization is uncertain and the results are therefore inconclusive.

The initial conditions of the experiment are unrealistic in that the specimens were at ambient temperature when lowered into the flux field at the start of exposure. It is unlikely a live bird would be capable of entering the flux field at an elevated level of exposure from ambient air space without first passing through areas of either higher or lower flux densities and then coming to equilibrium over some period of time (i.e. a transient period). Rather, the bird is likely to fly through air spaces with either higher or lower flux densities before passing through the volume of air space where exposure would be precisely at 50 kW/m^2 (to use the level asserted by the applicant as the threshold of concern), represented by an isopleth line on the applicant's flux field model map. A bird in flight would estimably be at the exact 50 kW/m^2 line for less than one second. In fact, a bird travelling perpendicular through the 50 kW/m^2 isopleth toward the receiver would reach an exposure level of 500 kW/m^2 in less than 15 seconds for the applicant's assumed flight speed of 30 miles per hour (14 meter per second, if it even survived those exposures. Under these conditions, the transient changes would be continuous and temperature rise on the feathers would be nearly instantaneous. This effectively decreases the "safe" exposure duration associated with a "safe" exposure of 50 kW/m^2 or less, which the experiment attempts to establish.

The experiments are premised on a 30 second exposure duration being the time required for a bird traveling at14 meters per second and the distance required for a bird to traverse a hypothetical air space with a constant flux density of 50 kW/m^2. Staff does not agree that such a flight pattern nor a 14 m/s flight speed (about 30 miles per hour) is plausible. To be protective of most species that could be exposed and considering the lower end of the range of flight speed that is plausible, a flight speed of 8 meters per second (about 18 miles per hour) is more appropriate to estimate potential impacts.

The experiment tests the hypothesis that a particular dose (i.e. 50 kW/m^2 for duration of 30 seconds) is the threshold at which an effect occurs on a bird. The applicant infers that a lesser exposure for a longer time would not produce an equivalent effect (i.e., 60 seconds at the lower intensity of 25 kW/m^2). However, the experiment does not address the fact that during exposure, the heat flow into and out of the bird feather caused by the flux is attempting to reach equilibrium and would change the amount of time at which effects would begin to occur.

The feathers on the specimens were not controlled for moisture content. The high latent heat of vaporization of water means that any significant variation in moisture content could significantly delay heating until the moisture is entirely removed from the feathers. No data was provided to assess potential errors, to address variability, or to specify degree of moisture content in the specimens' feathers.

7. **Question**: Would most of the plausible flight paths resulting in avian exposure be traversed in less than 30 seconds?

   Answer: No. The traverse times for the full range of potentially exposed birds exceed 30 seconds. The 30 second exposure time that the experiments postulate is calculated for a bird to traverse 420 meters at a speed of approximately 14 meters per second (30 miles per hour). This scenario does not consider the range of plausible flight speeds that occur as birds pass through the flux field.

8. **Question**: Do birds have any physiological or sensory capabilities that would allow them to sense or control the temperature rise that is occurring in their flight or tail feathers as the result of exposure to increasing radiant flux levels?

   Answer: No. The flight feathers are essentially dead tissue like human hair or nails. There is no physiological mechanism available in avian species to increase cooling on primary and tail feathers. The feathers do not have any nerves to sense the rising temperature to trigger such responses, and they do not have any muscles, blood flow, sweat glands or other mechanisms to facilitate such responses to compensate for heating. Exposed birds do not have any means of controlling temperature rise on these feather surfaces.

   The only mechanisms that would control temperatures on the surfaces of the flight feathers are convection and re-radiation as reflected in staff's analysis. These are governed by thermodynamic equilibrium where surface temperature is the result of balance between the energy entering the feather surface and the energy leaving the surface, and they remain outside the birds' ability to detect or control.

   Because heat energy moves from hotter to colder medium, the surface temperature of feathers must rise with any increase in radiant flux if factors controlling the convective heat transfer remain constant. These factors are ambient air temperature and flight speed. The temperature on the bottom surface of exposed feathers must increase with increasing radiant input in accordance with thermodynamic laws to maintain equilibrium. Thus, their temperature will be the direct result of equilibrium conditions where radiant energy input to the feathers are in balance with the energy leaving the feathers through convective and radiant heat loss. Under such conditions, an increase in radiant flux exposure will require an increase in the feather temperature to establish a new equilibrium condition on the surface of the feather. Depending on the degree and duration of exposure, this can cause destructive heating of the feathers.

9. **Question**: Did the SFS Study include exposure considerations that would allow their applicability to the diverse population of birds that may potentially be exposed to the flux field at the proposed facility?

   Answer: No. The experiment did not include plausible conditions that would allow applicability of the results to the entire population of potentially exposed birds at all reasonable conditions. In addition to all the reasons stated above, the specimens were larger, or a different kind and different coloration than the ones likely to be exposed. The specimens were pigeons, quail and domesticated chickens.

10. **Question**: Does the provided thermocouple and infrared data from the SFS Study support the conclusions in the report?

    Answer: No, for several reasons:

    The reported data (Data Response Set 3, Hidden Hills Solar Electric Generating System (11-AFC-2) is not representative of the effects of exposure on the test birds. The times reported for thermocouple temperatures ignored the entire exposure interval of interest, i.e. the time period of the highest temperatures that occurred during the flux exposure. All reported data was taken from the first 5 seconds of exposure, though the exposure was typically 30 seconds-long, and therefore did not indicate what highest temperatures were later reached during the exposure, and thus in no way could represent or explain the extent of damage that occurred to the birds. The temperatures reported in the SFS report systematically under-reported the actual temperatures recorded by the thermocouples.

    Numbers reported in the report tables for some specimens do not appear anywhere in the logger data for those samples, and appear to have no valid source. In spite of temperatures logged by the under-skin thermocouple on two of the specimens reaching 160 °C, the SFS report summary includes the statement “temperatures recorded beneath the feathers...did not indicate that any feather temperatures during the test approached 160 °C, a temperature that may cause structural and molecular changes in keratin” (Response to Data Set 3, p. 14). The report further offers no explanation of how approximately half of the test specimens had their feathers damaged to the extent of being singed by the solar flux exposures.

    Data taken during test runs in which there were un-responsive thermocouples (for possible reasons such as no or poor electrical connections, broken wires, excessive electrical noise, or a non-functioning data logger) were incorrectly included in the statistical analyses supporting the report's conclusions. Such incorrect data points should have been flagged as incorrect and removed from all evaluations with those test runs then being marked as "having no thermocouple temperature data." These data introduced bias into the results.

On several test runs, either the thermocouple leads were switched or mislabeled, so that the data as obtained and labeled represents a physical impossibility, e.g. internal temperature rising faster and higher than the under-skin temperature. Yet that data was also incorrectly kept in the analysis. One correlation of thermocouple-recorded internal temperature indicates that the quail internal temperatures actually decrease with increasing flux exposure intensity while all the other species showed increasing temperatures, yet no discussion of how this could occur was included in the report.

By design, even if all the thermocouples had worked reliably, they were not positioned to measure temperatures that would be meaningful to the question being addressed by the experiment which was, "Do feathers singe from exposure to concentrated solar flux?" Still, the data was reported in two reports with purported statistical significance measurements on a data set that included the incorrect data.

There is no correlation between the temperature data and the photographic evidence that birds' plumage was damaged by exposure to the flux. Further, the SFS report offered no explanation of how its reported temperatures (none higher than 95.6 °C on the feathers), fail to explain or account for feather burning damage indicating feather temperatures exceeding 300 °C, on approximately half of 36 the test specimens.

In spite of the problems described above, the experiment report states that the thermocouples "generally performed well." The report author acknowledged several of these problems with the temperature measurements at the workshop of February 11, 2013 on the Solar Flux Study, and stated there that the conclusions in his report in no way relied upon any of the recorded temperature data.

Accordingly, the data do not support any change to Staff's testimony.

References

Cal EPA 1993 – Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities, Part A: Overview, State of California Environmental Protection Agency, Department of Toxic Substances Control, Human and Ecological Risk Division, July 4, 1996 (See Page 22).

Cameron 2003 – Cameron GJ, Wess TJ, Bonser RHC, Young's Modulus Varies with Differential Orientation of Keratin in Feathers, Journal of Structural Biology 142 (2003) pp.118 - 123

U.S. EPA 2012 – Reference Dose (RfD): Description and Use in Health Risk Assessment, Background Document 1A, March 15 1993, Integrated Risk Information System (IRIS), Last updated on Wednesday, September 26, 2012 (See page 5, Table 1).

Wasco 2010 – Biochemistry and Structure-Function Relationships in the Proteinaceous Egg Capsules of *Busyocotypus Canaliculatus*, pages 12 and 14, UMI Dissertation Publishing, Copyright 2010 ProQuest LLC 789 East Eisenhower Parkway P.O. Box 1346 Ann Arbor, Mi 48106-1346.

11. **Question**: Has staff reviewed the information presented, and if so, how does it impact staff's assessment of potential impacts to avian fauna from solar flux?

Answer: Yes, however due to flaws in the experiments' design and analysis of the data, the results have not changed our analysis for several reasons.

The birds used for the study, chickens, pigeon, and quail, are not representative of avian species occurring at the arid HHSEGS site. The SFS study suggests that adverse effects correlate negatively with size, stating "Of the test subjects exposed to flux levels greater than 50kw/m2, 1 of the 7 chickens, 2 of the 8 pigeons, and 6 of the 7 quail showed muscle effects" (page 12). In general, the smaller the bird, or any object is, the faster it will heat up, consistent with the prior statement. Staff believes that had the SFS used smaller birds like or such as those expected at the HHSEGS site, adverse effects may have been noted at lower levels of concentrated flux.

During staff's February 11, 2013 workshop on the experiments, staff learned that only specimens that showed visible singeing were selected for tissue examination. If internal damage was present in the absence of external damage, this study approach would not have been able to detect it.

12. **Question**: The SFS studied relied on digital (by hand) manipulation as evidence of microscopic structure integrity. How does this method of examination impact the conclusions that may be drawn from the experiments?

Answer: The structures in question—barbs and barbules—are microscopic structures. Digital manipulation to test the integrity of feathers is too coarse of a method to examine such miniature features and would not detect structural damage to the keratin comprising the feathers, which gives them their mechanical properties. These examinations do not support any more than gross conclusions about the greatest extent of damage to birds from flux exposure, and does not support any conclusion about invisible yet still serious effects.

13. **Question**: At the workshop, staff was afforded a brief opportunity to review photographs of birds exposed to various levels of solar flux. Did the photos support the conclusions made in the SFS report and applicant's testimony?

Answer: No. The SFS relies upon the unscientific metric of "singeing" to describe all observed effects. However, the specimens often were photographed with their wings folded under them so that this portion of their bodies couldn't be inspected from the photos, and were of a resolution that did not allow staff to completely verify SFS analysis; additionally, some photo sets were incomplete (i.e., some lacked before and after exposure, front and back) for several specimens. Staging the specimens with outstretched wings would have been the best way to display and photodocument results and support the SFS conclusions. Moreover, staff believes that the characterization of the damage was subjective and incomplete in that it described what appeared to be many varying degrees of damage with a single "singeing" descriptor without elaboration.

14. **Question**: Were the data from the experiments properly statistically analyzed?

Answer: There were actually several competing factors in the analysis, such as flux density, bird color, bird species, and the fact that some of the bird specimens may have rotated during flux exposure. All of these variables factor into the ultimate impact that concentrated flux will have on a bird. These competing factors were not well controlled in the experiments, and to examine the effects of these factors on flux impacts, they should have been tested individually, not at the same time (using single regression).

15. **Question**: The applicant has posited that birds will be able dissipate heat loads from exposure to solar flux. Is this information accurate?

Answer: No. There are no published studies of live birds (or for that matter studies by which data from deceased birds have been used), nor is there any evidence presented by the experiments in question to suggest that any bird species would be able to thermoregulate – that is, to expel body heat sufficient to maintain internal body temperature below their critical thermal maximum, the temperature at which death occurs - in situations of flux exposure above the normal range of conditions to which they are subjected and to which they have evolved and adapted. For the reasons explained in great detail below, birds will begin to experience abnormal levels of heat stress as soon as they enter a region that adds energy to their body systems that approaches the upper end of their normal operating core temperature range and certainly when that temperature exceeds their critical thermal maximum, both of which would be experienced soon after entering a region of elevated solar flux.

When the skin temperature is higher than the core body temperature, heat conduction will be from the skin into the core, raising its temperature. Once the core temperature rises, metabolic heat transfer mechanisms get triggered and would normally carry excess core body heat to the skin for dumping to the air, will actually operate in reverse. In essence, blood flow will bring heat from the heated-to-above-core-temperature skin, into the body core, causing the core temperature to rise at an even faster rate, rather than to drop. In this way, the natural and automatic response of mechanisms that would normally help the bird to lose heat, instead rapidly increase its distress. The situation that concentrated solar flux places the bird in, is simply not anticipated by its natural response mechanisms.

Temperature Regulation

On the matter of temperature exchange and heat loss, birds have numerous mechanisms by which to conserve or to dissipate heat. These mechanisms may be physical or chemical, controlled by the autonomic nervous system or subject to "conscious" control (for example, the decision to fly from a potential predator), and may differ (or simple be better or less well-developed) from species to species.

Heat (temperature) is regulated and maintained within the body core and brain as needed by means of several systems. Those thermoregulatory functions that are not under conscious control are regulated chiefly by the hypothalamus. Changes in the circulatory system that help regulate core body temperature, primarily vasodilation (increasing the diameter of the blood vessels) and vasoconstriction (reducing the diameter of the blood vessels) are not under "conscious" control; thus, the "appropriate" reactions to hot and cold ambient temperatures occur automatically in response to one stimulus or its opposite. An increase in ambient temperature results in vasodilation while a decrease in body temperature results in vasoconstriction.

Within the normal or average range of ambient temperatures (referred to as the thermoneutral zone), these reactions may be limited in scope and enhanced or augmented by other mechanisms; for example, changes in feather positioning. However, when ambient temperatures fall below the thermoneutral zone (approaching the bird's lower critical temperature or LCT), heat production must increase and/or heat loss must decrease. Above the other end of the thermoneutral zone (upper critical temperature or UCT), heat loss must increase. At this point, even when other systems may become engaged (e.g., panting, open-mouth breathing, etc.) changes to the circulatory system are maximally put into play, uncontrollably.

Cold Response

In cold weather birds conserve heat in many ways, again including changes to the circulatory system, feather positioning, and assorted behaviors. Of particular importance is their use of the circulatory system, especially to the extremities (feet, legs, bill, etc.), which is either or both reduced or eliminated as needed. This is so effective that in arctic-dwelling diving ducks, temperature of the feet may actually drop below 32 °F/0 °C. - below the freezing temperature of water at sea level - with impunity. The simplest model (e.g., of a bird's foot) is to think of a central core occupied by one large artery (outgoing blood flow) that is surrounded by a network of smaller veins (return flow to the body core) - this network is generally referred to as a rete mirabile. By reducing the diameter of the arterioles and capillaries, a gradient is established virtually eliminating heat loss to the extremities. In some species (e.g., those diving ducks) these leg vessels may be shut entirely.

Heat Response

In hot weather as you might expect excess heat is dissipated by variations of these same systems; that is, by changes to the circulatory system, feather positioning, and assorted behaviors. As opposed to what happens in cold conditions, the circulatory system operates in reverse. That is, the circulatory system channels internal heat outward and as expected from basic physical laws, specifically, heat is dissipated from areas of high(er) temperatures to areas of low(er) temperature. With the system in this operating mode, elevated temperatures of, for example, a bird's feather, legs, or bill would be channeled inward, not outward. Some behaviors, especially flight, may help to reduce the internal heat load by removing surface (including buccal (aka the mouth cavity) surface) heat, but flight itself places great stress on heat exchange systems of birds due to the metabolic heat produced as a by-product of the consequent energy expenditure. (Note: birds, although more efficient that man-made machines, are only about 25% efficient at maximum in converting energy to power, thus 75% or more is produced as heat energy.)

Metabolic Contribution of Flight

Birds also have limits as to how fast they are able to fly and when flying at their fastest (a feat rarely achieved), they may do so for very short periods of time; for example, a rock pigeon flying at its fastest rate can maintain that speed for perhaps up to 10 minutes only. In other words, a bird in flight must be able to address ambient conditions (in this example, ambient or surrounding temperatures) but also the elevated heat load resulting from increased level of metabolic heat production. When operating within the thermoneutral zone, birds can accommodate and control both sources of heat energy, ambient and metabolic. Once the core body temperature exceeds the thermoneutral zone, they become stressed; their response is typically of two patterns, to stop flying (and if possible, seek shade or in some species water if available) or to suffer the equivalent of heat stroke. This level of stress may occur under normal conditions, for example, when flying fast in relatively hot conditions (See, for example, Tucker 1968). Desert birds, rather than fly about in the mid-day sun, which would be extraordinarily stressful when summer temperatures peak, seek shady refugia. Desert birds that are active in mid-day, (e.g., turkey vultures, Cathartes aura and white-throated swifts, Aeronautes saxatalis) typically glide or soar rather than fly. Birds simply do not do well in extreme heat; that is, extreme heating (here, from elevated solar flux) in context with some of the hottest weather conditions that occur naturally on Earth.

In other words, if such a bird, near its limit of thermal stress, or even one not so stressed, is exposed to a concentrated solar flux capable of heating its skin to a temperature that is higher that the bird's core body temperature (say 43 °C), heat diffusion will begin to flow from the higher temperature skin into the lower temperature body core, raising the core's temperature. When the core temperature begins to rise sufficiently, metabolic heat transfer mechanisms (such as increased blood flow under the skin) get triggered that normally would carry excess core body heat to the skin for shedding to the air. In this situation however, where the skin is being externally heated, these mechanisms, once triggered by elevated core temperature, will actually operate in reverse. The increased blood flow will bring heat from the heated-to-above-core-temperature skin, into the body's core, causing the core temperature to rise at an even faster rate than before triggering. In this way, the natural and automatic response of mechanisms that would normally help the bird to lose heat and cope with high ambient temperatures, will instead facilitate a rapid increase the bird's thermal distress. The situation that concentrated solar flux places the bird in, is simply not anticipated by its natural response mechanisms to thermal stress.

Metabolic heat significantly increases when birds are in flight, and avian species have developed several behavioral and physiological heat dissipation methods to cool body temperatures. Pigeons in flight, for example, can rapidly cool by exposing their head, neck, and buccal cavity (opening the mouth) to wind (St-Laurent and Larochelle, 1994). Starlings (Sturnus vulgaris) manage heat during flight by exposing their legs, head, and ventral brachial areas (under wings) for convection cooling purposes (Ward et al., 1999). Pigeons have been documented to fly at 12 meters per second (Biesel and Nachtigall, 1987) and starlings at 10 to 14 meters per second (Ward et al., 1999), speeds that allow for rapid heat transfers from a bird's body to the surrounding environment. Certain migratory species have developed unique molecular mechanisms that are known to rapidly dissipate heat during flight (i.e., eight times the rate of heat dissipation during sustained flight as at rest; Clementi et al., 1991). Live birds exposed to solar flux would be able to dissipate heat much more effectively than the deceased test subjects used for this study.

Nevertheless, the report fails to clearly establish any link between this general statement describing avian adaptation and the level of heat energy that would be experienced within the flux field of the proposed solar electric generating facility. Neither empirical data nor peer-reviewed publications are provided to substantiate this claim in context with the project.

The Ward et al (1999a) study cited in the report's literature section was conducted under the following laboratory conditions: "The mean Ts [surface temperature of the birds that were studied] of each section of the body was measured by thermography during four flights by each bird at 10.2±0.3ms-1 at air temperatures (Ta) between 15 and 25 °C [59 and 77 °F] to examine the effects of Ta upon Ts." Study specimens were not subjected to elevated levels of heat or other form of radiation; in fact these conditions approximate those expected at the proposed Hidden Hills site on an average day in winter. This reference and its assertions are irrelevant to the study and have no relevance to the project.

Ward et al (2004) also studied other facets of European starlings, specifically metabolic power as estimated from heat transfer, studies that were conducted under similar laboratory conditions to previous work with starlings. In this study, in contradiction to the report's assertion regarding efficient heat dissipation, this study found that "Radiative heat transfer decreased with increasing air temperature (Ta)" (p. 4294) and this in spite of the many of the documented behavioral and physical adaptations mentioned above.

The report states: "Certain migratory species have developed unique molecular mechanisms that are known to rapidly dissipate heat during flight ([i.e.], eight times the rate of heat dissipation during sustained flight as at rest; Clementi et al., 1991) (p. 15)." However, the Clementi study does not prove this assumption; but rather it simply asserts it and investigates one of the many pathways in which the phenomenon might be achieved. Specifically, the Clementi study investigates differences in hemoglobin molecules and their oxygen-carrying capacities in two species – the rock pigeon (*Columba livia*) and the common moorhen (*Gallinula chloropus*) – specifically during normal sustained flight. The study in no way supports this contention of an 8-fold rate of heat dissipation but only investigates a possible mechanism by which it might occur.

The Tucker study (1968), another of the many physiological investigations into avian physiology conducted under normal conditions for the species involved, found that the experimental data "…indicate that at temperatures near 20 °C, flying birds lose about 15% of their heat production through evaporative water loss." The contention that the heat production of flying birds is dissipated primarily by evaporation (Salt & Zeuthen 1960; Eliassen, 1963) is not supported. However, at 36-37 °C, the evaporative water loss of budgerigars [aka parakeets, *Melopsittacus undulatus*] increases by a factor of 3:1 until it accounts for almost 50% of the estimated heat production in flight.

"Problems of overheating probably prevent budgerigars from making long flights during many midday hours in their natural environment. Budgerigars in the wind tunnel at 37 °C became overheated and would not fly for as long as 20 minutes. Shade temperatures over much of Australia exceed 37 °C daily in the summer, and a flying bird would receive an additional heat load from solar radiation" (p. 84).

The Tucker study presents data that support our contention that birds will begin to experience abnormal levels of heat stress as soon as they enter a region that adds energy to their body systems that approaches the upper end of their normal operating core temperature range and certainly when that temperature exceeds their critical thermal maximum, both of which would be experienced soon after entering a region of elevated solar flux. A bird in flight near its thermal maximum can tolerate little additional stress (especially in the form of added heat). Thermal maxima for most bird species is around 42 °C and may be as high as 47 °C in only a few species.

16. **Question**: The SFS report contends that flux exposure periods (which ranged from 10 to 60 seconds) are longer than the exposure periods a bird would experience flying through the HHSEGS site. Is this accurate?

Answer: The SFS severely underestimates the volume of potentially harmful levels of flux as well as the distance through which a bird passing through the area might experience elevated levels of flux. The report in no way provides evidence that "live birds for the most part would traverse these areas more rapidly than the exposure periods used in the study" (p. 15). There are no data to support this assertion and the study did not address this issue anywhere in its experimental design or testing.

More importantly, there is no mention of migrants or migration, the description of which does not match any of the activity scenarios presented in this cursory discussion (i.e., "to move to a foraging or nesting area, display to attract a mate, protect their territory, forage, or for some other defined activity" (p. 15)). The purpose and essence of bird flight during migration is quite unlike the description presented herein and is highly variable, and may include lingering (e.g., in many raptor species), focused direct flight (i.e., to simply get from one location to another, or foraging; for example, swallows and swifts taking advantage of insect blooms or insect concentrations of other origin or purpose). Importantly, migrants would be the potentially most likely to be affected assemblage of birds that would pass through the general area of the facility (and thus, regions of generated solar flux), and which would not pass with any single behavior or purpose. Moreover, migrants would not have an experience-based response (as would, perhaps, a local population for which those individuals that make a "bad choice" would be quickly eliminated from the population and) when and if encountering a region of elevated flux. It is not possible, however, to predict with any certainty responses of any one bird much less to their populations overall.

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APPLICATION FOR CERTIFICATION FOR THE HIDDEN HILLS SOLAR ELECTRIC GENERATING SYSTEM

Docket No. 11-AFC-02

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DECLARATION OF SERVICE

I, Chester Hong, declare that on February 15, 2013, I served and filed copies of the attached Energy Commission Staff's Rebuttal Testimony, dated February 15, 2013. This document is accompanied by the most recent Proof of Service, which I copied from the web page for this project at: http://www.energy.ca.gov/sitingcases/hiddenhills/.

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I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct, and that I am over the age of 18 years.

Dated: February 15, 2013 /S/

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