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November 21, 2012

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Mike Monasmith, Project Manager (11-AFC-2)
Pierre Martinez, Project Manager (11-AFC-04)
Systems Assessment & Facility Siting Division
California Energy Commission
1516 Ninth Street, MS-15
Sacramento, CA 95814

Subject: Data Response, Set 3
Hidden Hills Solar Electric Generating System (11-AFC-2)
Rio Mesa Solar Electric Generating Facility (11-AFC-04)

Dear Mr. Monasmith and Mr. Martinez:

On behalf of Hidden Hills Solar I, LLC and Hidden Hills Solar II, LLC, and Rio Mesa Solar I, LLC and Rio Mesa Solar II, LLC (collectively, the "Applicants"), please find attached copies of Data Response Set 3.

Please call me if you have any questions.

Sincerely,

CH2M HILL

John L. Carrier, J.D.
Program Manager

Encl.

c: POS List
Project file

Technical Area: Biological Resources and Heat Flux Author: Carol Watson, Rick Tyler

BACKGROUND

At a joint Hidden Hills (11-AFC-2) and Rio Mesa (11-AFC-3) staff workshop on August 28, 2012, Bright Source Energy (BSE) presented information regarding activities conducted by Gary Santolo at a BSE facility (SEDC) in the Negev Desert of Israel. Mr. Santolo's information formed the basis of several assertions made by BSE at the workshop regarding the potential for impacts associated with avian exposure to concentrated radiant flux levels that would exist at the proposed facility. Staff needs documentation of the activities at SEDC to evaluate its relevance and applicability to the potential for impacts resulting from potential avian exposure to concentrated solar flux. Please note that materials considered proprietary should be docketed with a Confidentiality Request.

DATA REQUESTS

199. What was the intent of Mr. Santolo's activities at the SEDC facility?

Response: As presented by Mr. Santolo at the August 28, 2012 joint HHSEGS and RMS workshop, the avian/solar flux interaction study was conducted in response to questions asked by Staff regarding flux, and whether there were potential impacts to avian species from flux.

The study specifically addressed the following question, "What is the concentration of solar flux below which no observable effects on birds would be expected?" This information is available in Slide 26 of the presentation made by Mr. Santolo at the August 28, 2012 workshop ("August 28th Presentation"), which is available at:
http://www.energy.ca.gov/sitingcases/hiddenhills/documents/2012-08-28_joint_workshop/Applicant_Submitted_Power_Point_Presentation_for_082812_Joint_Workshop.pdf.

200. Did Mr. Santolo have direction provided to him under a contract or purchase order? If so, please provide a document that lays out the direction that BSE provided to him.

Response: Please see Attachment DR201, the Santolo Report, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

201. Did BSE or Mr. Santolo develop a methodology or procedure for the activities to be conducted at the SEDC facility? If so, please provide a copy.

Response: The methodology for the avian/solar flux interaction study was presented and explained by Mr. Santolo at the August 28, 2012 joint workshop. Information regarding the methods are available at Slides 27-28 and the assumptions for the study at Slide 29 of the August 28th Presentation.

Please also see Attachment DR201, which includes information regarding the methodology and the testing procedures for Mr. Santolo's study.

202. Was a final report or summary prepared for Mr. Santolo's activities at SEDC?

Response: The Santolo Report is provided as Attachment DR201. Mr. Santolo's avian/solar flux interaction study at the SEDC facility was also summarized and presented at the August 28th workshop, which included a description of the results and conclusions drawn from the study. Data from the study are available at Slides 31-34, results are available at Slides 35-36, and conclusions are available at Slide 39.

In addition, generally for this Data Response and its multiple subparts, please also see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

a. Please provide copies of the draft and final reports submitted to BSE.

Response: Please see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

b. Please provide the basis for the experimental design and the objectives of the experiment, including results of preliminary literature review (if conducted).

Response: These issues were discussed at the August 21, 2012 joint HHSEGS RMS workshop, were referenced in the August 28th Presentation, and are also addressed in the response to Data Request 199. Please also see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

c. Were any parts of the report confidential? If so, when will these sections be submitted under confidential cover to the Energy Commission?

Response: The information the Applicant intends to rely upon is public and presented in the final report, Attachment DR201.

d. Please provide all photographs of the exposed birds prior to and after each exposure regimen.

Response: Please see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

e. If no photos of the birds were taken, please provide notes or other documentation to describe in detail the color of the singed portion of the feathers and the distance from the feather edge and the point where no singeing had occurred.

Response: Please see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

f. Please provide a description of the method of measuring the duration of exposure and its accuracy.

Response: These issues were discussed at the August 28, 2012 joint HHSEGS RMS workshop, and are referenced in the August 28th Presentation. Please also see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

g. Was any testing stopped during the tests? If, so, can we get the aborted test results?

Response: No testing was stopped during the tests. Please also see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

h. Please provide a detailed description of the method and equipment used to measure the level of radiant flux exposure and its accuracy.

Response: These issues were discussed at the August 28, 2012 joint HHSEGS RMS workshop. Please also see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

i. Please provide a detailed description of the method and equipment used for measuring temperatures and its accuracy.

Response: These issues were discussed at the August 28, 2012 joint HHSEGS RMS workshop. Information on the method and equipment used for measuring temperature was presented in the August

28th Presentation at Slide 28. Please also see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

j. Were any measurements made of surface temperatures on the flight feathers? If so please describe the method used and its accuracy.

Response: These issues were discussed at the August 28, 2012 joint HHSEGS RMS workshop. As stated above, information regarding the method for measuring temperatures was presented on Slide 28 of the August 28th Presentation. Temperature data is presented in Slides 31 and 32 of the August 28th Presentation. Please also see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

k. Was the morphology of the feathers analyzed post exposure to determine if the feather's properties (insulation, air resistance, shape, etc) were altered during exposure to the concentrated solar radiation?

Response: Please see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

l. Please describe the method used to obtain the birds used in the study and the duration and method of storage between their death and the experiment.

Response: These issues were discussed at the August 28, 2012 joint HHSEGS RMS workshop. Please also see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

m. What were the temperatures of the bird samples at the start of, during, and end of their flux exposure?

Response: These issues were discussed at the August 28, 2012 joint HHSEGS RMS workshop. Please also see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

n. How long did the entire experiment take? How was the exposure intensity recalibrated and maintained constant?

Response: Please see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

o. Was the moisture content of the feathers measured or otherwise controlled? If so what was feather moisture content immediately prior to the experiment?

Response: No, moisture content of feathers was not measured. Please also see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

p. Was any microscopic analysis of the feathers conducted? If so, please provide photographs or describe in detail the observations?

Response: No microscopic analysis of the feathers was conducted. Please also see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

q. Other than naked eye visualization, was there any evaluation of the damage to integrity of flight-readiness of the feathers after exposure?

Response: These issues were discussed at the August 28, 2012 joint HHSEGS RMS workshop. In addition, please see Attachment DR201 for a description of the detailed observations, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

r. What where the environmental conditions at the time of the experiment: time of day, ambient temperature, humidity, wind speed, size of the uniform flux region and the intensity uniformity of the staging area where the birds were exposed?

Response: Please see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

s. Please provide all raw data collected for each exposure regimen.

Response: Please see Attachment DR201, in addition to Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations.

203. Has BSE conducted, or does BSE plan to conduct, any other tests, experiments and/or evaluations of the BSE-power tower design, or similar non-BSE power tower design with regard to heat flux or concentrated solar radiation?

Response: The Applicant reserves the right to conduct additional testing. To the extent the Applicant conducts such tests and determines they are relevant to any decision this Commission must make in this proceeding, the Applicant will inform the Commission of the testing conducted and the results thereof.

204. Is BSE aware of other studies, experiments or publications on the topic of the power tower technology and concentrated solar radiation?

Response: Yes. The Applicant has in prior Data Responses identified academic studies and reports from operational power tower facilities relevant to flux and avian issues. In addition, other studies and reports have been identified in the application for certification proceeding for the Rio Mesa Solar Electric Generating Facility (11-AFC-3). The academic studies and reports are identified in the following data responses:

- Hidden Hills Solar Response to CEC Data Request 29, November 2011;
- Hidden Hills Solar Response to CEC Data Request 57, November 2011;
- Rio Mesa Solar Response to CEC Data Requests 143 through 144, February 2012 (ocular issues);
- Rio Mesa Solar Response to CEC Data Requests 145 through 147, February 2012;
- Rio Mesa Risk Characterization Report to CEC, February 2012;
- Hidden Hills Solar Response to CEC Data Requests 161 through 171, April 2012;
- Rio Mesa Solar Response to CEC Data Requests 55 and 57, May 2012; and
- Rio Mesa Solar Response to CEC Data Request 159, July 2012.

In addition, please see the following academic studies and reports from operational power tower facilities relevant to flux and avian issues[1]:

[1] Docketed and placed on the Commission's website as part of the information exchange meeting that occurred on November 1, 2012 and served on November 19, 2012, TN-68293(1).

- Labinger, Zev, *Assessment of Potential Impacts to Birds from a Solar Thermal Power Plant, Dimona, Israel* (Interim Report, Spring Survey 2012);
- Pleguezuelos, Juan M., *Report: Environmental Impact of the GemaSolar Thermsolar Plant on the Bird Community in the Monclova Surrounding Area (Fuentes de Andalucía, Seville, Spain)* (Aug. 23, 2012);
- Pleguezuelos, Dr. Juan M. & Feriche, Dr. Monica, *Impact of the GEMASOLAR Solar Power Plant (La Monclova, Fuentes de Andalucía, Province of Seville) on the Bird Population- Report 4 (September 2010): Nesting avifauna in the study area during the plant construction phase (March-July 2009-2010)* (Sept. 10, 2010); and
- Pleguezuelos, Dr. Juan M. & Feriche, Dr. Monica, *Impact of the GEMASOLAR Solar Power Plant (La Monclova, Fuentes de Andalucía, Province of Seville) on the Bird Population- Report 5 (February 2012): Nesting Avifauna during the Final Plant Construction Phase (March-July 2011) and the First Operating Phase (August- December 2011)* (Feb. 2012).

BACKGROUND

In response to Rio Mesa Data Request #159, Bright Source Energy (applicant for both the 11-AFC-2 and 11-AFC-3 proceedings) provided depictions of the concentrated solar flux field that would exist around each solar tower. The information provided was derived using a model that predicts how the solar field concentrates the ambient solar radiant energy from the heliostats to the receiver on the central tower. Staff needs access to the model to evaluate its relevance and applicability to the potential for impacts resulting from potential avian exposure to concentrated solar flux. Please note that materials considered proprietary should be docketed with a Confidentiality Request. 205.

205. Please provide a functional electronic copy of the models used to produce the data and the flux isopleths figures in response to Rio Mesa data request #159.

Response: Please see the Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations. However, Applicant is willing to work with Staff to discuss alternative ways of satisfying Staff's information needs.

206. Please provide all documentation and manuals necessary to operate the model.

Response: Please see the Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations. However, Applicant is willing to work with Staff to discuss alternative ways of satisfying Staff's information needs.

207. Please provide a copy of all model inputs used to derive the figures provided in response to Rio Mesa data request #159.

Response: Please see the Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations. However, Applicant is willing to work with Staff to discuss alternative ways of satisfying Staff's information needs.

208. If necessary, please provide those portions under confidential cover to ensure the complete models and assumptions are provided.

Response: Please see the Applicant's Notice filed pursuant to Section 1716 of the Commission's regulations. However, Applicant is willing to work with Staff to discuss alternative ways of satisfying Staff's information needs.

Attachment DR201

Hidden Hills Solar Electric Generating System (HHSEGS)

(11-AFC-2)

Potential for Solar Flux Impacts to Avian Species

Submitted to the

California Energy Commission

Submitted by

Hidden Hills Solar I, LLC; and Hidden Hills Solar II, LLC

November 21, 2012

With Assistance from

CH2MHILL

2485 Natomas Park Drive
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Contents

Introduction

BrightSource Energy, Inc. (BSE) has proposed to construct and operate renewable solar energy generation facilities. BSE is one of several renewable energy companies that have developed solar distributed power tower (DPT) technology to produce renewable electricity. In general, DPT facilities focus multiple mirrored heliostats arrayed around a central tower on an energy receiver located at the top of the tower. Heat created by reflected sunlight within the solar energy receiver is used to produce steam that drives electrical generation turbines. DPT facilities are able to generate a more stable power supply over more extended periods compared with other renewable energy technologies. Renewable energy facilities that use DPT technologies have been proposed throughout the United States, Europe and other locations.

Federal and most state laws require that potential impacts associated with energy projects, including renewable and DPT plants, be evaluated prior to issuing final construction and operational approvals. As the number of renewable energy projects has grown in response to national and state clean, low-carbon emission electricity objectives, potential impacts to avian species associated with wind, photovoltaic, DPT and other technologies has emerged as a significant regulatory concern. A 1986 study (McCrary et al., 1986) of a tower plant located in California reached the overall conclusion that the impacts on the local bird population were "considered minimal." (*Id*., p. 140.)

DPT technology is known to produce solar flux that increases in intensity up to the location of the energy receiver on the central tower. Solar flux is the latent energy potential produced by a series of heliostats focusing solar reflections on the central power receiver and is typically measured in terms of kilowatts per square meter (kW/m^2). Flux associated with a DPT facility does not generate significant heat in unoccupied airspace, but generates energy that could be absorbed by solid objects that enter areas of elevated flux. At sea level along the equator, solar flux levels are approximately 1 kW/m^2. Solar flux levels are clustered around and increase with proximity to the power receiver at the top of the central tower.

The purpose of this report is to present the results of avian testing at an existing DPT facility. It is designed to develop empirical and physical information for assessing solar flux risks to avian species. As described below, a series of tests were performed in July 2012 at the SEDC facility under controlled conditions to further characterize flux-related avian impacts potentially associated with DPT facilities.

Methods

Overview

The SEDC is located in Dimona, Israel in the southern Negev desert and near a major avian migration flyway in the African-Syrian Rift Valley. The facility is operated by BrightSource Industries (Israel) (BSII), an affiliate of BSE, and uses the same technology that would be implemented at projects located in the United States. SEDC is a research facility that includes approximately 1,600 heliostats and is used to analyze and optimize DPT technology. As such, BSII has developed substantial information about the performance and flux characteristics of the facility, and the heliostat field can be adjusted to focus specific levels of solar flux on the central tower and on a calibration screen located below and in front of the boiler and condenser units on the tower.

The test protocol was designed to quantify the effects of varying solar flux levels on a representative range of species by suspending fully feathered (unplucked) deceased domestic chickens (*Gallo gallo*), rock pigeons (*Columba livia*), and coturnix (Japanese) quail (*Coturnix japonica*) in front of the calibration screen under specific flux conditions. Chickens and quail were purchased and pigeons were obtained from a pest bird-removal company. Birds were obtained throughout the study and were kept offsite until they were used for the study. Two methods were used for euthanasia of the birds prior to testing: 1) thoracic (cardiopulmonary, cardiac) compression; and 2) a carbon-dioxide chamber in which the heavier-than-air carbon dioxide was used to replace available oxygen. These methods are suggested by the American Veterinary Medical Association (AVMA) for euthanasia of research animals. Thoracic compression is commonly used in the field and carbon-dioxide is the method commonly used for euthanasia of laboratory animals. The advantages of thoracic compression cited by the AVMA are that the technique is rapid, apparently painless, and it maximizes carcass use for analytical/contaminant studies. The advantages of carbon-dioxide is that it is readily available at welding supply centers, is relatively safe to use, and suppresses an animal's ability to experience pain prior to death (AVMA, 2007).

The test subjects represent a range of larger (domestic chicken), medium (rock pigeon), and small (coturnix quail) avian body weights and varied feather coloring. Each test subject was mounted in a flying position (wings extended) on a system of cords and lowered to the front of the calibration unit where specific levels of flux were maintained by adjusting the heliostat array. After the first six rounds of testing, a calibrated flux measurement instrument was used to further assess flux levels at the screen. Each test subject was exposed to the flux for approximately 10, 20, 30, or, in one test, 60 seconds (Table 1), removed from the flux field, and carefully examined for evidence of singeing, burning, feather damage, or internal muscle or tissue effects. Internal and surface temperatures of the test subjects were measured before and after each test and recorded on data sheets. In addition, internal and under-skin mounted thermocouples took measurements at 1-second intervals during the tests.

As discussed below, excluding reference tests, 12 domestic chickens (13 tests), 12 rock pigeons, and 12 coturnix quail were analyzed at the SEDC. None of the test subjects exhibited evidence of singeing, burning, feather damage, or internal muscle or tissue effects from exposure to flux levels ranging from about 8.3 to 50 kW/m^2 for up to 60 seconds. Certain physical effects were observed in test subjects exposed to flux levels above 50 kW/m^2 for 20 or 30 seconds. Thus, this is considered a conservative effect threshold because unlike the dead test subjects, live birds are able to efficiently dissipate heat and shift position relative to the direction of energy sources such as solar flux. Live birds would also be likely to traverse the small areas of higher flux in a facility's airspace much more rapidly than the exposure periods used in the study.

General Testing Procedure

The tests were conducted using fully feathered (unplucked) dead coturnix quail, rock pigeons, and domestic chickens to represent various size classes of birds that have been documented to occur at the HHSEGS and RMS sites. Each subject was tested at ambient body temperature and was not chilled or frozen prior to testing. If a bird was stored (i.e., refrigerated) prior to use, it was allowed to warm to near ambient air temperature before testing. Each test subject was positioned as much as possible in a flying position with wings spread using wire or heat-resistant cord to hold the wings and tail in place. Once mounted, the test subjects were lowered from a balcony above the calibration screen to the center of the screen for a pre-determined amount of time.

Thermocouples (Lascar EL-USB-TC with K-type 10-cm probe [range -200 to +1350˚C], 1 sample/second) were placed by way of the throat (at least 10 cm), into the stomach of each subject to measure internal temperatures. In the quail the K-type probe went the entire length of the bird from mouth to tail. Thermocouples (Lascar EL-USB-TC with J-type probe [range -130 to 900˚C], 1 sample/second) were placed under the skin on the back, just below the base of the neck of each subject, to measure temperature beneath the feathers (the "under-skin" thermocouples). Data loggers were contained in a 15 cm piece of 7.6-cm PVC pipe wrapped in aluminum foil to prevent overheating. An equipment container was attached below each mounted subject. Each test round included the exposure and examination of one domestic chicken, rock pigeon, and coturnix quail test subject. Temperatures recorded on the data loggers were downloaded after each test round. Internal and external temperatures during the exposure period were recorded on the data loggers to assess potential effects of flux exposures during the time period that would be associated with brief, live bird movements over a solar facility.

Internal temperatures were also directly measured using an internal thermometer (iDevices Inc. [range 0 to 204˚C]) and feather surface temperatures were directly measured using an infrared thermometer (Supco LIT11TC set at 0.95 emissivity [range -60 to 500˚C]) before and immediately after each test.

Preformatted data sheets were used to collect and record the following information for each reference and subject test:

- Date and time of day;
- Unique identification code;
- Ambient temperature, wind speed, and amount of cloud cover;
- Test subject species;
- Plumage color of the test subject;
- Test subject (weight [g], total length [mm], and wing chord [mm];
- Level of flux encountered in each test;
- Duration of exposure (in seconds);
- Internal temperature prior to test (in ˚C);
- Internal temperature after test (in ˚C).
- External temperature prior to test (in ˚C) measured with an infrared thermometer;
- External temperature after test (in ˚C) measured with an infrared thermometer;
- Visual observations.

Relative humidity (%) was acquired from the weather station at SEDC after the testing was completed. The condition of each test subject's feathers and other external body parts were examined and evidence of damage to feathers, if applicable, was recorded. Most test subjects with post-exposure internal temperatures above 55˚C or those that exhibited visual feather or other surficial effects were dissected to determine if major muscles (i.e., breast and thigh) or internal organs were affected.

After each test, the subjects were tagged with a unique identification code and date. For example, a quail used in the first calibration screen test would be identified as test subject QU-CS-01.

Reference Test

To provide a reference baseline, one test subject from each test species was exposed to solar flux under ambient air conditions for one minute. Internal and external temperatures for the reference subjects were recorded in accordance with the general testing procedure described above.

Calibration Screen Test

The calibration screen located below and in front of the boiler and condenser units on the SEDC tower was used to calibrate the heliostat field to produce specific flux levels. The heliostats were calibrated at the center of the calibration screen. A standard and calibrated flux measuring instrument (Vatell Corp., TGH2000-0 Thermogage Circular Foil Heat Flux Transducer) was used to further document test flux levels after the first six test rounds were completed.

The test subjects were lowered from the balcony above into the center of the calibration screen, using wire or heat-resistant rope. The subjects were exposed to solar flux levels ranging from 8.3 to 78.3 kW/m^2 for periods of 10 to 60 seconds. The condition of feathers and internal and external temperatures before, after, and during each test were documented for each test subject. The condition of internal tissues and muscles of selected subjects was documented after testing was completed. Each test was conducted once on each species and each subject was used for only one test.[1]

Statistical Analysis Approach

Simple linear regression was used to analyze potential relationships between solar flux levels, internal and external temperatures, and test subject weight. The statistical analyses were conducted using StatView software (SAS Institute, 1998).

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[1] One test subject, a domestic chicken identified as CH-CS-09, was tested twice. It was first exposed for 18 seconds at 39.1 kW/m^2 in what was intended to be a 10-second test. There were no external effects observed, and after approximately 30 minutes CH-CS-09 was tested again at 40 kW/m^2 for 10 seconds to determine if a repeated exposure would have an effect. No effects were observed..

Results

Domestic Chicken (*Gallo gallo)*

The weight of the domestic chickens used in the study ranged from 1250 to 1800 grams. Four subjects had black plumage, one had light brown plumage, and eight had white plumage. No solar flux effects were observed on the reference subject or any test subject exposed to flux levels from 9.1 to 48.7 kW/m^2 for 10 to 60 seconds. Subjects with black plumage feathers displayed evidence of singeing when exposed to solar flux levels of 55.2 to 77.9 kW/m^2 for 20 or 30 seconds. Two subjects with white plumage showed no effects when exposed to solar flux levels of 60.9 and 77.9 kW/m^2 for 20 and 30 seconds and one subject displayed evidence of light breast feather singeing from exposure to a flux level of 77.9 kW/m^2 over 20 seconds (see Table 1). Feather damage was limited to areas that were visually identified as being singed. Singed feathers were discolored, brittle, inflexible, and tended to break easily back to the point where singeing was observed.

No muscle or internal organ effects were observed in any of the test subjects at any flux exposure level. One subject, CH-CS-04, displayed evidence of discolored and thickened skin beneath the breast feathers when exposed to a flux level of 77.9 kW/m^2 over 30 seconds.

Internal body temperatures measured immediately before and after each test increased by 0˚C (CH-CS-04, 05, 08, 10, 11) to 3˚C (CH-CS-01) and were not significantly associated with solar flux levels ($r^2 =0.14, F_{1, 11} =1.4, P = 0.259$). External temperatures measured immediately before and after each test using an infrared thermometer increased from 2.5˚C (CH-CS-12 increased from 33.1˚ to 35.6˚C) to 52.1˚C (CH-CS-04 increased from 28.8˚ to 80.9˚C). All but one test subject, CH-CS-04, displayed external temperature increases ranging from 2.5 to 18.2˚C. The relationship between external temperature changes and exposure to solar flux levels was approaching significance ($r^2 =0.31, F_{1, 12} =4.6, P = 0.058$).

TABLE 1.
Domestic Chicken (*Gallo gallo)* Summary Test Results, July 2012.

ID	Flux Level kW/m^2	Color	Weight (g)	Test time (sec)	Relative Humidity (%)	Ambient Temp (˚C)	Wind (m/sec)	Feather Effects	Muscle/Tissue Effects	Int-1/Int-2 (˚C)[a]	Int-Temp Change (˚C)	IR Therm. Ext-1/Ext-2 (˚C)[b]	IR Therm Ext Temp Change (˚C)
CH-REF	-	White	1450	60	25.3	32.7	<1			22/23	1	26.7/30.6	3.9
CH-CS-12	9.1	White	1700	30	37.1	34.7	4.0			28/29	1	33.1/35.6	2.5
CH-CS-01	15.8	Brown	1650	60	28.8	31.0	2.2			17/20	3	24.9/37.3	12.4
CH-CS-11	33.5	White	1425	30	45.6	33.5	1.1			34/34	0	31.9/37.9	6
CH-CS-09	39.1	White	1500	18	12.5	38.3	1.8			33/32	-1	36.3/46.1	9.8
CH-CS-09a	40.0	White	1500	10	12.5	39.1	3.9			33/34	1	34.3/43.0	8.7
CH-CS-08	48.7	White	1350	20	12.5	39.4	1.7			34/34	0	36.3/49.1	12.8

TABLE 1.

Domestic Chicken (*Gallo gallo)* Summary Test Results, July 2012.

ID	Flux Level kW/m²	Color	Weight (g)	Test time (sec)	Relative Humidity (%)	Ambient Temp (˚C)	Wind (m/sec)	Feather Effects	Muscle/Tissue Effects	Int-1/Int-2 (˚C)[a]	Int-Temp Change (˚C)	IR Therm. Ext-1/Ext-2 (˚C)[b]	IR Therm Ext Temp Change (˚C)
CH-CS-03	55.2	Black	1600	30	17.0	35.2	1.0	X		21/22	1	34.0/46.7	12.7
CH-CS-06	56.4	Black	1400	30	14.7	31.7	3.0	X		30/31	1	30.1/48.3	18.2
CH-CS-10	60.9	White	1250	30	52.9	31.1	0.9			36/36	0	31.6/45.8	14.2
CH-CS-02	77.9	Black	1400	30	22.6	33.4	5.8	X		-/-		28.3/40	11.7
CH-CS-04	77.9	Black	1800	30	16.4	31.5	1.9	X		37/37	0	28.8/80.9	52.1
CH-CS-05	77.9	White	1800	20	14.6	34.6	1.4	X		35/35	0	35.0/48.8	13.8
CH-CS-07	78.3	White	1800	20	14.4	33.5	0.0			35/36	1	30.5/47.8	17.3

[a] Int-1 = Internal temperature before exposure/Int-2 Internal temperature after exposure.

[b] Ext-1 = Surface feather temperature before exposure/Ext-2 Surface feather temperature 15 to 30 seconds after exposure taken with infrared thermometer.

Temperature changes measured by the internal and under-skin thermocouples did not significantly vary in accordance with the level of solar flux exposure. Internal temperature increases measured by the thermocouples ranged from 0.0 to 2.5˚C for all test subjects. The under-skin temperatures varied -0.5 to 3.0 ˚C for all but one test subject, which increased by 12.5˚C (see Table 2).

TABLE 2.

Internal and Under-skin Thermocouple Temperature Test Results During the First 5 Seconds of Exposure for Domestic Chickens (*Gallo gallo)*, July 2012.

				Internal Temperatures ˚C				Under-Skin Temperatures ˚C			
ID	Flux Level kW/m²	Color	Weight (g)	0 sec	3 sec	5 sec	Total Change	0 sec	3 sec	5 sec	Total Change
CH-REF	-	White	1450	32.5	32.5	32.5	**0.0**	25.5	25.5	25.5	**0.0**
CH-CS-12	9.1	White	1700	34.0	34.0	34.0	**0.0**	35.0	35.0	35.0	**0.0**
CH-CS-01[2]	15.8	Brown	1650	-	-	-	**-**	-	-	-	**-**
CH-CS-11	33.5	White	1425	29.0	29.0	29.0	**0.0**	33.3	33.3	33.3	**0.0**
CH-CS-09	39.1	White	1500	37.0	37.5	38.5	**1.5**	38.0	39.5	41.0	**3.0**

2 Thermocouples and data loggers were not available for the first test and methods of exposing the subjects and taking other measurements were identified during this test.

TABLE 2.
Internal and Under-skin Thermocouple Temperature Test Results During the First 5 Seconds of Exposure for Domestic Chickens (*Gallo gallo)*, July 2012.

				Internal Temperatures ˚C				Under-Skin Temperatures ˚C			
ID	**Flux Level kW/m²**	**Color**	**Weight (g)**	**0 sec**	**3 sec**	**5 sec**	**Total Change**	**0 sec**	**3 sec**	**5 sec**	**Total Change**
CH-CS-09a	40	White	1500	37.0	37.5	38.5	**1.5**	38.0	39.5	41.0	**3.0**
CH-CS-08	48.7	White	1350	34.0	34.0	34.0	**0.0**	34.5	35.0	35.0	**0.5**
CH-CS-03	55.2	Black	1600	29.0	29.5	29.5	**0.5**	22.5	22.5	23.0	**0.5**
CH-CS-06	56.4	Black	1400	32.0	32.5	32.5	**0.5**	30.0	30.0	29.5	**-0.5**
CH-CS-10	60.9	White	1250	34.5	34.5	34.5	**0.0**	35.2	35.2	35.2	**0.0**
CH-CS-02	77.9	Black	1400	29.0	29.5	31.5	**2.5**	22.5	23.0	23.0	**0.5**
CH-CS-04	77.9	Black	1800	30.5	31.0	31.0	**0.5**	35.5	36.0	36.0	**0.5**
CH-CS-05	77.9	White	1800	33.5	34.0	34.0	**0.5**	39.0	43.0	51.5	**12.5**
CH-CS-07	78.3	White	1800	33.0	33.5	33.5	**0.5**	35.5	36.5	37.5	**2.0**

Rock Pigeon (*Columba livia*)

The weight of the rock pigeons used in the study ranged from 170 to 290 grams. Two of the test subjects had pied (dark gray and white) plumage and 11 had gray plumage. No solar flux effects were observed on the reference subject or any test subject exposed to flux levels from 8.3 to 50.4 kW/m^2 for 10 or 30 seconds. Test subject feathers were singed when exposed to solar flux levels of 50.4 to 77.9 kW/m^2 for 20 or 30 seconds and pigeon feathers appeared to be more sensitive to higher flux exposures than feathers of other species. This was most pronounced along the flanks and back to the base of the tail. Two of the eight test subjects exposed to flux levels of 50.4 to 77.9 kW/m^2 for 20 or 30 seconds displayed evidence of tissue denaturing (see Table 3). Feather damage was limited to areas that were visually identified as being singed. Singed feathers were discolored, brittle, inflexible, and tended to break easily back to the point where singeing was observed.

Internal temperatures measured immediately before and after each test increased by 0˚C (PI-CS-02, 07, 08, 10, 12 to 3˚C (PI-CS-03 and 05) and were not significantly associated with solar flux levels ($r^2 = 0.02$, $F_{1, 12} = 0.2$, $P = 0.663$). External temperatures measured immediately before and after each test using an infrared thermometer increased by 3.2˚C (PI-CS-01) to 59.1˚C (PI-CS-07) and averaged approximately 25˚C. External temperature measurements were significantly related to the level of solar flux exposure ($r^2 = 0.61$, $F_{1, 12} = 15.6$, $P = 0.003$).

TABLE 3.
Rock Pigeon (*Columba livia)* Summary Test Results, July 2012.

ID	Flux Level kW/m^2	Color	Weight (g)	Test time (sec)	Ambient Temp (˚C)	Relative Humidity (%)	Wind (m/sec)	Feather Effects?	Muscle/Tissue Effects?	Int-1/Int-2 (˚C)[a]	Int-Temp Change (˚C)	IR Therm. Ext-1/Ext-2 (˚C)[b]	IR Therm Ext Temp Change (˚C)
PI-REF	-	Gray	235	60	32.6	27.3	<1			21/22	1	24.8/34.6	10.2
PI-CS-12	8.3	Gray	270	30	34.7	37.1	4.6			31/31	0	34.1/41.4	7.3
PI-CS-01	15.8	Pied	210	30	31.0	45.6	7.4			16/17	1	31.0/34.2	3.2
PI-CS-11	34.8	Pied	240	30	33.8	45.6	3.0			27/28	1	33.8/45.6	11.8
PI-CS-09	40.4	Gray	270	10	38.8	12.5	2.9			30/31	1	36.0/53.8	17.8
PI-CS-08	50.4	Gray	205	20	38.1	12.5	2.0	X		33/33	0	35.3/57.8	22.5
PI-CS-03	55.2	Gray	215	30	36.5	17.0	2.7	X		28/31	3	29.8/69.8	40.0
PI-CS-10	56.1	Gray	250	30	32.1	52.9	0.5	X		31/31	0	30.3/54.8	24.5
PI-CS-06	56.4	Gray	290	30	34.8	14.7	3.2	X		28/30	2	33.5/76.4	42.9
PI-CS-07	77.4	Gray	170	20	36.5	14.4	0.7	X	X	33/33	0	33.9/93	59.1
PI-CS-02	77.9	Gray	220	30	34.0	20.4	6.4	X	X	34/34	0	31.8/55.0	23.2
PI-CS-04	77.9	Gray	205	30	33.3	16.4	1.5	X		35/34	-1	31.8/66.6	34.8
PI-CS-05	77.9	Gray	280	20	35.2	14.6	2.4	X		33/36	3	37.9/56.0	18.1

[a] Int-1 = Internal temperature before exposure/Int-2 Internal temperature after exposure.

[b] Ext-1 = Surface feather temperature before exposure/Ext-2 Surface feather temperature 15 to 30 seconds after exposure taken with infrared thermometer.

Temperature changes measured by the internal and under-skin thermocouples did not significantly vary in accordance with the level of solar flux exposure. Internal temperature increases measured by the thermocouples ranged from 0 to 1.5˚C for all test subjects. Under-skin temperatures increased by 0 to 1.5˚C, except for two subjects where a temperature decline of -2 ˚C and an increase of 30.5˚C were recorded (see Table 4).

TABLE 4.
Internal and Under-skin Thermocouple Temperature Test Results for Rock Pigeon (*Columba livia)* During the First 5 Seconds of Exposure, July 2012.

				Internal Temperatures ˚C				Under-Skin			
ID	**Flux Level kW/m²**	**Color**	**Weight (g)**	**0 sec**	**3 sec**	**5 sec**	**Total Change**	**0 sec**	**3 sec**	**5 sec**	**Total Change**
PI-REF	-	Gray	235	22.0	22.0	22.0	**0.0**	30.5	30.5	30.5	**0.0**
PI-CS-12	8.3	Gray	270	34.0	34.0	34.0	**0.0**	33.0	33.5	31.0	**-2.0**
PI-CS-01[3]	15.8	Pied	210	-	-	-	**-**	-	-	-	**-**
PI-CS-11	34.8	Pied	240	28.5	29.0	29.0	**0.5**	34.0	34.5	34.5	**0.5**
PI-CS-09	40.4	Gray	270	32.5	33.0	33.5	**1.0**	32.5	32.5	33.0	**0.5**
PI-CS-08	50.4	Gray	205	-	-	-	**-**	36.5	37.0	37.5	**1.0**
PI-CS-03	55.2	Gray	215	28.5	28.5	28.5	**0.0**	30.5	31.0	31.5	**1.0**
PI-CS-10	56.1	Gray	250	30.5	31.0	32.0	**1.5**	29.5	30.0	30.5	**1.0**
PI-CS-06	56.4	Gray	290	28.5	28.5	28.5	**0.0**	35.5	36.5	37.0	**1.5**
PI-CS-07	77.4	Gray	170	33.0	33.5	33.5	**0.5**	36.5	48.0	67.0	**30.5**
PI-CS-02	77.9	Gray	220	34.5	34.5	34.5	**0.0**	35.5	36.5	37.0	**1.5**
PI-CS-04	77.9	Gray	205	35.5	36.5	37.0	**1.5**	35.0	35.0	35.0	**0.0**
PI-CS-05	77.9	Gray	280	35.5	36.5	37.0	**1.5**	36.5	36.5	36.5	**0.0**

Coturnix (Japanese) Quail (*Coturnix japonica*)

The weight of the coturnix (Japanese) quail used in the study ranged from 35 to 50 grams. All test subjects had brown plumage. No solar flux effects were observed on any test subject exposed to flux levels ranging from 11.3 to 47.4 kW/m^2 for 10, 20, or 30 seconds. Six of seven test subjects displayed evidence of feather singeing when exposed to solar flux levels of 53.0 to 77.9 kW/m^2 for 20 or 30 seconds. Subjects with singed feathers also displayed evidence of denaturing of breast, thigh, or leg muscles. No effects to internal organs were observed (see Table 5). Feather damage was limited to areas that were visually identified as being singed. Singed feathers were discolored, brittle, inflexible, and tended to break easily back to the point where singeing was observed.

Internal temperature measured immediately before and after each test increased by 2˚C (QU-CS-01) to 13˚C (QU-CS-04) for the test subjects. Internal temperature increases were not significantly associated with the level of solar flux exposure ($r^2 = 0.26$, $F_{1, 12} = 3.5$, $P = 0.092$). External temperatures measured immediately before and after each test using an infrared thermometer increased from 3.8˚C (QU-CS-01) to 16˚C (QU-CS-02). External temperature changes were significantly related to the level of solar flux exposure ($r^2 = 0.45$, $F_{1, 12} = 8.2$, $P = 0.017$).

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[3] Thermocouples and data loggers were not available for the first test and methods of exposing the subjects and taking other measurements were identified during this test.

TABLE 5.

Coturnix (Japanese) Quail (*Coturnix japonica*) Summary Test Results, July 2012.

ID	Flux Level kW/m²	Color	Weight (g)	Test time (sec)	Ambient Temp (˚C)	Relative Humidity (%)	Wind (m/sec)	Feather Effects?	Muscle/Tissue Effects?	Int-1/Int-2 (˚C)[a]	Int-Temp Change (˚C)	IR Therm. Ext-1/Ext-2 (˚C)[b]	IR Therm Ext Temp Change (˚C)
QU-REF	-	Brown	45	60	30.6	27.3	<1			25/25	0	23.4/28.9	5.5
QU-CS-12	11.3	Brown	45	30	35.1	37.1	4.0			29/32	3	32.8/42.8	10.0
QU-CS-01	15.8	Brown	35	30	31.0	28.8	2.2			31/33	2	32.1/35.9	3.8
QU-CS-11	33.0	Brown	45	30	34.4	45.6	2.6			32/36	4	33.2/38.3	5.1
QU-CS-09	40.4	Brown	55	10	38.9	12.5	2.8			30/33	3	36.1/41.8	5.7
QU-CS-08	47.4	Brown	35	20	38.3	12.5	5.3			36/39	3	36.6/45.9	9.3
QU-CS-10	53.0	Brown	40	30	32.0	52.9	3.6	X	X	30/36	6	30.6/44.7	14.1
QU-CS-03	55.2	Brown	45	30	36.7	17.8	4.7			33/36	3	33.2/45.8	12.6
QU-CS-06	56.4	Brown	50	30	35.9	14.7	4.2	X	X	34/42	8	34.9/47.5	12.6
QU-CS-07	72.6	Brown	40	20	37.7	14.4	1.5	X	X	36/39	3	38.1/51.0	12.9
QU-CS-02	77.9	Brown	45	30	33.8	20.4	3.2	X	X	36/39	3	31.0/47	16.0
QU-CS-04	77.9	Brown	20	30	33.3	16.4	0.3	X	X	32/45	13	32.8/41.9	9.1
QU-CS-05	77.9	Brown	40	20	35.6	14.4	0.6	X	X	41/48	7	36.6/49.5	12.9

[a] Int-1 = Internal temperature before exposure/Int-2 Internal temperature after exposure.

[b] Ext-1 = Surface feather temperature before exposure/Ext-2 Surface feather temperature 15 to 30 seconds after exposure taken with infrared thermometer.

Temperature changes measured by the internal and under-skin thermocouples did not significantly vary in accordance with the level of solar flux exposure. Internal temperature increases measured by the thermocouples ranged from 0-5˚C for all test subjects (see Table 6). Under-skin temperatures increased by 0-2˚C except for two subjects for which temperature increases of 5.5˚ and 7˚C were recorded (see Table 6).

TABLE 6.
Internal and Under-skin Thermocouple Temperature Test Results for Coturnix (Japanese) Quail (*Coturnix japonica*) during the First 5 Seconds of Exposure, July 2012.

				Internal				Under-Skin			
ID	**Flux Level kW/m²**	**Color**	**Weight (g)**	**0 sec**	**3 sec**	**5 sec**	**Total Change**	**0 sec**	**3 sec**	**5 sec**	**Total Change**
QU-REF	-	Brown	45	25.0	25.0	25.0	**0.0**	25.0	25.0	25.0	**0.0**
QU-CS-12	11.3	Brown	45	-	-	-	**-**	30.0	30.0	30.0	**0.0**
QU-CS-01	15.8	Brown	35	-	-	-	**-**	-	-	-	**-**
QU-CS-11	33.0	Brown	45	33.5	33.5	34.0	**0.5**	34.0	34.0	35.5	**1.5**
QU-CS-09	40.4	Brown	55	35.5	36.5	37.0	**1.5**	33.5	34.5	35.0	**1.5**
QU-CS-08	47.4	Brown	35	36.0	36.5	36.5	**0.5**	36.5	37.5	38.5	**2.0**
QU-CS-10	53.0	Brown	40	31.5	31.5	31.5	**0.0**	31.0	31.0	31.0	**0.0**
QU-CS-03	55.2	Brown	45	35.5	36.0	36.5	**1.0**	35.5	36.5	37.0	**1.5**
QU-CS-06	56.4	Brown	50	35.0	36.5	37.5	**2.5**	43.5	46.0	49.0	**5.5**
QU-CS-07	72.6	Brown	40	36.0	36.5	36.5	**0.5**	36.5	37.5	38.5	**2.0**
QU-CS-02	77.9	Brown	45	36.5	38.0	39.0	**2.5**	-	-	-	**-**
QU-CS-04	77.9	Brown	20	34.5	37.0	39.5	**5.0**	33.5	34.5	34.5	**1.0**
QU-CS-05	77.9	Brown	40	43.5	44.0	44.5	**1.0**	44.0	47.5	51.0	**7.0**
QU-REF	-	Brown	45	25.0	25.0	25.0	**0.0**	25.0	25.0	25.0	**0.0**

Body Weight and Temperature Changes

Body weight and internal temperature changes associated with exposure to solar flux levels were negatively related (as weight decreased, measured internal temperatures increased) for the test subjects ($r^2 = 0.19, F_{1, 34} = 7.7, P = 0.009$). No significant relationship between external temperature change and body weight was observed for any of the test subjects ($r^2 = 0.01, F_{1, 35} = 0.3, P = 0.595$).

Feather Effects

For each bird tested, feathers were visually and digitally examined by feeling, flexing and “unzipping” and “zipping” the hooklets to identify effects such as dryness, brittleness, and whether the integrity of the feather was compromised (e.g., feathers were checked to determine if the hooklets on the barbules were functioning properly). None of these effects were found in birds that were not singed. Singed feathers were dry and brittle and no longer had functioning hooklets.

Summary and Discussion

No observable effects on feathers or tissue were found in test birds where solar flux was below 50 kW/m^2 with exposure times of up to 30 seconds. Specifically, none of the test subjects in the three weight categories examined for this study exhibited evidence of external or internal effects from exposure to solar flux levels up to 50.4 kW/m^2 over 10 to 30 seconds. Three test subjects exposed to solar flux levels ranging from 50.4 kW/m^2 to 78.3 kW/m^2 for 10 to 30 seconds also exhibited no evidence of external or internal effects. Nineteen of 22 test subjects exposed to solar flux levels ranging from 50.4 kW/m^2 to 78.3 kW/m^2 over 20 to 30 seconds exhibited evidence of singed feathers, and 8 of the 19 subjects displayed evidence of muscle or tissue denaturing. Of the test subjects exposed to flux levels greater than 50 kW/m^2, 1 of the 7 chickens, 2 of the 8 pigeons, and 6 of the 7 quail showed muscle effects.

Although there is some variability in the thermocouple temperature measurements, the thermocouples generally performed well. The thermocouple itself cannot be exposed directly to the solar flux and must be placed beneath the skin, behind the feathers to obtain valid measurements. Avian skin does not have layers that contain fat and glands like mammalian skin so avian skin should have a minimal effect on thermocouple measurements. Consequently, the thermocouples do not directly measure the feather surface during exposure. Because solar flux is directional, the greatest exposure is perpendicular to the heliostats. The external under-skin measurement may have varied depending on the angle that the thermocouple area was in relation to the heliostats. A thermocouple could measure a decrease in temperature if it is positioned at a great angle relative to the flux direction and cooled by a breeze. In addition, it appears that solar flux did not significantly affect internal test subject temperatures. The length of the K-type thermocouple used for internal measurements may have measured a close-to-surface temperature in some of the quail test subjects due to their small size.

External temperatures of the test subjects had a linear and positive relationship with the solar flux level (Figure 1). Above 50 kW/m^2, the external temperature of pigeons increased more than was observed in quail or chickens. Pigeon feathers exposed to solar flux above 50 kW/m^2 also appeared to be affected to a greater extent than was observed in the other species.

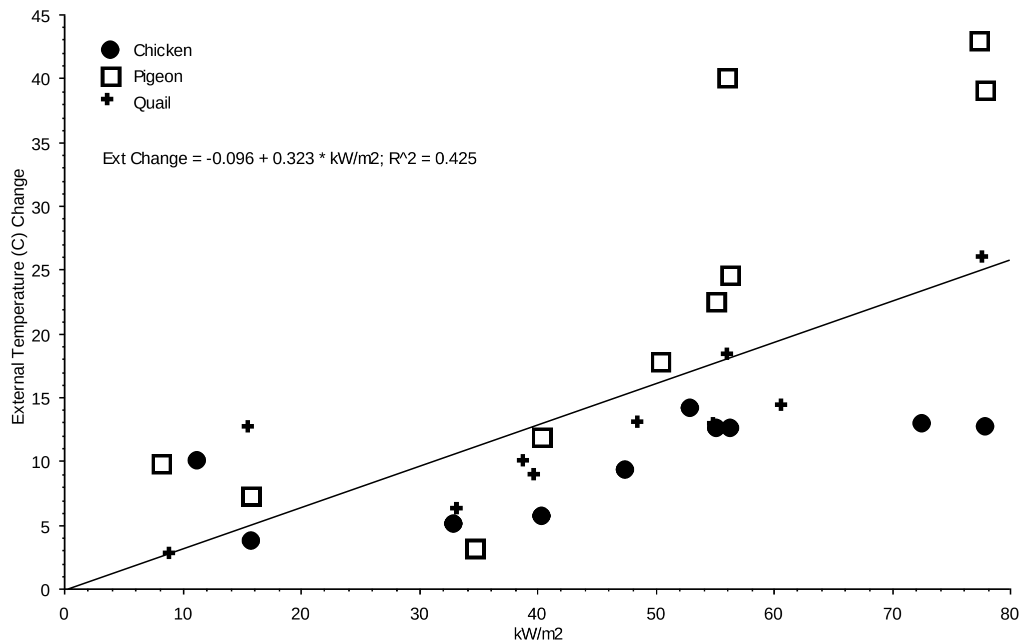

Figure 1. The measured external change in temperature at each solar flux level tested split by species.

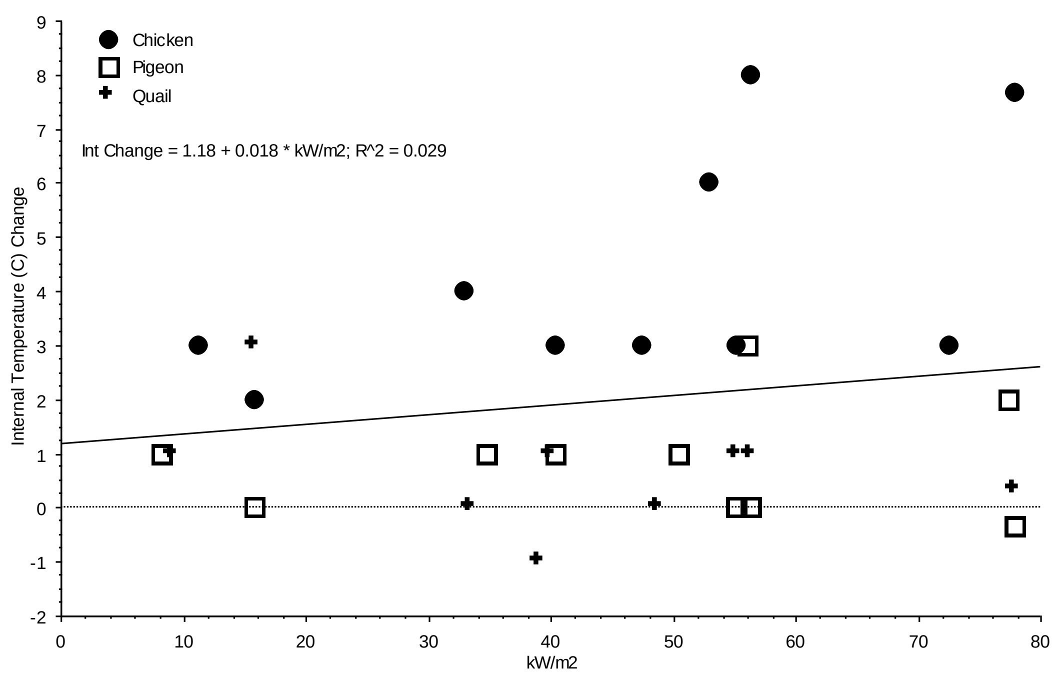

Figure 2. The measured internal change in temperature at each solar flux level tested split by species.

The test results indicate that solar flux may be more likely to affect subjects with darker, less reflective plumage. Of the seven domestic chickens exposed to solar flux levels above 50 kW/m^2 for 10, 20 or 30 seconds, for example, all subjects with black plumage displayed evidence of feather effects compared with one of three subjects with white plumage.

The pigeon test subjects also appeared to display more pronounced evidence of feather singeing and higher external and under-skin temperatures when exposed to solar flux above 50 kW/m^2 than other test species. This result could be related to the fact that the separation of pigeon feather tracts (pterylae) is less well-defined and denser than in domestic chickens or coturnix quail and more of a pigeon's body is covered with feathers (Lucas and Stettenheim, 1972a). Pigeon feathers are also surrounded by powder grains that are not fragments of the feather sheath or the feather but are derived from cells that surround the growing feather (Lucas and Stettenheim, 1972b). Pigeon test subject singeing was observed in areas along the sides of the trunk to the base of the tail, and anterior to the thigh and anterolateral to the tail where powder feathers are located (Lucas and Stettenheim, 1972a). External and under-skin temperatures were generally higher in pigeons than in the other birds tested and it is possible that the presence of powder feathers affected pigeon subject responses to solar flux.

Internal temperature changes and muscle or tissue effects were observed to a greater extent in the smaller coturnix quail test subjects. Muscle or tissue effects were observed in only one domestic chicken and two pigeon test subjects. These results indicate that solar flux does not heat efficiently or quickly and does not penetrate the feathers very well. Also larger birds may have a greater ability to store heat due to their larger body mass.

The heating did not appear to be uniform in birds and feathers that were singed. In many cases, barbules, hooklets, and texture all appeared to be normal even in locations directly adjacent to observed singed areas. While the temperature of feathers during the tests could not be measured directly with the available instruments (i.e. thermocouples and infrared thermometers) temperatures recorded beneath the feathers and the external measure of feather temperatures, which was generally taken about 15 to 30 seconds after exposure using an infrared thermometer, did not indicate that any feather temperatures during the tests approached 160˚C, a temperature that may cause structural and molecular changes in keratin (Takahashi et al., 2004).

In some cases, infrared measurements of feather surface temperatures taken immediately before and after exposure were apparently subject to potential external factors. An external feather temperature of 80.9˚C, for example, was recorded using an infrared thermometer for one chicken (CH-CS-04), a result that was nearly twice as high as other chickens exposed to similar levels of solar flux. The under-skin thermocouple for the same test subject reached a maximum temperature of 36˚C, a level that does not support the infrared measurement. The under-feather thermocouples were mounted in a fixed position on the test subjects, and the external measurements were made over the entire surface of the subjects to identify the highest temperatures generated by the exposure. The external measurements were made as quickly as possible after exposure and while the subjects were mounted on the test platforms. It is possible that heat from the mounting equipment might have interfered with the measurement recorded for CH-CS-04 or in certain other instances.

As discussed above, the testing protocol used deceased subjects with no capacity to actively dissipate heat or react to flux-related thermal effects. The highest wind gust was recorded during each test and wind speeds during the tests were generally low and similar (Tables 1, 3, and 5), with the highest gust recorded at 5.8 meters/second and were not informative of the effect on convective cooling. The test observations associated with deceased subject exposures held static for continuous periods of approximately 10 to 30 seconds are unlikely to be representative of exposure times for live birds for several reasons.

First, live birds are known to efficiently dissipate substantial levels of body heat. 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.

Birds in flight also would change position relative to directional energy sources such as solar flux. These movements would reduce the extent to which specific groups of feathers or other portions of a bird's body would be continuously exposed to flux. A bird in flight, flapping and banking to maneuver, would be unlikely to have prolonged exposure to the direction of the solar flux. The test subjects did not have the capacity to shift position in this manner and so were likely being exposed to the elevated flux levels longer than a free-living bird would be exposed at any one time. In addition, none of the flux levels caused instantaneous singeing and if a bird feels uncomfortable or threatened it would have time to move away from the source of the threat. Even though the flux can't be seen, moving in almost any direction would reduce the solar flux exposure because a bird attempting to move away from the uncomfortable heat by changing direction would change its angle to the heliostat and reduce the flux in some areas and possibly increase it in other areas. A bird flying towards higher flux would likely change direction if it felt increasing heat and decrease its exposure to the solar flux. Even if it flew into a higher flux area, the angle of the exposure would likely change so the same feathers would not continue to have the same exposure.

Finally, live birds for the most part would traverse these areas more rapidly than the exposure periods used in the study. Even when a bird is soaring over a small area, it is doing this with a purpose. Birds fly to move to a foraging or nesting area, display to attract a mate, protect their territory, forage, or for some other defined activity and are not likely to linger in the areas of elevated solar flux without some reason. Elevated solar flux levels would only occur near the power receiver located in the upper portion of the central tower at elevations of approximately 170-220 meters and approximately 65 meters from the center of each tower within this height range.

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STATE OF CALIFORNIA

Energy Resources Conservation
and Development Commission

APPLICATION FOR CERTIFICATION for the RIO MESA SOLAR ELECTRIC GENERATING FACILITY	))))	Docket No. 11-AFC-04

PROOF OF SERVICE

I, Deric Wittenborn, declare that on November 21, 2012, I served the attached *Rio Mesa SEGF Response to Staff Data Request, Set 3* via electronic and U.S. mail to all parties on the attached service list.

I declare under the penalty of perjury that the foregoing is true and correct.

Deric Wittenborn

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