Stephan C. Volker
Joshua A.H. Harris
Alexis E. Krieg
Stephanie L. Abrahams
Daniel P. Garrett-Steinman
Jamey M.B. Volker
M. Benjamin Eichenberg
Lauren E. Pappone

Law Offices of
Stephan C. Volker
436 – 14th Street, Suite 1300
Oakland, California 94612
Tel: (510) 496-0600 ❖ Fax: (510) 496-1366
svolker@volkerlaw.com

11.172.01

October 10, 2013

VIA EMAIL AND U.S. MAIL

Robert J. Hingtgen
San Diego County Planning & Development
Services Department
5201 Ruffin Road, Suite B
San Diego, California 92123-1666
Robert.Hingtgen@sdcounty.ca.gov

Re: Scoping Comments of The Protect Our Communities Foundation, Backcountry Against Dumps and Donna Tisdale for the Draft Programmatic Environmental Impact Report on the Soitec Solar Development Project

Dear Mr. Hingtgen:

Pursuant to the California Environmental Quality Act ("CEQA"), Public Resources Code ("PRC") section 21000 *et seq.*, the Protect Our Communities Foundation, Backcountry Against Dumps and Donna Tisdale (collectively "Conservation Groups") submit the following scoping comments for the Programmatic Environmental Impact Report ("PEIR") being prepared for the Soitec Solar Development Project ("Soitec Solar" or "Project").

At the outset, Conservation Groups oppose this Project as an unnecessary industrialization of scenic and environmentally sensitive rural land, including important wildlife habitat and farmland. To avoid many of the Project's significant environmental impacts while still providing renewable energy, Conservation Groups urge San Diego County ("County") to analyze and adopt as an alternative to the proposed Project the development of non-fossil fuel distributed generation projects near demand centers in already-disturbed areas. In further expression of these major concerns and others, Conservation Groups submit the following scoping comments.

I. PROJECT BACKGROUND

As described in the Notice of Preparation Public Review Period ("Notice") circulated by the San Diego County Planning and Development Services Department, the Soitec Solar Project would involve the construction and operation by Soitec Solar Development, LLC, of four separate

concentrated photovoltaic ("CPV") electrical generation facilities spread over 1,473 acres in eastern San Diego County, with a combined estimated electrical generation capacity of 168.5 megawatts ("MW"). The "Tierra Del Sol" project would be located on 420 acres at the California-Mexico border south of Boulevard, and would have a nameplate generation capacity of 60 MW. The "Rugged" project would encompass 765 acres just northeast of Boulevard across I-8, and have an estimated capacity of 80 MW. The 22-MW capacity "LanEast" facility would use 233 acres adjacent to I-8 to the east of Boulevard. And the 6.5-MW capacity "LanWest" facility would cover 55 acres adjacent to the LanEast facility on its western side.[1] The Project would operate year-round for *at least* 25 years – the term of the power purchase agreements ("PPAs") between Soitec Solar Development (and its subsidiaries) and San Diego Gas & Electric Company ("SDG&E").

To generate electricity, the Project would use *7,290* CPV trackers, each approximately "48 feet across by 25 feet tall." Initial Study, p. 9 (quote); Notice, p. 1. Given their massive size and considerable weight, each of the *1,200-square foot* CPV trackers would require mounting on a 28-inch steel mast that is either (1) inserted into a hole up to *20 feet deep*, (2) vibrated into the ground up to 20 feet deep, or (3) attached to a large concrete foundation, causing significant environmental disruption. Initial Study, p. 3. In addition, *each* of the four facilities – Tierra Del Sol, Rugged, LanWest and LanEast – would require underground and overhead collector systems, operations and maintenance buildings and grounds, an on-site collector substation, and an overhead generator tie-line ("gen-tie line") connecting the on-site substation to SDG&E's rebuilt Boulevard Substation. Initial Study, pp. 7-8; Notice, pp. 1-2. Constructing this infrastructure would require at least *44 million gallons of water* – or approximately 135 acre-feet – for the Tierra Del Sol and Rugged facilities *alone*. *Id*.

Given the Project's extensive footprint in environmentally sensitive areas, and the amount of infrastructure and natural resources required to construct and operate it, the Soitec Solar Project will have substantial and likely irreparable environmental impacts, all of which the County must analyze in its PEIR. To avoid many of those impacts while still providing renewable energy, the County should analyze and adopt as an alternative to the proposed Project the development of non-fossil fuel distributed generation projects near demand centers in already-disturbed areas.

---

[1] Via letter on September 5, 2013, Soitec Solar Development (and its subsidiary LanWest Solar Farm LLC) requested that the County "withdraw the Major Use Permit Application for the LanWest solar farm project," and "close the case out." However, because Conservation Groups have not received confirmation that the LanWest Major Use Permit application has officially been withdrawn, and because the facility is discussed as part of the Project in the Initial Study and the Notice, Conservation Groups conservatively treat the facility as still part of the Project in these scoping comments.

II. THE COUNTY SHOULD ANALYZE AND ADOPT A DISTRIBUTED GENERATION ALTERNATIVE

To comply with CEQA, agencies must consider a "reasonable range" of alternatives. 14 Cal.Code.Regs. ("CEQA Guidelines") § 15126.6(a). To do so here, the County must analyze a distributed generation alternative. As discussed below, increasing distributed generation capacity in San Diego County by more than 168.5 MW – the expected generating capacity of the Soitec Solar Project – is not only feasible, it is environmentally and economically preferable.

A. Distributed Generation Is Feasible

The evidence is clear: Distributed generation – including such sources as solar photovoltaics ("PV"), small-scale rooftop wind turbines and combined heat and power plants – is both technically and economically feasible. In his testimony on "Alternatives to Large-Scale Wind and Solar Projects in San Diego County" presented at the July 20, 2012, San Diego County Planning Commission meeting, engineer Bill Powers, an expert on San Diego-area electrical systems planning, detailed many of the reasons why a distributed generation alternative is both feasible and desirable.[2]

Indeed, distributed generation is not only feasible, *it is already in use and rapidly expanding*. For example, SDG&E is on pace to add between 80 and 100 MW of distributed solar photovoltaic capacity in its service territory each year from 2013 through 2020. This new PV generation will be developed under the auspices of programs such as the Renewable Auction Mechanism program, which the California Public Utilities Commission ("CPUC") approved in December 2010.[3] Under that program, California will add 1,000 MW of local PV by 2015, 80.7 MW of which were allocated to SDG&E. SDG&E will also be allotted approximately 50 MW of local PV under the 750 MW SB 32 feed-in tariff distributed PV program.[4] Furthermore, by the end of 2016, approximately 180 MW of distributed PV capacity will be added in SDG&E's service territory under the California Solar Initiative "million solar roofs" program.[5] Combined,

---

[2] Mr. Powers' testimony is attached hereto as Exhibit 1.

[3] CPUC Decision D.10-12-048, "Decision Adopting the Renewable Auction Mechanism," December 16, 2010, p. 30, Table 1, available at: http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/128432.pdf.

[4] CPUC feed-in tariff website, description of SB 32, available at: http://www.cpuc.ca.gov/PUC/energy/Renewables/feedintariffssum.htm.

[5] California Center for Sustainable Energy, "Overview of Solar Incentive Programs," October 9, 2009, p. 7, available at: http://www.slideshare.net/ccsemedia/overview-ofsolar-incentive-programs.

approximately 410 MW of local PV capacity will be developed in SDG&E's service territory by the end of 2015. And SDG&E has the ability to add much more, as its territory has at least 7,000 MW of urban and suburban PV potential.[6]

In addition to distributed PV, SDG&E is also on pace to add a substantial number of distributed combined heat and power plants over the next decade. Biogas- or biomethane-fired CHP plants are renewable portfolio standard-eligible, and there are up to 1,700 MW of currently estimated biogas and/or biomethane potential in California to fuel those plants.[7] California's AB 32 greenhouse gas compliance strategy calls for the development of 4,000 MW of CHP by 2020.[8] Since SDG&E supplies about 7 percent of the state's electricity,[9] about 280 MW of new CHP should be allocated to and added in SDG&E's service territory by 2020 to comply with the AB 32 target.

And, as discussed below, expanding SDG&E's renewable energy portfolio – and California's more broadly – with distributed instead of remote, industrial-scale generation will cause much less harm to the environment and public health, while also providing a more robust and sustainable economic stimulus.

B. Distributed Generation Is Better for the Environment and the Economy than Remote, Industrial-Scale Generation Projects Like Soitec Solar

Distributed energy projects such as rooftop solar PV have substantial environmental, aesthetic, economic and public safety benefits over remote, industrial-scale solar energy facilities

---

[6] Powers, *San Diego Smart Energy 2020: The 21st Century Alternative*, October 2007, p. 48, available at: http://www.etechinternational.org/new_pdfs/smartenergy/52008_SmE2020_2nd.pdf.

[7] CEC PIER Program, Consultant Report, "Distributed Renewable Energy Assessment – Final Report," August 11, 2009, Appendix Bio-Power, p. 49, available at: http://www.cleancoalition.org/storage/references/11-aug-09_Navigant_distributed%20renewable%20energy%20assessment_final%20report.pdf.

[8] CPUC Decision D.10-12-035, "Decision Adopting Qualifying Facility and CHP Program Settlement Agreement," December 16, 2010, available at: http://docs.cpuc.ca.gov/WORD_PDF/FINAL_DECISION/128624.PDF.

[9] California Energy Commission, "2007 Integrated Energy Policy Report, December 2007," p. 27, Figure 1-11, available at: http://www.energy.ca.gov/2007publications/CEC-100-2007-008/CEC-100-2007-008-CMF.PDF.

such as the Soitec Solar Project.[10] They do not mar the landscape with massive, glare-producing and unsightly CPV panels, or their associated powerlines, substations and industrial operations and maintenance buildings. They are much less likely to ignite catastrophic wildfires (see Section V below). They don't displace agriculture and wildlife habitat (see Sections IV and VIII below). They present a much smaller threat to wildlife (see Section IV below). They do not waste electricity due to conductor resistance and corona discharges along lengthy transmission lines.[11] Their reliability is far greater. And they are easier to upgrade as technology improves.

In addition, as these solar PV technologies improve and the liability costs of utility-scale renewable energy facilities become clearer, the per-watt installed price for distributed solar PV systems should soon drop below that of remote, utility-scale projects like the Soitec Solar Project. In likely recognition of this trend, many utility-scale renewable energy project developers themselves agree that distributed generation is the future of renewable energy power. For example, NRG Energy, Inc., CEO David Crane stated the following in a 2011 call with financial analysts:

> Ultimately, however, we fully recognize that the current generation of utility-sized solar and wind projects in the United States is largely enabled by favorable government policies and financial assistance. It seems likely that much of that special assistance is going to be phased out over the next few years, leaving renewable technologies to fend for themselves in the open market.
>
> We do not believe that this will be the end of the flourishing market for solar generation. We do believe that it will lead to a *stronger and more accelerated transition from an industry that is currently biased towards utility-sized solar plants to one that's focused more on distributed and even residential solar solutions on rooftops and parking lots*.
>
> We are already planning for this transition now within NRG, so that any potential

---

[10] As former California Public Utilities Commission ("CPUC") Commissioner John Bohn acknowledged, "[u]nlike other generation sources, [distributed generation] projects can get built quickly and without the need for expensive new transmission lines. And . . . these projects are extremely benign from an environmental standpoint, with neither land use, water, or air emission impacts." CPUC, "CPUC Approves Edison Solar Roof Program," Press Release, June 18, 2009, *available at:* http://docs.cpuc.ca.gov/published/News_release/102580.htm.

[11] The U.S. Energy Information Administration estimates that California lost nearly *18 million* kilowatt-hours of electricity in 2010, due primarily to conductor resistance, corona discharges and other transmission and distribution line losses. Energy Information Administration, January 27, 2012, *State Electricity Profiles 2010*, DOE/EIA-0348(01)/2, at p. 30, *available at:* http://www.eia.gov/electricity/state/pdf/sep2010.pdf.

> decline in either the availability of utility-sized solar projects or in the attractiveness of the returns being realized on these projects, *will be exceeded in aggregate by the increase in the business we are doing on smaller distributed and residential solar projects* . . . . (emphasis added).[12]

In sum, distributed generation is not only feasible, it is environmentally and economically preferable to remote, utility-scale renewable energy generation facilities like the Soitec Solar Project.

III. HYDROLOGIC IMPACTS

CEQA requires the County to identify in its PEIR the likely water sources for the Project, and analyze the "environmental impacts of exploiting those sources" and "how those impacts are to be mitigated." *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* ("*Vineyard*") (2007) 40 Cal.4th 412, 421 (quote), 434, 440-441. "An EIR that neglects to explain the likely sources of water and analyze their impacts, but leaves long-term water supply considerations to later stages of the project, does not serve the purpose of sounding an environmental alarm bell." *Id*. at 441 (internal quotations and citation omitted)

Thus far, the County has merely noted that construction of the Tierra Del Sol and Rugged facilities would use at least 20 and 24 million gallons of local groundwater, respectively, for a total of more than *135 acre-feet*. Initial Study, pp. 7-8; Notice, pp. 1-2. CEQA requires more. The County must not only estimate the water needed to construct the other two Soitec Solar Project generation facilities – LanWest and LanEast – it must identify the *operational* water use for the entire Project. And if the evidence shows that Project operation "would demand . . . more than 75 acre-feet of water annually," the County must also prepare a Water Supply Assessment under Water Code section 10910. Water Code § 10912.

Furthermore, the County must do more than state that the Project will use local groundwater. It must identify the specific aquifer – and even well sites – from which the groundwater would be extracted, and the impacts of pumping therefrom. For example, the County must determine whether the Project would extract water from the Campo-Cottonwood Sole Source Aquifer – which seems likely, since the Project sits directly on top of it – and how such extraction would impact that fragile aquifer, the nearby wells, and the local population's ability to

---

[12] Seeking Alpha, April 22, 2011, "NRG Energy's CEO Discusses Q4 2010 Results – Earnings Call Transcript," at p. 7, *available at:* http://seekingalpha.com/article/254272-nrg-energy-s-ceo-discusses-q4-2010-results-earnings-call-transcript (attached hereto as Exhibit 2)

obtain adequate water supplies.[13] Without this information, it would be impossible to analyze the impacts of supplying water to the Project as CEQA requires. *Vineyard*, 40 Cal.4th at 434 ("The ultimate question under CEQA . . . is whether [the EIR] adequately addresses the reasonably foreseeable *impacts* of supplying water to the project").

IV. HARM TO WILDLIFE

As the County admits, the "project sites contain sensitive biological habitats with the potential for use by sensitive and/or protected species." Initial Study, p. 19. Among those "sensitive and[] protected species" that the Project would likely harm are the federally endangered Quino checkerspot butterfly, whose critical habitat extends near the Project sites, the federally endangered Peninsular bighorn sheep, the golden eagle, and the burrowing owl, which is a California State Species of Special Concern. The County must thoroughly analyze the Project's impacts to these and other species in its PEIR.

In their 2011 *BioScience* article, Jeffrey Lovich and Joshua Ennen identify many of the "known and potential impacts of utility-scale solar energy development on wildlife in the desert Southwest,"[14] which the County should likewise analyze here. The impacts they identify from "facility construction and decommissioning" include the following:

- "Destruction and modification of wildlife habitat;"
- "Direct mortality of wildlife;"
- "Dust and dust-suppression effects;"
- "Road effects;"
- "Off-site impacts;" and
- "Destruction and modification of wildlife habitat."

Exhibit 4 at 984. They also identify the following impacts "due to facility presence, operation, and maintenance:"

- "Habitat fragmentation and barriers to movement and gene flow;"
- "Noise effects;"
- "Electromagnetic field effects;"
- "Microclimate effects;"
- "Pollution effects from spills;"

---

[13] A copy of the official federal Environmental Protection Agency map of the sole source aquifer is attached hereto as Exhibit 3.

[14] Lovich, J.E. & J.R. Ennen, 2011, "Wildlife Conservation and Solar Energy Development in the Desert Southwest, United States," *BioScience*, 61(12): 982-992, at p. 984 (attached hereto as Exhibit 4).

- "Water consumption effects;"
- "Fire effects;" and
- "Light pollution effects, including polarized light."

Id. Because, like the environments studied by Lovich and Ennen, the Soitec Solar Project is located in a predominantly southwestern desert (specifically high desert) environment, the County should analyze all the listed impacts in its PEIR.

V. PUBLIC HEALTH AND SAFETY IMPACTS – FIRE

The California Department of Forestry and Fire Protection ("CalFire") has identified much of the area in and around the Project sites as a Very High Fire Hazard Severity Zone.[15] And within that context, the Project poses a grave risk of igniting, exacerbating and preventing the effective fighting of catastrophic wildfires. Not only do utility-scale solar energy generation plants and their associated transmission, substation and other facilities frequently cause wildfires, they greatly impede fire suppression efforts and pose safety risks to responding firefighters. For example, the Project, like other energy generation and transmission facilities in the San Diego County and Imperial County areas, would create a substantial hazard for low-flying spotter and bomber aircraft that apply aerial retardant. It would be nearly impossible to see the Project's transmission lines in the smoke filled skies, and either pilots would be forced to risk their lives by flying when the lines were not clearly visible, or aerial fire suppression would be stymied. The great risks to firefighters and impediments to firefighting caused by transmission lines are discussed in detail by Mark Ostrander, retired Battalion Chief with CalFire, in his April 14, 2011, expert testimony in a federal lawsuit challenging the Bureau of Land Management's approval of the Sunrise Powerlink project, which is attached as Exhibit 7 hereto. When combined with the extreme limitations industrial-scale solar projects and power lines put on ground firefighting attacks, the huge risks associated with aerial firefighting efforts would make large fires in the Project area virtually uncontrollable.

In addition to the Project's direct fire impacts, the Project also poses significant cumulative fire impacts of the Project alongside the many other energy projects in the region. The cumulative impacts of the industrialization of eastern San Diego County have the potential to permanently alter the fragile desert and mountain ecosystems there through a process called type conversion, described below:

> Plant invasions are widely recognized as significant threats to biodiversity conservation worldwide. One way invasions can affect native ecosystems is by changing fuel properties, which can in turn affect fire behavior and, ultimately,

[15] This is shown in CalFire's 2009 recommended map of very high fire hazard severity zones in the local responsibility area (attached hereto as Exhibit 5), and its 2007 adopted map of very high fire hazard severity zones in the state responsibility area (attached hereto as Exhibit 6).

> alter fire regime characteristics such as frequency, intensity, extent, type, and seasonality of fire. If the regime changes subsequently promote the dominance of the invaders, then an invasive plant-fire regime cycle can be established. As more ecosystem components and interactions are altered, restoration of preinvasion conditions becomes more difficult.[16]

As a result of the unacceptably high fire risks that the Project poses, Conservation Groups urge the County to reject the Project as currently proposed.

VI. PUBLIC HEALTH AND SAFETY IMPACTS – ELECTRIC AND MAGNETIC FIELDS

The Project would expose Project workers, wildlife and others to electric and magnetic field ("EMF") radiation. People and wildlife near the many inverter modules for the Projects CPV systems would be particularly susceptible to harm. Recent studies, such as those by Dr. Samuel Milham and Dr. Magda Havas, have linked EMF exposure with an increase in ailments such as diabetes, fibromyalgia, chronic fatigue syndrome and attention deficit disorder, among others.[17] Similarly, as reported in Lovich and Ennen's recent *BioScience* article, Doctor Alfonso Balmori (in a 2010 article) found the "possible impacts of chronic exposure to athermal electromagnetic radiation" on mammal species to include "damage to the nervous system,

---

[16] M.L. Brooks *et al.*, "Effects of Invasive Alien Plants on Fire Regimes," *Bioscience*, 54:677-688, available at: http://www.californiachaparral.com/images/Brooks_et_al_Effects_of_Invasives_on_Fire_Regimes.pdf.

[17] *See, e.g.,* Samuel Milham, "Attention Deficit Hyperactivity Disorder and Dirty Electricity," *Journal of Developmental and Behavioral Pediatrics*, September 2011 (attached hereto as Exhibit 8); Samuel Milham, "Historical Evidence That Electrification Caused the 20th Century Epidemic of 'Diseases of Civilization,'" *Medical Hypotheses*, 74:337-345, 2010 (attached hereto as Exhibit 9); Samuel Milham and L. Lloyd Morgan, "A New Electromagnetic Exposure Metric: High Frequency Voltage Transients Associated With Increased Cancer Incidence in Teachers in a California School," *American Journal of Industrial Medicine*, 2008 (attached hereto as Exhibit 10); Magda Havas, "Dirty Electricity Elevates Blood Sugar among Electrically Sensitive Diabetics and May Explain Brittle Diabetes," *Electromagnetic Biology and Medicine*, 27:135-146, 2008; Magda Havas, "Electromagnetic Hypersensitivity: Biological Effects of Dirty Electricity with Emphasis on Diabetes and Multiple Sclerosis," *Electromagnetic Biology and Medicine*, 25:259-268, 2006, available at: http://www.next-up.org/pdf/Magda_Havas_EHS_Biological_Effets_Electricity_Emphasis_Diabetes_Multiple_Sclerosis.pdf; The National Foundation for Alternative Medicine, "The health effects of electrical pollution," available at: http://d1fj3024k72gdx.cloudfront.net/health_effects.pdf.

disruption of circadian rhythms, changes in heart function, impairment of immunity and fertility, and genetic and developmental problems." Exhibit 4 at 987. Furthermore, even though there remains some disagreement over the impacts of EMF, many "authors suggest that [this] . . . should not be cause for inaction. Instead, they argue that the precautionary principle should be applied in order to prevent a recurrence of the 'late lessons from early warnings' scenario that has been repeated throughout history." *Id*. The County must analyze the Project's EMF impacts in the PEIR.

VII. PUBLIC HEALTH AND SAFETY IMPACTS – GLARE

The County must analyze the Project's potential to cause significant glare from its 1,200-square foot CPV panel arrays. This glare would not only be an aesthetic nuisance to nearby residents and recreationists, it would pose a significant safety hazard to drivers. This hazard would be particularly acute for those driving along I-8 past the adjacent LanWest and LanEast facilities.

VIII. AGRICULTURAL IMPACTS

Nearly 400 acres of the Project sites are zoned for agriculture, as either A72 (General Agriculture) or A70 (Limited Agriculture). Initial Study, p. 16. And much of the "proposed [Rugged] project site has been used for grazing purposes for at least the past 20 years." *Id*. Indeed, in support of the agricultural use of those lands and for the purpose of preserving them in agricultural use under the Williamson Act (Government Code section 51200 *et seq.*), the County designated an area including part of the Tierra Del Sol site as an Agricultural Preserve (AP 77-46). *Id*. at pp. 8, 9, 15. The Project would undo all of that, and cause significant agricultural impacts. *Id*. at p. 9 (Project would require disestablishment of the portion of Agricultural Preserve 77-46 on the Tierra Del Sol site).

By removing agricultural lands from grazing and agricultural production for *at least 25 years* (with "additional terms anticipated" and a solar facility lifespan of more than 30 years), and stripping those lands of their legal agricultural use protections, the Project makes it unlikely that the lands would be ever again be available – let alone used – for grazing or agriculture. One major reason for that is erosion of topsoil. As the Initial Study acknowledges, the soils on at least the Tierra Del Sol and Rugged sites "have a soil erodibility rating of 'severe.'" Initial Study, p. 24. By converting these areas to an high-intensity industrial use from low-intensity grazing, agricultural and other rural uses, the Project would likely cause substantial erosion of fertile and difficult-to-replace topsoil.

Further impairing the viability of grazing and agriculture in the County would be the Project's impact on ranching- and agriculture-serving businesses. As more ranch land and farmland is converted to non-agricultural uses, and as more ranching- and agriculture-serving businesses close or reduce their stocks, it becomes harder and more expensive for the remaining ranchers and farmers to cost-effectively obtain the supplies and services (e.g. veterinarian care) to

maintain their pastures, crops and animals. This in turn results in more ranch land and farmland conversion, and even greater reductions in agricultural services. It is a vicious cycle of ripple and cascading effects whose cumulative impact on the ranching and agricultural economy is rarely acknowledged, let alone adequately evaluated.

The County must fully analyze these and other impacts to ranching and agriculture, both on the Project sites and in the region generally. The County must also ensure that it complies with the Williamson Act (*e.g.* Government Code sections 51232 and 51233) and the County Board of Supervisors Policy No. I-38 in disestablishing the portion of Agricultural Preserve 77-46 on the Tierra Del Sol site, and analyze compliance with those land use laws and policies in the PEIR.

IX. NOISE IMPACTS

In analyzing the Project's audible noise impacts, the County should normalize its noise emission estimates to account for the fact that the Project area is a rural community with little to no prior exposure to industrial noise, such as would be produced by Project. In addition, the County should analyze not only the Project's audible noise emissions and impacts, but its inaudible infrasound and low-frequency noise emissions too, which have recently been shown to have a much greater potential to impact humans than previously thought.[18]

X. GLOBAL WARMING

The Initial Study states that while the Project will produce some GHGs through construction and operation, it "is expected to offset greenhouse gas ("GHG") emissions by serving as a longterm renewable energy source, thereby decreasing overall emissions attributable to electrical generation in California." Initial Study, p. 27. The County should not be so swift in its conclusions. It must carefully examine these conclusions in the PEIR, analyzing all the Project's potential GHG emission sources and comparing the total emissions per kilowatt-hour (averaged over the expected life of the Project) to the other energy sources the County implies will be displaced.

In assessing the Project's GHG emission impacts in the PEIR, the County must do more than just calculate the GHG emissions from construction activities, construction-related vehicle traffic and employee vehicle use during Project operation, which is all the Initial Study indicates will be done. Initial Study, p. 27. The County must also (1) assess the Project's substantial *embedded* greenhouse gas emissions: the GHG emissions associated with production of the materials used to construct the Project, such as the photovoltaic panels; and (2) compute the change in GHG emissions from the soil on the Project site resulting from the Project's conversion

---

[18] Salt, Alec & Jeffery Lichtenhan, 2012, "Perception-based protection from low-frequency sounds may not be enough," presented at InterNoise 2012 in New York City, New York, August 19-22, 2012, at p. 5 (attached hereto as Exhibit 11).

of the land from grazing, agricultural production and other lower-intensity rural uses to the proposed industrial-scale CPV facilities. Additionally, the County must ascertain whether the electricity produced by the Project would actually either (1) supplant electricity currently generated by fossil fuel-based systems, or (2) meet a future energy demand that would otherwise be met with fossil fuel-based generation.

XI. CONCLUSION

Conservation Groups oppose this Project as an unnecessary industrialization of scenic and environmentally sensitive rural land, including important wildlife habitat and farmland. To avoid many of the Project's aforementioned significant environmental impacts while still providing renewable energy, Conservation Groups urge the County to analyze and adopt as an alternative to the proposed Project the development of non-fossil fuel distributed generation projects near demand centers in already-disturbed areas. The County must also fully analyze each of the foregoing environmental impacts in its PEIR.

Respectfully submitted,

Stephan C. Volker
Attorney for The Protect Our Communities Foundation.,
Backcountry Against Dumps and Donna Tisdale

SCV:taf

LIST OF EXHIBITS

1. Powers, Bill, July 20, 2012, "Alternatives to Large-Scale Wind and Solar Projects in San Diego County," presentation at the July 20, 2012, San Diego County Planning Commission Regular Meeting;

2. Seeking Alpha, April 22, 2011, "NRG Energy's CEO Discusses Q4 2010 Results – Earnings Call Transcript;"

3. U.S. Environmental Protection Agency, Region 9 GIS Center, 2008, "Campo-Cottonwood Sole Source Aquifer: Designated Area" (map);

4. Lovich, Jeffrey E., and Joshua R. Ennen, 2011, "Wildlife Conservation and Solar Energy Development in the Desert Southwest, United States," *BioScience* 61(12):982-992;

5. California Department of Forestry and Fire Protection, June 12, 2009, "Very High Fire

Hazard Severity Zones in LRA: As Recommended by CalFire" (map), CalFire Map ID: FHSZL_MAP;

6. California Department of Forestry and Fire Protection, November 7, 2007, "Fire Hazard Severity Zones in SRA" (map), CalFire Map ID: FHSZS_MAP;

7. Declaration of Mark Ostrander in Support of Plaintiffs' Motion for Preliminary Injunction and Application for Temporary Restraining Order, April 14, 2011, Docket # 122-5 in Case # 3:10-CV-01222 (S.D.Cal.);

8. Milham, Samuel, September 2011, "Attention Deficit Hyperactivity Disorder and Dirty Electricity," Letter to Editor, *Journal of Developmental and Behavioral Pediatrics*;

9. Milham, Samuel, 2010, "Historical Evidence That Electrification Caused the 20th Century Epidemic of 'Diseases of Civilization.'" *Medical Hypotheses*, 74:337-345;

10. Milham, Samuel & L. Lloyd Morgan, 2008, "A New Electromagnetic Exposure Metric: High Frequency Voltage Transients Associated with Increased Cancer Incidence in Teachers in a California School," *American Journal of Industrial Medicine*;

11. Salt, Alec & Jeffery Lichtenhan, 2012, "Perception-based protection from low-frequency sounds may not be enough," presented at InterNoise 2012 in New York City, New York, August 19-22, 2012;

EXHIBIT 1

Alternatives to Large-Scale Wind and Solar Projects in San Diego County

Presented at San Diego County Planning Commission Regular Meeting

July 20, 2012

Bill Powers, P.E.
Powers Engineering
4452 Park Blvd., Suite 209
San Diego, CA 92116
(619) 295-2072
(619) 295-2073 Fax
bpowers@powersengineering.com

I. Introduction

Q: Please state your name, job title, and business address.

A: William A. Powers, P.E., principal of Powers Engineering, 4452 Park Blvd., Suite 209, San Diego, California, 92116.

Q: Please describe your qualifications.

A: I have a B.S. in mechanical engineering from Duke University and a Master of Public Health degree in environmental sciences from the University of North Carolina – Chapel Hill. I am a registered professional mechanical engineer in California with 30 years of experience in the energy and environmental fields. I began my career converting Navy and Marine Corps shore installation power plants from oil-firing to domestic waste, including woodwaste, municipal solid waste, and coal, in response to concerns over the availability of imported oil following the Arab oil embargo. I have permitted five 50 MW peaking turbine installations in California, as well as numerous gas turbine, microturbine, and engine cogeneration plants around the state. I organized conferences on permitting gas turbine power plants (2001) and dry cooling systems for power plants (2002) as chair of the San Diego Chapter of the Air & Waste Management Association.

I am also the author of the March 2012 Bay Area Smart Energy 2020 strategic energy plan. This plan uses the zero net energy building targets in the California *Energy Efficiency Strategic Plan* as a framework to achieve a 60 percent reduction in GHG emissions from Bay Area electricity usage by 2020. I authored the October 2007 strategic energy plan for the San Diego region titled "San Diego Smart Energy 2020." The plan uses the state's Energy Action Plan as the framework for accelerated introduction of local renewable and cogeneration distributed resources to reduce greenhouse gas emissions from power generation in the San Diego region by 50 percent by 2020. I am the author of several articles in Natural Gas & Electricity Journal on use of large-scale distributed solar photovoltaics (PV) in urban areas as a cost-effective substitute for new gas turbine peaking capacity. I have a B.S. in mechanical engineering from Duke University and an M.P.H. in environmental sciences from the University of North Carolina – Chapel Hill. My resume is attached as Exhibit A to this testimony.

II. Renewable Distributed Generation and State Energy Goals

Q: Does priority emphasis on renewable distributed generation (DG) resources advance the state's energy goals?

A: Yes. Customer decisions to utilize DG to offset consumption of electricity from the grid is consistent with state energy goals, including the loading order, the Governor's 12,000 MW goal for DG, and the state's ambitious net zero energy building goals.

Q: How does DG contribute to the state's loading order?

A: The California Energy Commission ("CEC") and the California Public Utilities Commission ("CPUC") developed the *Energy Action Plan* in 2003 to guide strategic energy planning in California.[1] It establishes a resource priority list, or loading order, to guide strategic energy planning. The loading order prioritizes energy efficiency and demand response, renewable energy, combined heat and power, followed by utility natural gas-fired resources. The *Energy Action Plan* is explicit that rooftop PV is an element of building energy efficiency standards. *Energy Action Plan I* states that California should "[i]ncorporate distributed generation or renewable technologies into energy efficiency standards for new building construction." The CPUC confirmed in January 2012 that the "loading order applies to all utility procurement, even if pre-set targets for certain preferred resources have been achieved."[2] Customers utilizing renewable DG advance the loading order by reducing demand on the grid at the point-of-use with clean energy.

Q: Describe the Governor's 12,000 MW goal for new renewable DG resources.

A: Governor Jerry Brown proposes through his *Climate Strategy* and *Clean Energy Jobs Plan* that a majority of the new renewable energy resources to be built in the state by 2020, 12,000 MW of total of 20,000 MW, be local renewable power.[3]

---

[1] Energy Action Plan I: http://www.energy.ca.gov/energy_action_plan/2003-05-08_ACTION_PLAN.PDF
[2] *See* Commission Decision 12-01-033 at 20-21.
[3] Governor Jerry Brown, April 25, 2012 Support Letter for DRECP Process, at 2 (http://www.drecp.org/meetings/2012-04-25-26_meeting/presentations/04_Office_of_the_Governor_Paper.pdf.; Governor Jerry Brown, *Clean Energy Jobs Plan*, June 2010.

Q: Do you have an estimate for how much SDG&E might contribute to the Governor's 12,000 MW goal?

A: SDG&E demand represents about 8 percent of statewide electricity demand.[4,5] The proportionate SDG&E share of 12,000 MW of new local renewable energy in California by 2020 would be about 960 MW.

Q: Is SDG&E close to reaching this estimated goal of 960 MW new local renewable generation?

A: No. At the end of 2011, SDG&E territory had about 120 MW of net-metered (NEM) PV systems online.[6] SDG&E is required to maintain a certain minimum amount of local generation supplies to assure local grid reliability. Instead of promoting local solar, SDG&E is promoting the construction of a number of new peaking gas turbine power plants to address an issue that could be more cost-effectively addressed with local solar.

Q: How does DG contribute to the state's net zero building goals?

A: The CPUC and SDG&E, SCE, and PG&E jointly developed the *California Long Term Energy Efficiency Strategic Plan* in 2008.[7] The *Plan* was updated in 2011.[8] It calls for 25 percent of existing homes to reach 70 percent reduction in energy usage by 2020, and 50 percent of existing commercial buildings to reach zero net energy by 2030. The concept of net zero energy is shown graphically in Figure 1.

The *Energy Efficiency Strategic Plan* assumes that 50 percent of existing commercial buildings achieve net zero energy by 2030 with no interim 2020 target. The CPUC projects that 15 to 20 percent of existing commercial buildings will reach net zero energy by 2020, as shown in Figure 2.

---

[4] CEC Final Staff Report, *California Energy Demand 2012-2022 Final Forecast - Volume 1: Statewide Electricity Demand and Methods, End-User Natural Gas Demand, and Energy Efficiency*, May 2012, p. 2. Statewide 2011 electricity demand was 273,103 GWh.

[5] SDG&E Application A.08-11-014 , *Prepared Direct Testimony of Greg Katsapis - Authority to Update Cost Allocation And Electric Rate Design*, November 14, 2008. Forecast 2009 SDG&E demand was 20,890 GWh.

[6] J.C Thomas – SDG&E, *San Diego/Solar Stakeholder Collaboration Rates & Educational Overview*, January 25 & 27. 2012, p. 48 (for current NEM level).

[7] See: http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/eesp/ .

[8] CPUC, *California Energy Efficiency Strategic Plan*, January 2011 Update.

Figure 1. Graphical Representation of Net Zero Energy Concept[9]

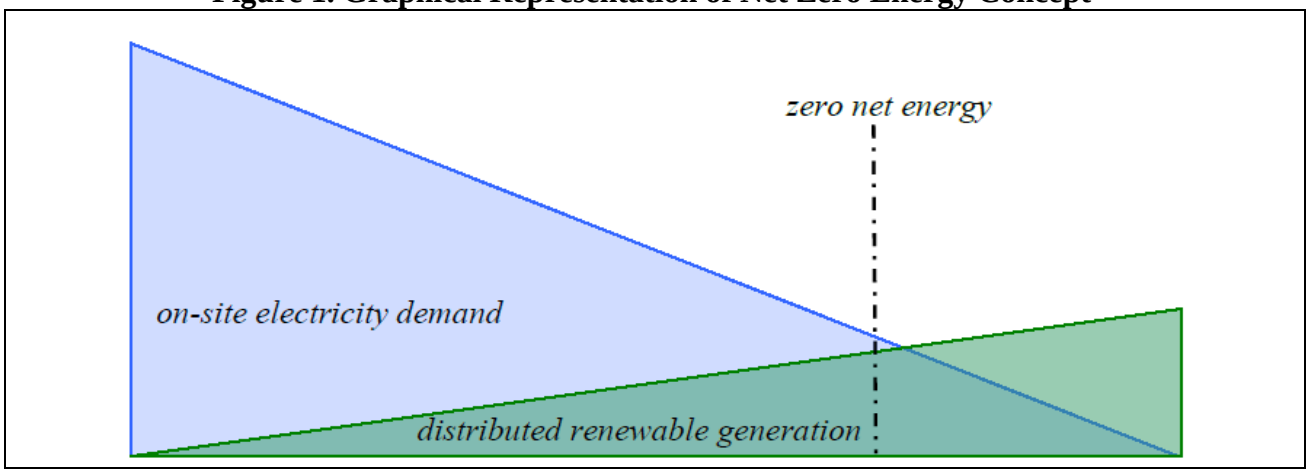
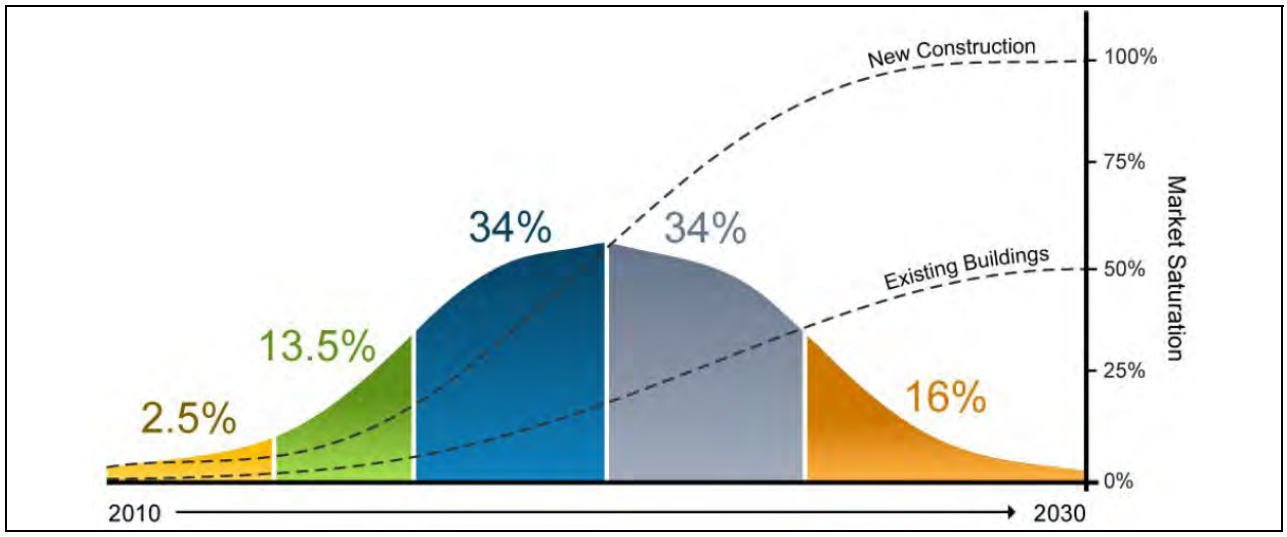


Figure 2. CPUC Estimate of Rate of Retrofit of Existing Commercial Buildings to ZNE from 2010 to 2030[10]



Q: How much DG is required to fully realize the net zero building goals?

A: Statewide, full implementation of the existing residential and commercial load reduction goals in the *Energy Efficiency Strategic Plan* would result in about 14,000 to 15,000 of rooftop PV by 2020.[11] This is consistent with the Governor's target of 12,000 MW of

[9] *California Energy Efficiency Strategic Plan*, January 2011 Update: http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/eesp/.

[10] CPUC, *California Energy Efficiency Strategic Plan - Zero Net Energy Action Plan: Commercial Building Sector*2010-2012, August 31, 2010, Appendix C, p. 34. See: http://www.cpuc.ca.gov/NR/rdonlyres/6C2310FE-AFE0-48E4-AF03-530A99D28FCE/0/ZNEActionPlanFINAL83110.pdf.

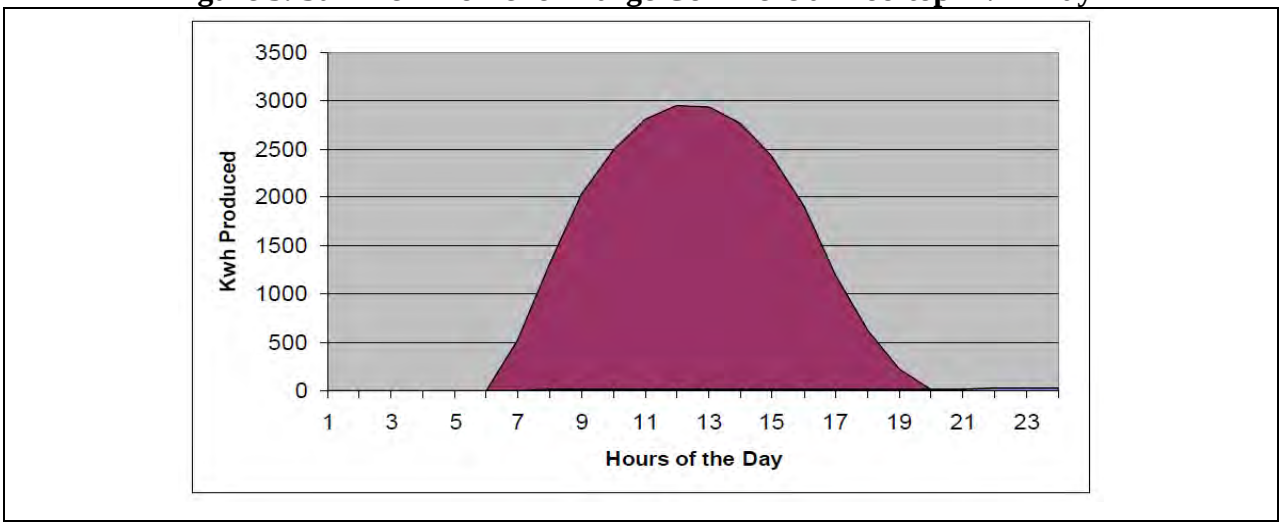
[11] B.Powers, *Bay Area Smart Energy 2020*, March 2012, Table 10-1, pp. 88-89. Assume 15 percent existing commercial buildings are ZNE by 2020, and for the 25 percent of existing homes that reduce demand by 70 percent,

new local renewable energy, and would add about 960 MW of rooftop solar to San Diego by 2020.

Q: Does rooftop solar PV, in particular, advance these state energy goals?

A: Yes. The only currently operational CPUC program available to achieve these *Energy Efficiency Strategic Plan* rooftop PV targets is net-metering (NEM).[12] The clear day electricity production profile of a south-facing rooftop PV system is shown in Figure 3. Output is at its maximum around 1 pm, and is about 50 percent of maximum at 5 pm.

Figure 3. Summer Profile for Large Commercial Rooftop PV Array[13]



The peak day demand of major SDG&E customer categories is shown in Figure 4. The three commercial SDG&E customer categories, Small Commercial, Medium Commercial & Industrial, and Large Commercial & Industrial, reach maximum demand at mid-day. Demand gradually decline over the course of the afternoon.

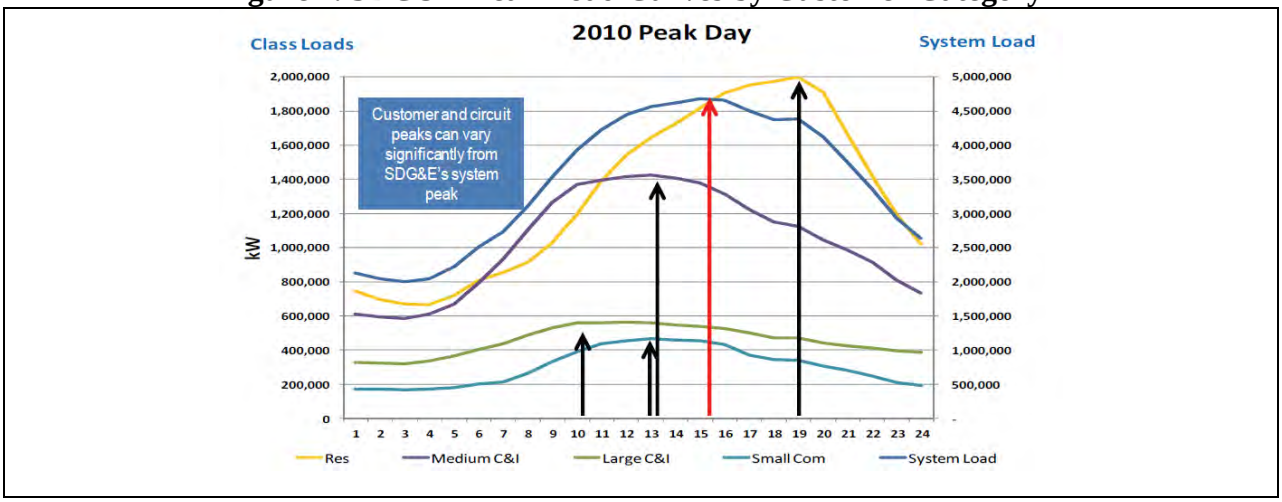
---

30 percent is achieved through energy efficiency and 40% is achieved with rooftop PV. Multi-family reduces demand by 40 percent, of which 30 percent is achieved through energy efficiency and 10 percent though rooftop PV. The amount of rooftop PV necessary to achieve these targets is 14,000 to 15,000 MW_{ac}, assuming an average PV output of 1,800 to1,900 kWh-yr per kW_{ac} installed. See: http://pacificenvironment.org/downloads/BASE2020_Full_Report.pdf

[12] The Commission approved a tariff structure for 750 MW (statewide) SB 32 feed-in tariff legislation in D.12-05-035, issued on May 31, 2012. The tariff structure is called the Renewable Market Adjusting Tariff (ReMAT). The capacity limit is 3 MW. Projects must be located at sites with minimal transmission and distribution interconnection costs. There is no pure requirement that the ReMAT projects be located in or near load centers.

[13] P. Shoemaker - PG&E, *Basics of Photovoltaic (PV) Systems for Grid-Tied Applications*, PowerPoint, 2008.

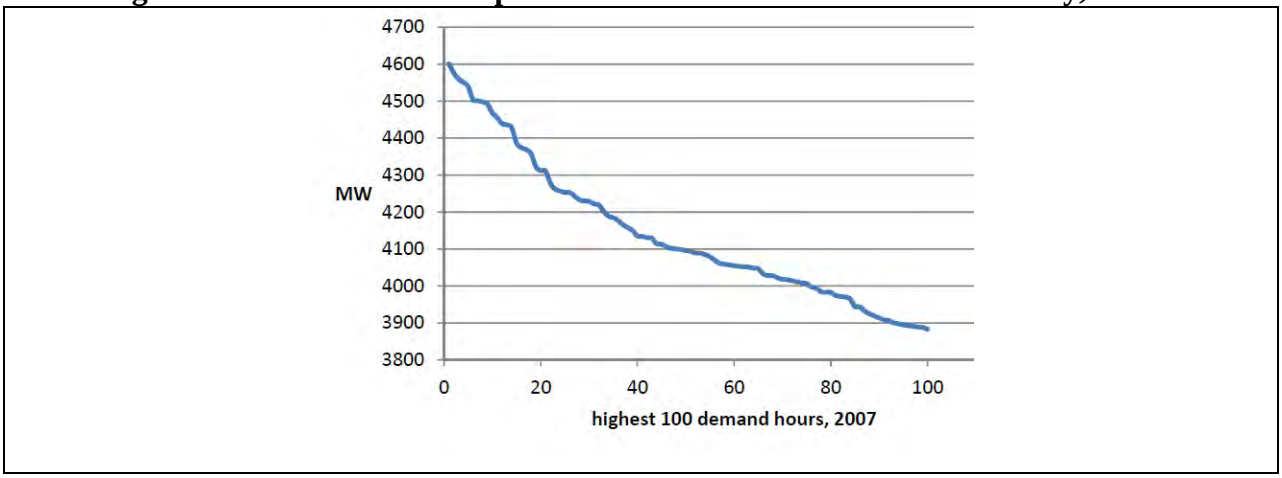
Figure 4. SDG&E Peak Load Curves by Customer Category[14]



Q: Is it appropriate to focus on the availability of the solar resource in the top 100 hours of peak demand when assessing the availability of rooftop solar?

A: Yes. SDG&E allocates generation capacity charges based on use in the top 100 demand hours of the year. As SDG&E states, "The "Top 100 hours" methodology allocates revenues based on the customer classes' contribution to the top 100 hours of system load during a given annual period."[15] This makes sense, as expensive peaking capacity resources are financed and maintained primarily to address demand during the highest demand hours of the year. SDG&E load drops rapid in the top 100 demand hours, as shown in Figure 5.

Figure 5. Load Decline in Top 100 Demand Hours in SDG&E Territory, 2007[16]



[14] SDG&E Application A.11-10-002, *Revised Prepared Direct Testimony of Chris Yunker*, February 2012, p. 7.
[15] SDG&E Application A.11-10-002, *Application for Authority to Update Marginal Costs, Cost Allocation, and Electric Rate Design. Revised Prepared Direct Testimony of William G. Saxe - Chapter 3*, February 2012, p. 4.
[16] CAISO OASIS database, "System Load": http://oasishis.caiso.com/

Q: Is rooftop PV at least as reliable as peaking gas turbine capacity during top 100 hours of demand?

A: Yes. NEM PV is at least as reliable as peaker capacity during top 100 demand hours in SDG&E territory. Powers Engineering correlated hourly 2007 SDG&E load data from the California Independent System Operator "OASIS" online database to hourly cloud cover and global irradiance data to assess the availability of the solar resource in San Diego County during peak demand hours. 2007 datasets were used because all datasets for 2007 were readily available at reasonable cost at the time the evaluation was initiated.

"Availability of the solar resource" is defined here as the percentage of potential solar energy, also known as global irradiance, that was actually available to produce PV electricity in a given hour. The reason that the solar resource would not be fully available is cloud cover. To put the 2007 peak load data set in perspective, the 2007 SDG&E load, at 4,601 MW, was about 250 MW higher than the 2011 peak load of 4,355 MW. The lower cut-off load level in the analysis was 3,500 MW. In 2007, there were 239 hours where the SDG&E demand was at or above 3,500 MW. The results of the analysis are presented in Table 1.

Table 1. Availability of Solar Resource During Peak Demand Hours in SDG&E Territory

Demand hour range	Load Range (MW)	Average Solar Resource Availability (%)
Top 10 demand hours	4,468 – 4,601	98
Top 20 demand hours	4,312 – 4,601	99
Top 100 demand hours	3,883 – 4,601	99
Top 239 demand hours	3,500 – 4,601	99+

The actual availability of the solar resource across the top 10 demand hours in 2007 was 98 percent. It was 99 percent in the top 20 demand hours, and 99+ percent for the top 239 demand hours. As noted, the top 239 demand hours represent all one-hour SDG&E

demand at or above 3,500 MW. 3,500 MW is over 1,150 MW below the all-time peak one-hour demand recorded to date in SDG&E territory, 4,687 MW in September 2010.[17]

There will be times during the on-peak period, which covers weekdays June 1 – October 1, 11 am – 6 pm, when skies are overcast and the NEM operator will draw all electricity from SDG&E. However, these are modest or low demand periods with system loads less than 3,500 MW where there is no stress on the distribution system and no peaking units are operational.[18] A subset of this on-peak period is the 100 highest demand hours of the year that determine the allocation of capacity costs among commercial customers. During this critical peak demand subset, commercial NEM PV is at least 98 percent available.

Q: Does rooftop PV provide reliable capacity during the top 100 hours of peak demand?

A: Yes. NEM PV systems provide capacity at an availability of at least 98 percent in aggregate during critical peak demand. This high availability is as good or better than natural gas-fired peaking resources. As SDG&E's states, the addition of 750 MW of new NEM PV capacity in SDG&E service territory would be expected to reduce the average peak hour load in August (3-4 pm) by over 400 MW.[19] Scattered cloud conditions do exist on occasion in SDG&E service territory during the top 100 hours of demand. However, the aggregate availability of the solar resource during these infrequent scattered cloud conditions is approximately 80 per cent or greater. A detailed analysis of solar resource availability during the 100 peak hours in SDG&E territory is provided in Attachment A.

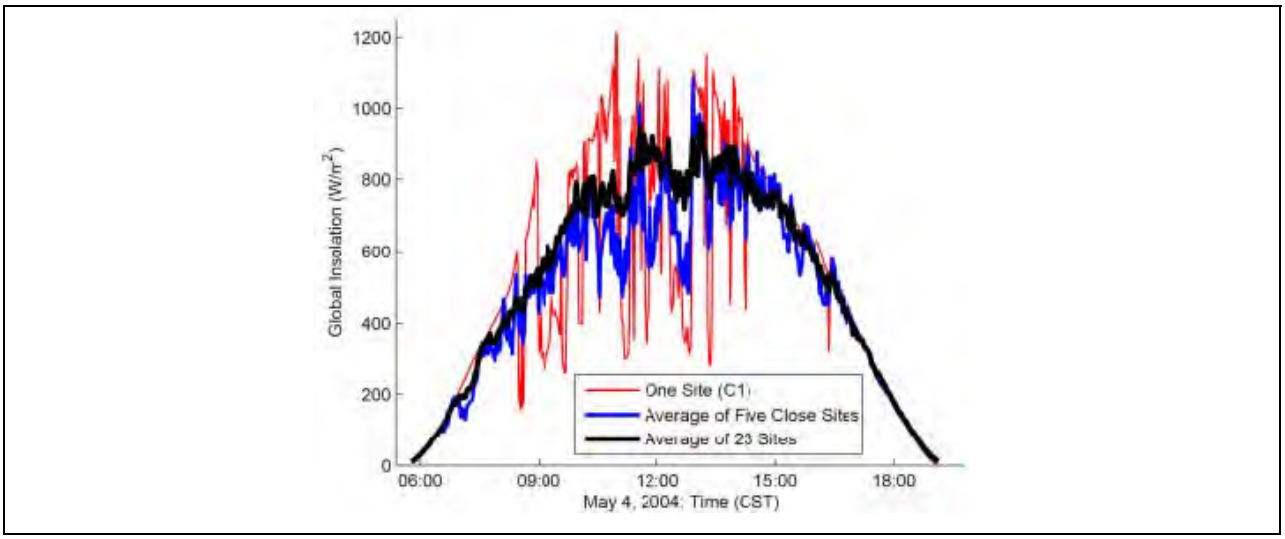
Distributed PV is also predictably available in aggregate on days with scattered clouds, when the output of multiple geographically-dispersed PV systems is combined.[20] This output characteristic of multiple-geographically dispersed distributed PV systems is shown in Figure 6.

---

[17] SDG&E Comments on the Proposed Decision of Commission Peevey Regarding the Calculation of the Net Energy Metering Cap, May 1, 2012 in CPUC Docket R.10-05-044.
[18] See Powers Engineering hour-by-hour comparison of load and weather conditions in SDG&E service territory in 2007 with demand at or above 3,500 MW, included with this testimony as Attachment B.
[19] *See* Ex. SDG&E-105, Table 5A-2 at DTB-5-A and Table 5A-6 at DTB-7-A.
[20] Lawrence Berkeley National Laboratory, *Implications of Wide-Area Geographic Diversity for Short-Term Variability of Solar Power*, September 2010, p. 25. See: http://eetd.lbl.gov/ea/emp/reports/lbnl-3884e.pdf.

The San Diego area already has at least 15,000 distributed PV systems.[21] The output from these dispersed PV systems on days with scattered clouds is reliable in aggregate due to the dispersion of these PV systems over hundreds of square kilometers of developed areas in San Diego County.

Figure 6. Multiple PV Sites Smooth Aggregate PV Output on Partly Cloudy Days



NEM PV is reliably available during the top 100 demand hours in SDG&E service territory. As a practical matter, NEM PV systems will automatically provide electricity, individually on clear days and in aggregate on days with scattered clouds, at very high availability during periods of critical peak demand. Whether this electricity is used on-site or exported, it reduces demand on the grid.

Lawrence Berkeley National Laboratory (LBNL) recently completed an analysis of the capacity value of PV, solar thermal, and wind generation. The authors identify the purpose of the study as the quantification of the economic value of these renewable resources, noting that "Resource procurement and investment decisions are made more difficult by the variable and unpredictable nature of variable generation. Part of what is

[21] J.C Thomas – SDG&E, *San Diego/Solar Stakeholder Collaboration Rates & Educational Overview*, January 25 & 27. 2012, p. 48.

missing from simple comparisons is an evaluation of the economic value of the energy generated." [22]

The LBNL study states that the marginal value of PV is high at low penetration due to high capacity value. The economic significance of this high capacity value is described as:

> This high value at low penetration is largely due to the ability of solar resources to reduce the amount of new non-renewable capacity that is built, leading to a high capacity value. The magnitude of the capacity value of solar resources depends on the coincidence of solar generation with times of high system need, the cost of generation resources that would otherwise be built, and decisions regarding the retirement of older, less efficient conventional generation.[23]

Specifically LBNL indicates the capacity value of PV is higher than the capacity value of a combined cycle gas turbine until the PV penetration rate reaches the 5 to 10 percent penetration level. The penetration of NEM PV in SDG&E's territory is currently about 1 percent.

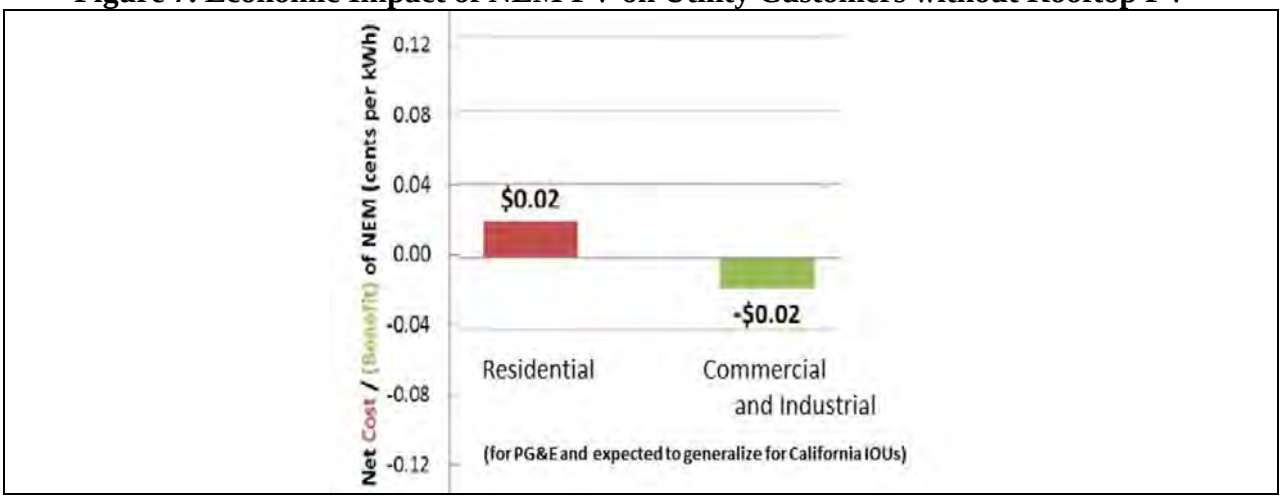
Q. Would rooftop solar impose new costs on non-solar ratepayers?

A. No. Despite SDG&E claims to the contrary, net metering (NEM) imposes no net costs on utility customers without NEM PV systems, as shown in Figure 7.

SDG&E co-authored a study of that estimates the 2010 rooftop PV potential in San Diego County at more than 4,400 MWac.[24] 4,400 MWac is equivalent to SDG&E's one-hour peak load. [25] The only potential brake on continued rapid growth of NEM rooftop PV in the San Diego local area is the NEM cap. Assuming California continues to increase its NEM cap as it has done in the past to accommodate foreseeable near-term growth

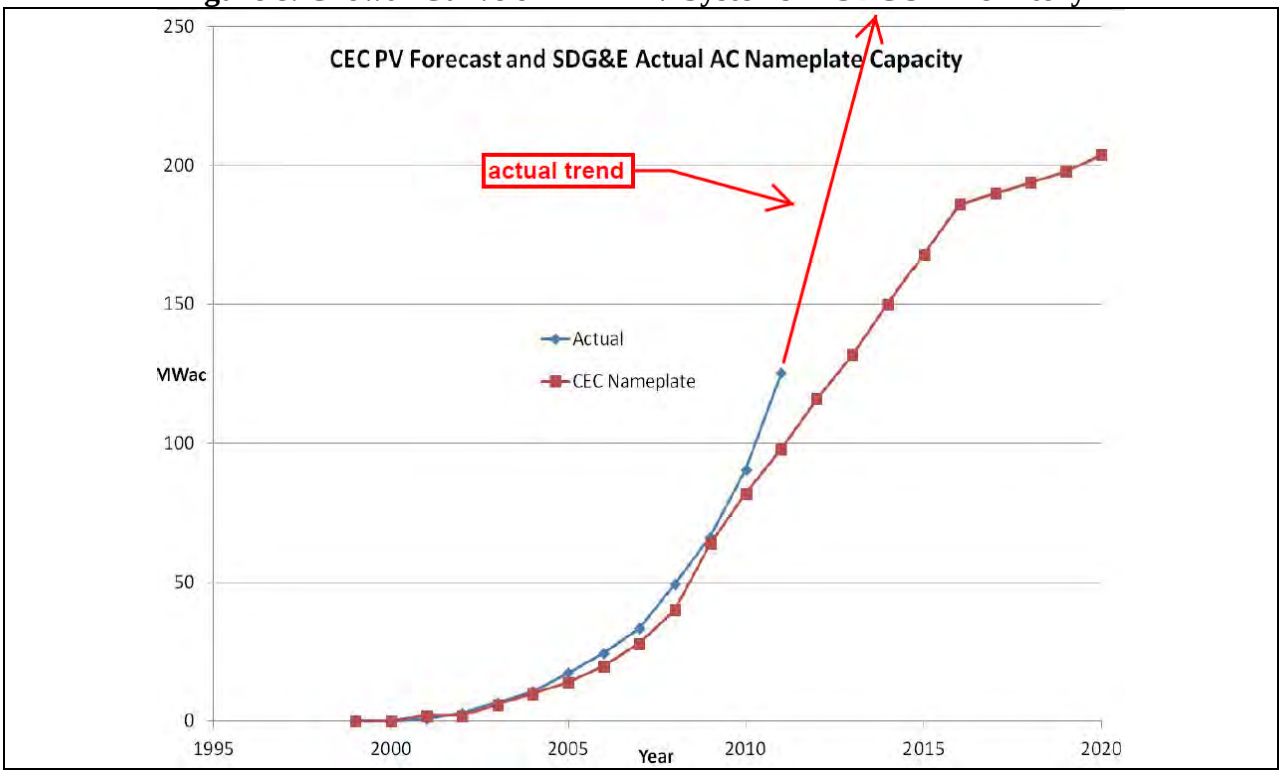
[22] A. Miller and R. Wiser – Lawrence Berkeley National Laboratory, *Changes in the Economic Value of Variable Generation with Increasing Penetration Levels: A Pilot Study of California* (PowerPoint summary), June 2012.
[23] A. Miller and R. Wiser – Lawrence Berkeley National Laboratory, *Changes in the Economic Value of Variable Generation with Increasing Penetration Levels: A Pilot Study of California* (report), June 2012, p. 6.
[24] San Diego Regional Renewable Energy Study Group, *Potential for Renewable Energy in the San Diego Region*, August 2005, Chapter 2: Solar Photovoltaic Electric. See: www.renewablesg.org.
[25] CAISO OASIS database. SDG&E 2011one-hour peak was 4,355 MW on September 7, 2011 (HE 16).

Figure 7. Economic Impact of NEM PV on Utility Customers without Rooftop PV[26]



in NEM PV systems, SDG&E territory would add in the range of 1,000 MW of NEM PV systems by 2020. Figure 8 shows the growth curve for NEM PV systems in San Diego.

Figure 8. Growth Curve of NEM PV Systems in SDG&E Territory[27]



[26] GreenTech Media, *CPUC on verge of major decision about solar's net metering*, May 15, 2012. Graphic from: Crossborder Energy, *Re-evaluating the Cost-Effectiveness of Net Energy Metering in California*, December 22, 2011, Figure 3, p. 10. See: http://votesolar.org/wp-content/uploads/2012/01/Re-evaluating-the-Cost-effectiveness-of-Net-Energy-Metering-in-California-1-9-2012.pdf.

[27] J.C Thomas – SDG&E, *San Diego/Solar Stakeholder Collaboration Rates & Educational Overview*, January 25 & 27. 2012, p. 48.

SDG&E currently has about 15,000 customers with NEM PV systems.[28] This is about 1 percent of SDG&E's 1.4 million customers. SDG&E projects that at a 15 percent NEM adoption level, the cost to non-NEM customers would be $120 million in additional transmission and distribution charges shifted from NEM customers to non-NEM customers.[29] As shown in Figure 7, at a 1 percent penetration rate, NEM PV systems are producing 120 MW of nameplate capacity. At 15 percent penetration, assuming a linear relationship, NEM PV systems will have a nameplate capacity of 1,800 MW in SDG&E territory. Without questioning here the validity of the SDG&E "cost shift" dollar amount, if 1,800 MW of NEM PV capacity imposes $120 million per year in cost shift to non-NEM customers, then 600 MW of NEM PV capacity would impose a proportionately smaller cost shift of $40 million per year.

The CEC estimates the fixed cost of new peaking capacity at approximately $283/kW-yr.[30] 300 MW of new peaking resources have fixed cost, which will be borne by SDG&E ratepayers, of $85 million per year over 20 years.[31] 600 MW of NEM PV capacity in the San Diego local area would provide at least 300 MW of capacity that is reliably available at times of peak demand. It would be far more economically beneficial to SDG&E ratepayers collectively to locate 600 MW of NEM PV capacity in the San Diego local area under the existing NEM tariff structure and not build 300 MW of peaking natural gas-fired resources to address the lack of solar resources in the local area.

Regarding distributed PV generally, the Commission observed with its approval of the PG&E 500 PV project that:[32]

> "This solar development program has many benefits and can help the state meet its aggressive renewable power goals," said CPUC President Michael R. Peevey. "Smaller scale projects can avoid many of the pitfalls that have plagued larger renewable projects in California, including permitting and transmission challenges. Because of this, programs targeting these resources can serve as a valuable complement to the existing Renewables Portfolio Standard program."

[28] Ibid, p. 48.
[29] Ibid. p. 51.
[30] CEC, *Comparative Costs of California Central Station Electricity Generation*, January 2010, Table B-4, p. B-5.
[31] $300/kW-yr x 450,000 kW = $135 million per year.
[32] CPUC Press Release – Docket A.09-02-019, *CPUC Approves Solar PV Program for PG&E,* April 22, 2010.

PV should be counted towards meeting Resource Adequacy peak needs. The CEC has recognized the value of energy generated from distributed PV as a cost-effective substitute for natural gas-fired peaking generation. The CEC denied an application for a 100 MW natural gas-fired peaking gas turbine plant, the Chula Vista Energy Upgrade Project (CVEUP) in San Diego County, in June 2009. The application was denied in part because the CEC opined that rooftop PV could potentially achieve the same objectives for comparable cost.[33]

This June 2009 CEC decision implies that any future applications for gas-fired generation in California should be measured against using distributed PV to meet the demand. The final CEC decision in the CVEUP proceeding states:[34]

"Photovoltaic arrays mounted on existing flat warehouse roofs or on top of vehicle shelters in parking lots do not consume any acreage. The warehouses and parking lots continue to perform those functions with the PV in place. (Ex. 616, p. 11.). . . . Mr. Powers (expert for intervenor) provided detailed analysis of the costs of such PV, concluding that there was little or no difference between the cost of energy provided by a project such as the CVEUP (gas turbine peaking plant) compared with the cost of energy provided by PV. (Ex. 616, pp. 13 – 14.). . . . PV does provide power at a time when demand is likely to be high—on hot, sunny days. Mr. Powers acknowledged on cross-examination that the solar peak does not match the demand peak, but testified that storage technologies exist which could be used to manage this. The essential points in Mr. Powers' testimony about the costs and practicality of PV were uncontroverted."

The CEC concluded in the CVEUP final decision that PV solar arrays on rooftops and over parking lots may be a viable alternative to the gas turbine project proposed in that case, and that if the gas turbine project proponent opted to file a new application, a much more detailed analysis of the rooftop PV alternative would be required.

Numbers from the California Solar Initiative demonstrate high on-peak availability for distributed PV, at least 50 percent.[35] Solar PV is predictably available during periods of peak demand. The Commission FEIR/FEIS for the Powerlink project conservatively

[33] CEC, Chula Vista Energy Upgrade Project - Application for Certification (07-AFC-4) San Diego County, *Final Commission Decision*, June 2009.
[34] *Id.* at pp. 29-30.
[35] *See* Itron, *CPUC CSI Report* at p. 5-6 to 5-10 (June 2010) http://www.cpuc.ca.gov/NR/rdonlyres/70B3F447-ADF5-48D3-8DF0 5DCE0E9DD09E/0/2009_CSI_Impact_Report.pdf

assumes 50 percent of nameplate PV capacity is available at peak.[36] The reason for this is the fact that peak production from a fixed PV array occurs at mid-day and the demand peak generally occurs in mid-afternoon.

Q. Do remote wind and solar projects impose high indirect costs on ratepayers that are not imposed by local solar?

A. Yes. SDG&E's $2 billion Sunrise Powerlink transmission was largely justified on importing solar power from Imperial County. Expansion of the Sunrise Powerlink and Southwest Powerlink transmission corridors is proposed to increase imports of wind and solar from East County and Imperial County. The high cost of new transmission lines and transmission upgrades to move remote wind and solar to San Diego, and the justification of new local gas-fired peaking plants due in part to the failure to add sufficient local solar, make the emphasis on remote wind and solar resources more costly to the consumer than local solar.

Q. Is the San Diego County wind resource available during summer peak demand period?

A. No. Due to the nature of the wind resource in the San Diego area, there is relatively less wind power generated in the summer months when electricity demand is highest, and even less produced during the summer mid-afternoon peak hours. This phenomenon is shown in Figure 10, the month-to-month wind energy production from the 50 MW Kumeyaay wind farm in eastern San Diego County, and Figure 11, a SDG&E peak summer day demand curve and 24-hour summer wind output curve for San Diego-area wind resources.[37] What this data means is that relatively little of potential San Diego area wind power will be operating during summer peak demand periods.

---

[36] CPUC FEIR/FEIS for SDG&E Sunrise Powerlink Project, *E.5 New In-Area Renewable Generation Alternative*, October 2008, p. E.5-8. "In its PEA, SDG&E discounts the nameplate rated capacity of solar PV systems by 50 percent because only a fraction of a PV system's rated capacity is available during the utility's hour of peak demand." See: http://www.cpuc.ca.gov/environment/info/aspen/sunrise/toc-feir.htm. See also SDG&E 5/10/12 Response to CEJA's Second Set of Data Requests, Q14. The NQC of the NRG Borrego Solar project will be: 16 MW ÷ 26 MW = 0.62 (62 percent).

[37] The summer wind output curve in Figure 11 assumes a hypothetical future scenario where San Diego County's full wind potential of 1,350 to 1,530 MW is developed (see: www.renewablesg.org). Even with this high level of installed wind capacity, the wind output during summer afternoon peak demand hours is no more than 300 MW as shown in Figure 11.

Figure 10. Month-to-Month 2008 Wind Energy Production, Kumeyaay Wind Farm[38]

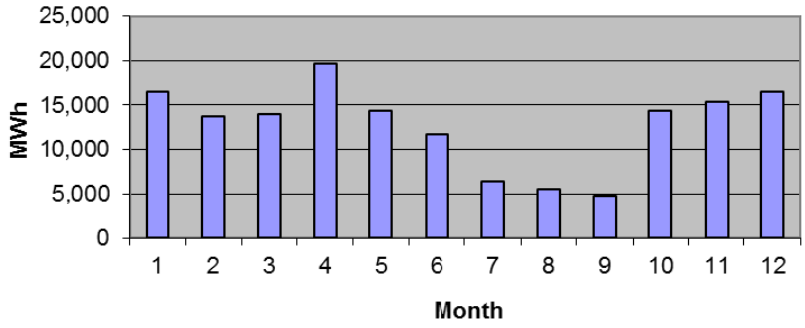
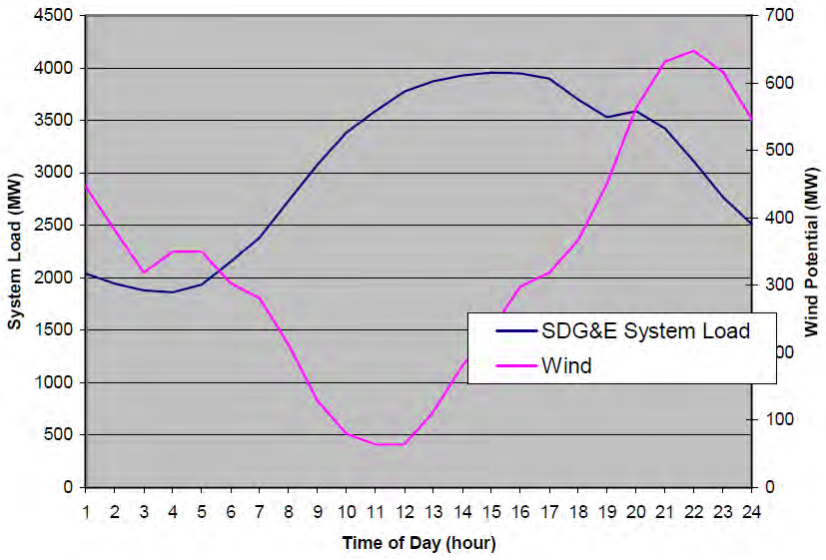


Figure 11. SDG&E Peak Summer Load and Summer Wind Profile[39]



[38] U.S. DOE, Energy Information Administration, 2008 Form 923 Monthly Time Series, Kumeyaay Wind Farm.
[39] San Diego Regional Renewable Energy Study Group, *Potential for Renewable Energy in the San Diego Region – Chapter 4: Wind*, August 2005. The wind output shown on the right hand vertical axis assumes a total potential installed wind capacity of 1,350 to 1,530 MW. The near-term installed wind potential in the San Diego region is 206 MW, one-seventh the wind potential assumed in creating the purple wind output curve in Figure 4. See: http://www.renewablesg.org/.

EXHIBIT 2

NRG Energy's CEO Discusses Q4 2010 Results - Earnings Call Transcript

February 22, 2011 | about: NRG

Executives

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Christian Schade - Chief Financial Officer and Executive Vice President

Mauricio Gutierrez - Chief Operating Officer and Executive Vice President

Nahla Azmy - Vice President of Investor Relations

Jason Few - SVP of Mass Markets and Operations, Reliant Energy, Inc.

Analysts

Anthony Crowdell - Jefferies & Co

Dan Eggers - Crédit Suisse AG

Brandon Blossman - Tudor, Pickering, Holt & Co. Securities, Inc.

Charles Fishman - Pritchard Capital Partners, LLC

Jonathan Arnold - Deutsche Bank AG

Ameet Thakkar - BofA Merrill Lynch

Theodore Durbin - Goldman Sachs Group Inc.

James Dobson - Wunderlich Securities Inc.

Brian Chin - Citigroup Inc

NRG Energy (NRG) Q4 2010 Earnings Call February 22, 2011 9:00 AM ET

Operator

Good day, ladies and gentlemen, and welcome to the Fourth Quarter and Full Year 2010 NRG Energy Earnings Conference Call. My name is Deanna, and I'll be your operator for today. [Operator Instructions] And I would now like to turn the call over to your host for today, Ms. Nahla Azmy, Senior Vice President of Investor Relations. Please proceed.

Nahla Azmy

Thank you, Deanna. Good morning, and welcome to our Fourth Quarter and Full Year 2010 Earnings Call.

This call is being broadcast live over the phone and from our website at www.nrgenergy.com. You can access the call presentation and press release through a link on the Investor Relations page of our website. A replay of the call will also be available on our website. This call, including the formal presentation and the question-and-answer session, will be limited to one hour. In the interest of time, we ask that you please limit yourself to one question with just one follow-up.

And now for the obligatory Safe Harbor statement. During the course of this morning's presentation, management will reiterate forward-looking statements made in today's press release regarding future events and financial performance. These forward-looking statements are subject to material risks and uncertainties that could cause actual results to differ materially from those in the forward-looking statements. We caution you to consider the important risk factors contained in our press release and other filings with the SEC that could cause actual results to differ materially from those in the forward-looking statements in the press release and this conference call.

In addition, please note that the date of this conference call is February 22, 2011, and any forward-looking statements that we make today are based on assumptions that we believe to be reasonable as of this date. We undertake no obligation to update these statements as the result of future events except as required by law.

During this morning's call, we will refer to both GAAP and non-GAAP financial measures of the company's operating financial results. For complete information regarding our non-GAAP financial information, the most directly comparable GAAP measures and a quantitative reconciliation of those figures, please refer to today's press release and this presentation.

And now with that, I'd like to turn the call over to David Crane, NRG's President and Chief Executive

Officer.

David Crane

Thank you, Nahla, and good morning, everyone, and welcome to our year-end 2010 earnings call. Today, with me, and participating in the presentation is Mauricio Gutierrez, the company's Chief Operating Officer; and Chris Schade, the company's Chief Financial Officer. Also with me today and available to answer questions are Jason Few, who runs NRG's retail company, Reliant; and Chris Moser, who runs the commercial operations function for this company.

So without further ado, to begin -- so ladies and gentlemen, current and perspective shareholders of NRG, as we speak today, it's now been 32 months since natural gas prices began their relentless fall and the economy at large entered into a great recession, the likes of which, I'm sure none of us wish to experience again in our lifetimes, yet the financial performance of NRG during this period has been superb. And that financial performance has been built on the foundation of an equally exceptional operating performance across all phases of our operations and across all our regions.

In 2010, the second full year of the great recession, our financial performance surpassed all previous years of company results, save for fiscal year 2009, which was of course the first year of the great recession, a year in which we performed spectacularly, achieving both record financial performance and the acquisition of Reliant.

While I am, for the most part, extremely pleased with both the company's financial and its operating performance during 2010, I am acutely mindful of the fact that NRG shareholders did not see any of the benefits of our exceptional performance and share price appreciation during that year. As a management team, we recognize that we have a long way to go in presenting NRG's present value and future potential to the market.

In this presentation and in subsequent presentations that Mauricio, Chris and I will be making during the spring Investor Relations season, we intend to make a concerted effort to explain the NRG value proposition. From the competitive strength of our core businesses, even in a low commodity price environment, to the meaningful and measurable value of our growth opportunities, as well as our effective risk mitigation in areas which we believe to be of concern to the investment community.

So starting with 2010, as summarized on Slide 3, the company continued to generate a very high level of EBITDA in excess of $2.5 billion and also throw off a substantial amount of free cash flow. Indeed, in regard to what should perhaps be the most important metric to shareholders, free cash flow yield, our free cash flow yield for 2010 was a robust 29%, making our seven-year average exceed 23%. And in response to some people who said that we should measure free cash flow for these purposes after both maintenance and environmental CapEx, we have done it in that way but before growth CapEx.

A substantial amount of that free cash flow yield was redeployed back to stakeholders in the form of debt repayment and through our 2010 share buyback program and also into various growth initiatives, which we'll discuss in a minute. But over $650 million of excess free cash flow was returned as cash into the company's coffers, with the result being that our liquidity position at the end of 2010, $4.3 billion of total liquidity with $3 billion of cash on hand, is stronger than it has ever been.

It has always been my position that next to safety, the most important thing that we do as executive management at NRG is capital allocation, and given the amount that we are investing on an annual basis and the record amount that we currently have available either to invest in growth or to return to our equity and debt stakeholders, capital allocation has never been more important than it is now. As

such, I'm going to focus the greater part of my remaining remarks on capital, which we expect to invest in our growth initiatives in the months and years to come. Chris will focus a good deal of his comments on capital to be returned to stakeholders.

In terms of the allocation of capital to our growth initiatives, it's important to start with the obvious point that we want to invest the company's capital in assets and initiatives that not only are likely to yield a return significantly in excess of our risk-adjusted weighted average cost of capital, but also in businesses and initiatives which advance the company's strategy.

As depicted on Slide 4, the company's long-term strategy for some time has been twin-tracked. First, to strengthen and enhance our generation to retail business in our core markets through superior operating performance, continued implementation of our first-lean-enabled, long-term hedging program and pursuit of both select acquisitions and the repowering of our older facilities with advantage locations inside load pockets in our core markets. This comply of our strategy which we have pursued with relentless consistency and a high degree of effectiveness for the past five years was joined a couple years ago with a supplemental strategy that is overtly green and designed to take advantage of the societal trend towards sustainability.

This sustainability trend is, in our opinion, about to accelerate as a result of the emergence of various consumer-oriented disruptive technologies, which will make green energy at the consumer level the focal point of sustainability. We made considerable progress on both strategic fronts during 2010, with substantial advances across every facet of our sustainability initiative.

From our rollout of our eVgo network in Houston, which is centered around an innovative fueling package in approach to electric vehicle infrastructure that is already being replicated in other locations through the smart meter e-Sense applications now being sold by Reliant in quantity, to our unique approach to CCS/EOR being funded in collaboration with the DOE at our Parish facility in Texas. All of these initiatives are exciting and off to a good start. All will, I am confident, return considerable value to NRG to shareholders in the medium term.

You will hear more about these initiatives in the future but not today, because today, consistent with my theme, I want to concentrate my comments on the growth initiatives which are more immediate and which are key priorities for deployment of your investment capital during 2011. This is shown on Slide 6.

By way of background, in 2010, we committed substantial growth capital in four general areas: Zero carbon renewables, with an emphasis on solar; new advanced nuclear development; conventional gas-fired acquisitions and repowerings; and green retail acquisitions in the form of Green Mountain Energy. All four are likely to be areas of additional capital expenditure in 2011 but with very different investment profiles from 2010.

First, we expect an acceleration and significant expansion in our equity capital invested in high-growth, high-return solar projects. At the greater part of our utility scale, solar portfolio should achieve financial close and enter the construction phase during 2011.

Second, investment in conventional generation assets should be relatively flat year-on-year, as spending on GenConn and Cottonwood should give way to spending on El Segundo, but conventional CapEx could increase depending on our development success at Astoria, Saguaro or Encina and also, whether we find any strategic assets that can be acquired at value.

Third, capital invested in green retail should drop precipitously as obviously the big expenditure in this

area in 2010 with the acquisition of Green Mountain. The amount of capital that we will be investing in and around Green Mountains business in 2011 or to expand into new geographic markets, bigger customers segments and new complimentary green product offerings is fairly minimal.

And finally, and similarly and perhaps, contrary to popular investor belief, even if the STP nuclear development project stays on course, the development capital projected to be required of NRG in 2011 will be far less than half of what we invested in 2010 and will be a mere fraction of what we will be investing in solar projects and other capital allocation alternatives.

So this is a lot to digest, so let's go through a little bit more slowly, starting on Slide 7 with Green Mountain. Four months ago, we paid $357 million for a business that we expect to contribute $70 million, $80 million of EBITDA in 2011, plus, we expect Green Mountain to continue to deliver on a 20-plus percent compound annual growth rate trajectory that they have delivered for the past decade. But we didn't acquire Green Mountain just to continue with business as usual. We wanted to take advantage, and we wanted them to take advantage of what we believe are very substantial synergies between Green Mountain and NRG.

Essentially, we want Green Mountain to accelerate the depth and breadth of their growth in close cooperation with us on the same path that they were following on their own, which means expansion into a high retail price Northeast markets, where they start with a natural green-leaning constituency, also, expansion into the larger Commercial segment of the C&I market than they have previously sought to access. And finally, expansion of their value-added product offerings to include distributed green generation.

It's early days yet, but on at least the first two of these, they are already beginning to bear fruit. Green Mountain has established a small but fast-growing footprint in New York Zone J, and in terms of larger C&I customers, they have won landmark business like the Empire State Building. We expect to be reporting on these and many more successes from and with Green Mountain as the year progresses.

Turning to conventional generation on Slide 8. 2010 was an uneven year, with the successful acquisition of Cottonwood and the repowering at Devon and Middletown, balanced by the missed opportunities surrounding Dynegy's California asset. Cottonwood and Devon have been smoothly integrated into our South Central and NEPOOL lineups respectively, and we are very pleased with the results today.

Looking forward to 2011, we're very focused on the successful repowering of El Segundo, an advantage which we hope to derive from having a modern, fast-start, low-heat rate, combined-cycle plant inside the Los Angeles basin load pocket. Beyond El Segundo, we hope to make progress on similar repowering efforts at Astoria in New York City and Encina in San Diego County. Beyond our own Repowering pipeline, the capital we deploy in the acquisition of conventional power plants, obviously, will depend on market conditions and asset availability in our core regions.

While the acquisition market is lumpy, generalities are difficult and predictions are often proved wrong, the optimism I once held at the first half of 2011 would be a buyer's market for CCGTs in the United States has largely dissipated. I see no sign of a flood of assets on the market and the combined cycle of transactions which have been announced recently have been priced at levels significantly above what we could justify to ourselves or explain to our shareholders.

With respect to our nuclear project, while important steps forward have occurred in several areas since our last earnings call, very little of it can be seen with the naked eye. As before, really all critical

aspects of the STP 3 & 4 project run off of our receipt of an acceptable conditional loan guarantee from the government. Certainly, it is a challenge for us to complete meaningful discussions about PPAs with potential off-takers, while the loan guarantee application remains pending.

So our exit ramp analysis, which is set forth on Slide 9, remains largely unchanged from the previous quarter. Likewise, our viewpoint with respect to NRG's continued participation in the project remains at the most challenging of these hurdles, which is the long-term off-take requirement, effectively needs to be addressed no later than the third quarter of 2011 before the project enters the substantial pre-construction phase.

As such, we reiterate the view which is clearly articulated in both our 10-K and in today's earnings release, that NRG will be in a position by late this summer to make a final decision on our continued financial participation in this project. At that point, the market should have substantially greater clarity about the prospects for this project and NRG's role in it.

While we understand that there is skepticism amongst some investors that the project can go forward in the current low gas price environment, we nonetheless, believe it might be helpful to you for us to outline as shown on Slide 10 the future capital commitment of NRG in respect to this project, should it stay on track, with NRG continuing to support it financially.

The overall message is that due to a combination of first, the very substantial sum that NRG has previously committed to the project development, particularly during the first half of 2010 after the settlement with CPS. Second, taking into account our expectation of an optimal hold amount in the project for NRG of approximately 40%, which is down from the 67% that we will own if and when TEPCO invests in a project post-loan guarantee award. And third, due to the value ascribed to NRG for its contribution of the site, NRG's cash commitment to the project going forward is less than what otherwise would be suggested by our projected ownership level.

In summary, should the project proceed to financial closing, the total cash commitment for NRG at our 40% hold level should be something just short of $800 million in aggregate, including cash invested to date. Beyond that, we are likely to have an LC commitment to a standby equity crossover line facility that will be fixed. And while that number has not yet been finally fixed, you should be thinking in the range of a few hundred million dollars maximum.

In exchange for this size investment in STP 3 & 4, we expect cash flow from dividends and tax benefits in the range of $500 million a year for the first several years of operations. Obviously, this is a very attractive return but one which we believe is well just justified given the extraordinary challenges of the undertaking.

Now pulling it back from where we hope the project will be in 2016 or 2017 to where we are here in the first quarter of 2011, you should be focused on what happens after announcements of acceptance of the loan guarantee. As the loan guarantee acceptance naturally will trigger certain funding obligations from our partners, NRG's share of cash development spent for the remainder of the development phase should approximate $50 million for all of 2011 and half that for 2012.

While our perspective 2011, 2012 development standard is perhaps substantially less than many in the market were anticipating, it remains a lot of money to us, and we're taking very seriously our commitment to retain our financial discipline around this project and prevent exposure of our balance sheet beyond the specific commitments that I've outlined in this presentation.

Now turning to Slide 11, last but certainly not least, there is the solar pipeline. I've said many times,

and I'll repeat here, that in my 20 years in this business, I had never seen investment opportunities in this sector that offer more attractive combination of high returns, low construction risks, long-term PPAs and repeatable business opportunities than the utility-sized solar projects that we currently have in our advanced development portfolio.

As such, we intend to do as much of this business as we can get our hands on, with the result being that by the end of this year, we may well have a total initial equity investment in our solar portfolio that exceeds the total amount that we may ever invest in STP 3 & 4 at very attractive near-term returns. The limiting item for us in terms of these solar investments is our ability on our own to make optimal use of the considerable tax benefits which will be generated by these projects. This is a topic that Chris Schade will discuss in a few minutes.

What I will end by saying is that this extraordinary pipeline of utility-sized solar projects, which our colleagues at NRG Solar have managed to develop or acquire, provides us with a truly unique opportunity to develop over the next few years a solar portfolio of true scale and significant benefit, even in the context of the larger portfolio of NRG.

Ultimately, however, we fully recognize that the current generation of utility-sized solar and wind projects in the United States is largely enabled by favorable government policies and financial assistance. It seems likely that much of that special assistance is going to be phased out over the next few years, leaving renewable technologies to fend for themselves in the open market.

We do not believe that this will be the end of the flourishing market for solar generation. We do believe it will lead to a stronger and more accelerated transition from an industry that is currently biased towards utility-sized solar plants to one that's focused more on distributed and even residential solar solutions on rooftops and in parking lots.

We are already planning for this transition now within NRG, so that any potential decline in either the availability of utility-sized solar projects or in the attractiveness of the returns being realized on these projects, will be exceeded in aggregate by the increase in the business we are doing on smaller distributed and residential solar projects through our Green Mountain and even our Reliant retail sales channel.

With that, I'll turn it over to Mauricio.

Mauricio Gutierrez

Thank you, David, and good morning, everyone. NRG continued its strong operating and commercial performance during the fourth quarter, making 2010 one of NRG's best years. Slide 13 highlights a few of the key accomplishments achieved in 2010.

Starting with safety, we're particularly pleased with our record performance this year. Our OSHA recordable rate improved 26% over 2009. Our top performance remained strong with 90% availability of our baseload fleet, just shy of our 2009 level. This performance was achieved despite a forced outage event on our STP nuclear plant in November, which I will cover in more detail in the next slide.

On the environmental front, we delivered our second best year, and our FORNRG program far exceeded our 2010 goal. As I mentioned to you on our last call, controlling our cost is a priority, given the challenging economic environment our industry is facing.

Our Commercial Operations Group increased our hedge levels in 2011 and continues to look for opportunities to catch the odd years of favorable prices. We successfully transitioned to the Nodal Market in ERCOT and began integrating Green Mountain Energy and the Cottonwood combined cycle plant into our portfolio.

With respect to our projects under construction, the Indian River Unit 4 environmental back-end control project continues to be on track and on budget to be operational by January 2012. Our Middletown project in Connecticut received all major equipments in the fourth quarter and continues to be on schedule for operation this summer. Finally, the El Segundo Energy Center completed aboveground demolition of two existing units and secured major equipment orders. El Segundo is on track to be operational by the summer of 2013.

Turning to our plant performance metrics on Slide 14. Safety continues to be our number one priority. We are very proud to report that we achieved top decile in the industry, making 2010 our best OSHA recordable year. We have 25 sites with no injuries and nine sites certified or recertified as OSHA VPP Star worksites.

Net generation decreased by 6% in the fourth quarter due to mild weather across Texas and a 22-day on-plan outage at STP Unit 2 during the month of November. The forced outage event was the result of a breaker failure during routine testing and was extended to repair a reactor coolant pump seal. In order to prevent recurrence, similar electric components were checked in both units. Unit 2 has operated without any issues since it was brought back to service on November 26.

For the full year, net generation was flat from 2009 levels. Increased generation in the Northeast and South Central regions driven by the strong summer weather and the addition of Cottonwood, were offset by lower generation in California and Texas.

For 2010, our coal fleet availability finished the year above the sub-quarter performance level for the industry. WA Parish led the fleet with 92.6% availability factor, and Limestone had the best reliability for the year, with a 1.6% forced outage rate.

Our FORNRG 2.0 program exceeded the 2010 goal by $49 million, and it is on track to achieve our goal of $150 million by 2011, one year earlier than planned. Savings were achieved through a combination of reliability, capacity and efficiency improvements at generating assets and cost savings across our corporate and regional groups.

Turning to our retail operations on Slide 15, we closed out the year with another strong quarter. Volumes and margins were consistent with our forecast, while Operations delivered better-than-expected asset management and lower operational costs.

The Mass segment continues to drive segment improvement in net customer attrition with a 57% reduction in the fourth quarter versus 2009. This result was driven by marketing, sales and introduction of innovative products to meet our customer needs.

In 2010, we led Texas in innovation, enrolling over 175,000 customers on our Reliant e-Sense product and services that utilize smart grid technology. We also introduced new and unique offers like carbon-state [ph] and home protection products, adding not only incremental EBITDA but increased customer stickiness.

We continue to maintain the lowest PUC customer complaint rate while balancing customer counterpricing. Throughout 2010, we aligned to successfully demonstrate that we have stabilized

customer attrition and expect to achieve zero net attrition in 2011.

In the C&I segment, both renewal and new deal win rates continue to improve. We have expanded our business in several Northeast states where we can leverage existing energy assets and increase product offerings to include products such as backlog generation. These provides a solid platform to grow our business in 2011.

Business continues to show some fundamentals as you can see on Slide 16. Weather-normalized demand grew by 2% year-on-year and ERCOT set a new winter peak low of 57 kilowatts in February, an increase of almost 2.5% from the previous record. I'd like to take this opportunity to address the events in Texas on February 2.

The men and women of NRG Texas worked very hard to help meet the high demand for electricity due to the extreme cold conditions, increasing our generation by more than 60% from the previous day. Although we had some operational issues, of the approximately 9,500 megawatts of power we had available in Texas during the low-shed event, we maintained between 97% and 91% of that capacity online. I want to thank all our employees in Texas for their dedication and extraordinary efforts during these events.

Now moving on to reserve volumes in ERCOT, we see a positive feature of our generation portfolio with reserved margins tightening faster than expected. This is to some extent reflected in the forward heat rates, as you can see on the chart on the lower right-hand quarter. We believe this trend will continue, given the robust growth and the expectation that asset retirement will outpace new builds. We have not seen as much coal-to-gas switching in Texas as we have in the Northeast and Southeast regions. In fact, cash generation was down year-on-year due to increases in new coal and wind generation in Texas.

In the Northeast, the back-end market continues to make some news. In New York, the recent FERC order to increase cost of new entry should provide a boost to capacity prices in New York City and rest of state, benefiting our New York portfolio. In PJM, prices remain uncertain until more clarity is given around the minimum offer price rule, the subsidized generation in New Jersey and Maryland and review demand outlook.

Moving on to Slide 17, you can see our detailed plan to control air emissions for each of our coal plants. As stated in our last earnings call, our plan is to invest approximately $720 million through 2015 in environmental projects tailored to comply with future regulations.

Just to remind everyone, the proposed CAIR rule does not require additional capital for compliance. The HAP MACT proposed rule should be released in mid-March, and as you can see in the table, our plant considers mercury controls on all our coal units.

Intake modifications and repowering are expected to meet once for cooling requirements. We only have dry fly ash disposals at our all coal facilities. And finally, in most of our facilities, we burn low sulfur, low chlorine PRB coal.

Moving on to our hedge profile and commodity sensitivities on Slide 18. Our baseload portfolio is now 100% hedged in 2011 and 50% hedged in 2012, providing the protection in the short term where gas prices continue to be weaker given the oversupply situation. Beyond 2012, we choose to remain significantly open.

After two years of low gas prices, we believe the downside risk is limited. Our combination of

incremental demand from the power sector, particularly in light of possible coal plant retirements, some signs of the interest rate by producers, indication that drilling to home acreage may be ending, and a move from dry to wet gas production will provide better opportunities to catch our baseload portfolio in the future.

With respect to retail, we have increased our pipe load to 66% in 2011 from 57% in the third quarter. We continue to match as much generation load as possible to start maximum synergies between our retail and wholesale portfolios.

Our power and coal hedges continue to be well managed in 2011 and 2012. Given the shape of the coal curve and steep contango, we have not added any additional occasions since the last quarter. We also remain well hedged in terms of coal transportation now for some time.

Our sensitivity to commodity prices is agreeable for 2011, with 2012 to 2015 largely unchanged from last quarter. Let me remind you that this sensitivity is around our baseload portfolio. Interest expense, our portfolio is well-positioned to benefit, particularly, in the Texas and South Central regions.

With that, I will turn it over to Chris who will discuss our financial results.

Christian Schade

Thank you, Mauricio, and good morning. Beginning with the financial summary on Slide 20, full-year 2010 adjusted EBITDA was $2.514 billion, just shy of the record 2009 adjusted EBITDA of $2.618 billion and within our previously stated guidance of $2.5 billion to $2.55 billion. As a result of our continued strong operating performance, adjusted cash flow from operations for 2010 was robust at $1.76 billion.

The company's liquidity position at year end, excluding funds deposited by counterparties, stood at nearly $4.3 billion, a $458 million increase from December 31, 2009, liquidity of approximately $3.8 billion. Our cash balance at year end 2010 available for both working capital as well as our 2011 capital allocation program was approximately $2.9 billion.

Now turning to a summary of our 2011 guidance in Capital Allocation Plan. First, we reaffirmed the preliminary 2011 EBITDA guidance range of $1.75 billion to $1.95 billion. Second, and as part of our 2011 capital allocation program, we are planning to repurchase $180 million of common stock, and complete $240 million of term loan debt repayments and $39 million for additional facilities, all of which is consistent with NRG's commitment to return excess capital to its stakeholders. Third, in 2011, in addition to the amount deferred from 2010 as a result of extending the cash grant availability, we are currently planning to commit an additional $640 million of net investment to advance our Repowering and renewable development program, particularly, utility-scale solar.

Now turning to a more detailed review of 2010 adjusted EBITDA result from Slide 21. The company reported near record results of $2.514 billion adjusted EBITDA, only $104 million lower than the 2009 adjusted EBITDA of $2.618 billion. These results were achieved despite the decline in forward prices across all of our regions and clearly benefited from our wholesale generation hedging program and the continued strong performance of Reliant Energy.

During the year, Reliant Energy contributed $711 million of adjusted EBITDA. Comparatively, these results are lower by $158 million from 2009 as we overlined for only eight months of that year. The year-on-year decline was driven by an 18% decline in Mass margins, which were the direct result of price reductions enacted following the acquisition, as well as lower margins on customer renewals and

new customer acquisitions reflective of the competitive market. All told, for 2010, Reliant saw net customer attrition rates improve to 0.4% from 0.7% in 2009 with total customers at year end steady at 1.5 million.

The wholesale business meanwhile generated $1.8 billion in adjusted EBITDA, $173 million lower as compared to a record 2009 EBITDA of $1.976 billion. The comparative year-to-date decline is largely explained by a 32% drop in baseload hedge prices in the Northeast, as well as lower margins in Texas, caused by a 60% increase in fuel costs, due largely to higher coal transportation costs at our WA Parish facility. These results were partially offset by an increase in adjusted EBITDA of $28 million from the South Central region due to increases in generation and contracted sales.

Also increasing adjusted EBITDA were our newly acquired assets, including Green Mountain Energy, Cottonwood, Northwind Phoenix, South Trent Wind Farm, as well as the full year of operations from the Blythe solar project.

For the fourth quarter, the company reported adjusted EBITDA results of $444 million, a $45 million decline versus 2009. Reliant Energy contributed $117 million of adjusted EBITDA compared to $104 million for the fourth quarter of 2009. Reliant's quarterly results were favorable $13 million driven by an improvement in operating costs primarily due to better customer payment habits as related to a decrease in bad debt expense.

In the fourth quarter of 2010, our Wholesale Generation business contributed $327 million of adjusted EBITDA, a $58 million decline compared to fourth quarter '09. The change in results can largely be attributed to the following items: In the Northeast region, 35% lower hedge prices and a 25% decrease in generation resulting in a $57 million decline in energy margins quarter-over-quarter. The decrease in generation was largely a result of coal-to-natural gas switching and offsetting this decline in energy margins were favorable year-on-year operating and maintenance expenses of $13 million.

In Texas, the 10% decline in generation at the Limestone and WA Parish facilities due to lower power prices and reduced demand led to a 6% decline in overall generation for the region. Offsetting this decline were favorable year-on-year operating expenses of $17 million that included gain on land sales of $6 million in 2010.

Now turning to Slide 22. As I mentioned a moment ago, total liquidity at year-end 2010 excluding funds deposited by hedged counterparts remained strong at nearly $4.252 billion. Total cash stood at $2.959 billion, an increase of $653 million as compared to the 2009 year-end cash balance of $2.3 billion. The drivers of the cash increase included adjusted cash from operations of $1.76 billion and debt proceeds of $1.317 billion.

These increases were offset by several items: First, five completed acquisitions totaling about $1 billion, which included $507 million for Cottonwood generation station, $357 million for Green Mountain, $100 million for Northwind Phoenix, $32 million for South Trent Wind Farm and for the U.S. solar portfolio, 720 megawatts of development projects in nine states in California and Arizona. Second, debt and fee payments totaling $813 million, including Term Loan B payments of $453 million and a repayment of a common stock fund or CSF of $190 million.

And third, capital expenditures excluding NINA of $445 million, including $199 million of maintenance, $184 million of environmental, primarily related to the Indian River Air Quality Control System project, and $62 million of growth investments. For the full year, we made cash contributions to NINA totaling $170 million primarily in the first half of 2010. And finally, we completed share

repurchases of 8.5 million shares, totaling $180 million.

Now turning to 2011 guidance on Slide 23. Our EBITDA guidance remains unchanged from our November 24 range of $1.75 billion to $1.95 billion. Included in this guidance range are wholesale expectations of $1.2 billion to $1.3 billion, retail expectations of $480 million to $570 million, and Green Mountain of $70 million to $80 million. As Mauricio discussed earlier, we are about 100% hedged on our baseload generation for 2011 and are thus comfortable with our forecasted results.

As we look forward to our Wholesale business in 2012, we are currently in excess 50% hedged with a higher average price in 2011 as indicated in our SEC filings. Due to this position and based on the current forward curves, we expect flat to marginally lower year-on-year wholesale results in 2012 from 2011. These results will be supplemented with adjusted EBITDA of $85 million from our repowering and solar investments in 2012 that are not subject to market fluctuations.

For our retail business in 2011, our current expectations, assuming normal weather, are an EBITDA range of $480 million to $570 million, the decrease in 2011 guidance compared to current 2010 results is largely explained by lower unit margins in Reliant's Mass business. Reliant's C&I business margins are also expected to decline slightly, but be directly offset by higher terawatt-hours served, reflecting our continued dedication to this growing client base in both Texas and PJM.

Finally, we expect Green Mountain Energy to contribute $70 million to $80 million of EBITDA. We are very excited about enhancing the growth prospects for our Green Energy Retail business during the process of integrating the business with our growing renewables portfolio to enhance these future growth prospects.

During our Q3 earnings call, we discussed the 2011 free cash flow guidance of $425 million to $625 million, and we now currently anticipate free cash flow for 2011 to be in a range of $150 million to $350 million. The difference in guidance is largely explained by certain timing of solar projects, due to Congress extending the availability of cash grants for renewable projects through 2011. NRG postponed its large investments in solar projects from 2010 to 2011, resulting in $267 million of solar expenditures pushed into '11 and relates primarily to our Agua Caliente, Ivanpah and CVSR solar projects.

As we often like to emphasize, we are in a strong cash flow position based on Friday's closing stock price of $20.89 and our affirmed outlook. Free cash flow before growth yield currently stands at between 16% to 20%, or $3.36 to $4.17 per share.

Slide 24 shows the company's projected 2011 year-end cash position which we project to be about $2.5 billion. Beginning with the portion of the Capital Allocation Plan that includes share repurchases and debt repayments in 2011, the company intends to repurchase $180 million of common stock, which is within the constraint of the restricted payments basket; repay $240 million of debt related to our Term Loan B agreement; and approximately $39 million in other facilities. It's important to note that the company made a Term Loan B prepayment in November that totaled $200 million.

And finally, complete $907 million of capital allocation in the following projects: $50 million in NINA; $219 million for other Repowering investments including El Segundo, GenConn Middletown, eVgo, Texas Reliability and Princeton Hospital and $638 million for solar projects, net of cash grant proceeds, and including the $267 million of deferred payments from 2010.

During the third quarter conference call, I also mentioned that we usually maintain a minimum cash balance of $700 million largely for working capital margin requirements, the timing of cash payments,

of interests, property taxes, as well as equity for projects we have under construction throughout the year. Thus, for 2011, we estimate a balance of just over $1.8 billion to allocate between perhaps additional share repurchases, contingent on the restricted payments basket expansion, further investments of high-growth opportunities and continued opportunistic management of our debt structure.

On January 11, the company issued $1.2 billion of 7 5/8 senior notes due 2018 and announced the simultaneous cash tender for $1.2 billion of the outstanding 7 1/4 senior notes due 2014. As of January 25, nearly 945 million bonds have tendered, and the remaining 250 million will be redeemed by the end of February pursuant to the embedded coal price. As a result, we've improved our debt maturity profile, all of our public debt matures after 2016, and replace the restricted covenant package with one permitting greater efficiency and flexibility to return value to all NRG stakeholders.

On a go forward basis, we will continue to moderately embed in calls in the 2016 and '17 maturities and be opportunistic about replacing those bonds with less restricted covenant packages, similarly to how we handle the 2014 maturity.

Looking at NRG's combined Repowering and Solar portfolio and our EBITDA contribution on Slide 25, you can clearly see the benefit of the program with nearly $550 million of recurring contribution by 2015.

During the fourth quarter, our El Segundo Repowering project received prior approval from the California Public Utilities Commission for a ten-year Power Purchase Agreement with Southern California Edison. Commercial operation's expected in the summer of 2013.

Our large utility-scale solar projects will also begin to reach commercial operations between the summer of '13 and the first quarter of 2014, and these projects collectively are driving this EBITDA growth. These solar investments are attractive for their high-teens returns, very low construction risks and offtake agreement of 20-plus years with highly rated counterparties. We will continue to provide updates on the progress of these projects as they move into construction and operation.

As we continue to invest and grow our solar portfolio, it's important to highlight a few economic benefits created with these projects. Slide 26 shows how the combination of cash grant, maker's depreciation and strong cash flows from the PPAs for our projects result in a payback for our investments, in some cases by 2014, and retain stable cash flows for the remaining term of the PPAs.

Though we believe there will be a turnaround in commodity markets, we are mindful of our ability to create enough taxable income for us to fully absorb tax benefits created by these solar investments. There is clearly a limit to how much tax efficiency we could absorb in any one year before reducing the total project returns. As such, to both minimize the tax leakage and enhance our returns, in 2011, we will pursue new equity investors for our solar portfolio, who have both the appetite for tax benefits and seek investment to one of the largest utility-scale solar portfolios in the world. New equity investors would not only help to optimize our existing tax position but allow us to continue to invest in future projects with high returns.

We expect to launch this initiative soon and look forward to sharing the progress in the future. Now I'll pass it back to David for final comments.

David Crane

Thank you, Chris, and thank you, Mauricio. And so in conclusion, on Slide 28, we put what we think

are some of the value drivers around the investment proposition at NRG. And it starts with the fact that 2 1/2 years into the commodity price down cycle, it appears to us that the end is in sight, the bottom of the trough has been reached, and the only way to go is up. When or how quickly gas prices will recover remains open to conjecture, but the case for rising heat rates in our core market of Texas is clear and compelling. And we've positioned our portfolio and our hedge both to benefit from that upturn.

Second, even in a political environment that has turned more conservative in the past year, market mandates for renewable generation and for solar power in particular, remain well supported in both the red and blue states. And the result for us has been a fast-growing portfolio of projects that will contribute substantially to shareholder value creation over the short to medium-term.

Finally, there's the inherent value unique amongst our peer group of Wholesale generation combined with the leading retail position. While we have executed to such great success in Texas, together with Reliant, we are now in position to replicate with Green Mountain in the fast-growing green and retail energy sector. It's a bright future indeed, and for all of us at NRG, we'll strive to realize its vantage on behalf of the shareholders of NRG.

So Deanna, with that, we'd be happy to take some questions.

Question-and-Answer Session

Operator

[Operator Instructions] The first question will come from the line of Daniel Eggers, Crédit Suisse.

Dan Eggers - Crédit Suisse AG

David, I was just trying to marry up some of the comments made about some of the solar investment opportunities. If I look at Slides 25 and 26, the cash investment and then the earnings contribution you guys show there, is that based on the things that are in hand right now, or is there a assumption of the amount of incremental projects who would have to get signed this year to help get to those numbers?

David Crane

I think what we're showing, Chris, correct me if I'm wrong, is the Tier 1, which are projects, which in my personal estimation are ones that have a 90-plus percent chance of achieving financial closure.

Christian Schade

Yes, that's actually correct, Dan.

Dan Eggers - Crédit Suisse AG

So these are things that are already in place, and this would be less contribution than what you said in your comments earlier, David, about having equity investment and solar greater than what you do see in South Texas ultimately?

David Crane

I'm sorry. Say it again?

Dan Eggers - Crédit Suisse AG

So this earnings contribution represents an investment less than what you think you can get to from the solar perspective based on your comments earlier in the presentation?

David Crane

I mean there are more projects behind this portfolio.

Dan Eggers - Crédit Suisse AG

When do you see the opportunity this year to announce off projects? And how would you see this sell down equity go as far as changing the earnings contribution profile from these projects? And how much could you sell down, do you think?

Christian Schade

Well, we're going to get to how much we can sell down as we move through the process. But very clearly, any amount we sell down will sort of be a pro rata reduction in EBITDA. And so depending on how much we do, we'll certainly let you know. But we do believe that the sell down will allow us to provide incremental more equity into other projects we have yet to announce. But what David said, we're on the bubble given the benefits from the government largesse, which we think still exist but perhaps will run out in the next couple years. And those projects will also be assumed as sort of returns consistent with what we've seen to date.

Dan Eggers - Crédit Suisse AG

And I guess one last question just on South Texas. David, if you could maybe just -- we go through the numbers as far as how much cash you expect to throw off in the project, and then to clarify that, contribution's based on kind of the pricing you'd need it to be able to receive in order to earn economic return on that project?

David Crane

Well, so you're saying you're -- Dan, you're actually looking forward to 2016 and '17? Yes, I mean, looking at Page 10, I mean, through the first few years, when we've talked about receiving $500 million of cash, that's based on our view on where gas prices go, which is, obviously, some way up from where they are now, sort of into the $6 to $7 range. Having said that, Dan, we've stressed the returns on the nuclear project from an IRR perspective, sort of $4 gas in perpetuity model. And the IRR in the project, it would still be in double digits, but obviously, the higher gas prices, the better we do. But it works, the numbers work even at a $4 gas environment. And the reason that is the case, Dan, is because, obviously, the tax benefits associated with nuclear project, particularly, the production tax credits, meaning that through the first several years of the nuclear project, the economics are more driven actually by the tax benefits than they are by the price of electricity.

Dan Eggers - Crédit Suisse AG

Do you see IRR as working in $4 gas to the equivalent of a mid-30s power price, you would see the plant being economic?

David Crane

In a $4 gas, the plant is, yes. I mean, again, it's a low-teen return. I'm not sure that -- it's not the return we're seeking, but it's not a single digit return or a negative return.

Operator

The next question will come from the line of Ameet Thakkar, Bank of America Merrill Lynch.

Ameet Thakkar - BofA Merrill Lynch

Mauricio, you kind of indicated that the path with hedging, despite, I guess, some uptick in heat rates in Texas and you also didn't do much in the way of coal as well. I mean is your expectation that PRB prices should follow gas down? Or are you guys a little bit more neutral on gas at this point?

Mauricio Gutierrez

Well, I mean, if you look at our hedge profile, the next few years, we're pretty well hedged on both sides, so power and coal. We can justify the contango that exists with the coal curve. And given the inventory that we have and the hedge profile, we think that we can weigh to be more opportunistic about when to catch the coal prices. With respect to gas, we continue to see further declines in the front part of the curve, which we've been pretty well insulated. But as I mentioned in my remarks, I mean, I think when you look at 2012 and beyond, and where those price levels are, we see very little downside risk from that. And we think that there are several factors that are converging that could potentially move gas prices, assuming they could be higher than where they are today.

Ameet Thakkar - BofA Merrill Lynch

And then David, real quick on STP. I just want to make sure I understood, I guess, some of your answers to the previous questions. You see returns in kind of the teens area, given the $4 gas for STP?

David Crane

Yes, so the returns would be in the teens area in the $4, in perpetuity model. Again, this is based on the idea that we're running a model where there's roughly 1,000 megawatts of power sold by long-term contract, and the rest is taken into the merchant market. So the $4 gas would apply to the 2,000 in the merchant market. And yes, you're right, what it shows is a return in the teens, in that sensitivity. I would also tell you, Ameet, both in response to your question and I should say to Dan, also, we run this with no value associated to the zero-carbon aspect of it, so the price on carbon directly or indirectly would be on top of this.

Ameet Thakkar - BofA Merrill Lynch

And then so is like the 1,000 megawatts of PPA cover, I guess, under that analysis, is that really kind of the goal to kind of continue to move forward and not exit, I guess, exit land for on Slide 9?

David Crane

Well, Ameet, almost as a -- I mean, from the beginning, I think that we have said to our investor base that we, at least, would not proceed with the project unless there was a significant amount of long-term offtake associated with the project. And so, roughly 1,000 megawatts has been something we talked about from the beginning. On top of that, Ameet, the conditional loan guarantee, if and when it's announced, it's called a conditional loan guarantee because there are conditions associated

with it. And probably the most substantive condition, the condition we would be focused on is that the government would require us to have approximately that same amount of long-term offtake agreement contracted, which was a condition, again that we were happy to agree with the government on since we had said that we wouldn't go forward with it either. So that's why we would be doing that.

Operator

And the next question will come from the line of Ted Durbin, Goldman Sachs.

Theodore Durbin - Goldman Sachs Group Inc.

If I could just ask a little bit about the capital allocation. You're obviously coming out of 2010 here with a high cash balance. I'm just trying to understand a little bit better the allocation of the capital towards the renewables and whatnot, maybe extending that relative to between cash to stakeholders. Could you just talk a little bit more about that?

Christian Schade

As we said, we're committing to a $180 million stock repurchase, and that's within the confines of our restrictive payment basket. We're also going to be making required debt repayments under our term loan program, Term Loan B program. We've also earmarked potential investment in our solar projects, and these are projects which we had -- some of which we're announced late last year and early this year and would be subject to the cash grant program under the government. So all of those projects and repowering projects from El Segundo and GenConn Middletown. But those are the programs at least that were part of the capital allocation program for this year. That's what we've announced. We have $1.8 billion after which we would be able to deploy into additional repowering should they be available and new solar projects that we see on the horizon, as I've said before, all of which offer us the opportunity for very attractive returns.

David Crane

And just to add, Ted, I think you phrased the question almost as if it was an either/or, and I guess that may be a little different. I mean, given the company's free cash flow generation and the cash we have on hand, we haven't really seen it as an either/or. In terms of returning capital to shareholders through the share buyback, we do as much as we can under the restrictive payment basket. Over the past years, we've constantly evaluated whether or not we could negotiate a way to have more room to do more, but the expense of doing that has always made that impractical. So from our perspective, it has not been an either/or decision. It's been do both.

Theodore Durbin - Goldman Sachs Group Inc.

Does that cost of getting the ability to do more of a buyback, you're still seeing that as not worth the expense of getting that?

Christian Schade

That's right. We think the expense to negotiate with the bondholders is being punitive. And as I said in the prepared remarks, the approach that we took on the 2014 maturity to wait for the calls to come due than to call away and refinance was we felt unattractive and a cost-beneficial way to do it. We have calls coming up in February for the 2016 maturity which we'll keep an eye on. The 2017 are not yet callable, will be so within a year. The high-yield market remains very attractive from financing

perspectives, so we'll continue to look at that closely. But just to further what David said, with the excess cash in addition to the $180 million as we said, we'll certainly consider future stock repurchases if it can fall within the confines of hedging expansion we see in our restrictive payments basket throughout the year as well.

Theodore Durbin - Goldman Sachs Group Inc.

I appreciate the commentary on sort of the assets side. It sounds like you're not seeing the values on the CCGT side that you were before, but you did do the Cottonwood transaction. Are there other holes in your portfolio, where you say, "Geez, we'd really like to add some mid-merit assets whether it's more in South Central or whatnot?" And kind of talk about where you'd like to build up the portfolio.

David Crane

Well, I think the place where we'd like to build up the portfolio, and again, we've been fairly -- well, it took us six years to execute on the idea that we needed a load following plant in South Central. So just because I say this, I don't want you to think any sort of announcement's around the corner, because I'm actually skeptical that we can achieve anything. But we would definitely like to have some more baseload-following capability in PJM, particularly Eastern PJM. Having said that, we don't have any optimism about anything coming available in that footprint that we would find probably at a reasonable price. But we keep our ear to the ground. I would say that has been our single greatest priority second to backing up Big Cajun, which we've now achieved with Cotton.

Operator

And the next question will come from the line of Jonathan Arnold, Deutsche Bank.

Jonathan Arnold - Deutsche Bank AG

My question is, on STP, you believe the option for the second 10%, the TEPCO would take -- had a May expiration date on it, we recall from the original 8-K. But is there a similar date around the base 10% investment that's contingent on the loan guarantee acceptance? Is May a kind of drop-dead date for that whole arrangement with TEPCO?

David Crane

I don't believe there's a drop-dead date. And John, Tokyo Electric well understands the pace of development. I don't want to speak to them, but I think their enthusiasm for participating in this project is unchanged from when we announced the deal a year ago. So I don't remember any sense of date, but I have a very high level of confidence that if the loan guarantee comes that Tokyo Electric will participate in the project.

Jonathan Arnold - Deutsche Bank AG

And can you also give us a sense of -- well, obviously, your contribution is relatively small over this '11, '12 period. What would the $25 million in '12 be absent additional sell downs? And maybe some kind of sense of how much is actually being spent on the project itself during this next couple of years.

Christian Schade

Well, what it would be without the sell down, I'll have to get back to you on that. The amount of money that has to be invested towards in order for us to proceed is it's several hundred million dollars. But Jonathan, it's really hard to put it in those terms. Because like a good portion of it is long lead time materials in Japan which are actually funded with the credit facility from Toshiba. So maybe we can break out and provide it to you or do it next quarter. Just the development spend for now, in order for us to proceed against the sources of capital, because it's really not useful if you look at it as one-lump sum, because various things are paid for with different buckets of money.

Jonathan Arnold - Deutsche Bank AG

And if I may just on one other topic, what indications are you getting from DOE on these discussions at a level of hedging through PPAs that would be acceptable to them on the project?

David Crane

Well, I think that the condition is very specific. And I think back, it's the same as I answered to Ameet. It's something just less than 1,000 megawatts.

Operator

The next question will come from the line of Jay Dobson, Wunderlich Securities.

James Dobson - Wunderlich Securities Inc.

I was hoping you could give us some insight into the offtake discussions. The local media's covered some interesting transactions, or at least, proposals that you had. So I'm just wondering if you can give us some insight into where things stand and sort of what your level of optimism is currently.

David Crane

It's a good question, and I think what I would say without -- I mean, it's difficult to comment with discussions that are underway. And in fact, normally, we don't comment on it but since as you said, there's been discussions by the public, I guess I should say some things. I would say, first of all, I think there's an openness, a willingness, and interest on several load-serving entities, large load-serving entities in the Texas market to talk about long-term offtake. And I would also say that the events of early February in Texas, where a part of the reason the state had rolling brownouts or even blackouts is because people couldn't get gas to some power plants, I think has reinforced the idea that having fuel diversity in the state is something that load-serving entities want to have. So there's a fairly high level of interest from various parties, but the big qualifier I always put on this question is, right now, as you say, it's really discussions. I mean, the project isn't really real to off-takers until we have a loan guarantee. So I would describe anything that we're doing with any counterparty at this point is being preliminary. And so that's what I would tell you. And based on what we're being told by the camp, their interest level, I'm guardedly optimistic. But mainly, my main attitude towards all this is, let's wait and see what happens when the loan guarantee's announced, because that's when ourselves and our counterparties are going to have to get down to business, and people are going to have to make commitments on both sides. So that's the main thing, and what we're trying to empathize here is that, that phase, and hopefully that phase will begin within the coming weeks, is something that basically needs to be resolved by the summer so that we can all have clarity as within the company and U.S. investors and analysts as to where we stand vis-à-vis this project.

James Dobson - Wunderlich Securities Inc.

As an unrelated follow-up, on the solar side, I'm not sure if this is good for your or for Chris. I assume in addition to selling an equity stake, you'd consider selling a tax equity there, and how do you consider those two alternatives?

Christian Schade

Yes, very much so. I think the equity stake that we are contemplating is tax equity, it's a structuring issue. But we're certainly looking to pass off the tax attributes that are generated from this portfolio to tax equity investors. I think, one thing as a follow-up to a question before is that we'd certainly be looking to sell this equity at a premium. The returns that we're seeing perhaps from these investors are below the expected returns that we see in the high-teens, and so that sort of premium or IRR arbitrage gain will certainly benefit us in having development premium for this. But our goal here both is to bring equity into these projects and also, to lay off some of the tax that perhaps, does not necessarily accrue to NRG.

James Dobson - Wunderlich Securities Inc.

And Chris just a last follow-up, the capacity of the RP basket at year end?

Christian Schade

It was about $160 million. So the $180 million that we announced today will be spread out for a couple of quarters.

Operator

The next question will come from the line of Brandon Blossman, Tudor, Pickering Holt & Co.

Brandon Blossman - Tudor, Pickering, Holt & Co. Securities, Inc.

I guess just a follow-up on the tax equity question, probably for Chris. Just to be clear, is the tax equity partner or sell down required to optimize the tax benefits of the current solar portfolio, or is that something you need to do to increase the size of that portfolio?

Christian Schade

I think it's not necessarily required. I think it benefits the returns of the portfolio and allows us to continue to invest in the space. As David said, we're seeing a lot of opportunities elsewhere, and I think when we start to layer on other utility-sized projects in addition to what we have, there is a limit to the capacity of tax attributes that we can assume. So we think it's important. We're seeing a lot of interest and opportunities to invest in this space by sort of nontraditional investors who want to get green, and so we think it's a big opportunity for us, who are certain taxpayers as well. So it's for us to check a lot of boxes along the way. First and foremost to optimize our tax position in appropriate years, as well as to allow us to continue to invest in the space.

Brandon Blossman - Tudor, Pickering, Holt & Co. Securities, Inc.

And how does that dovetail with STP's tax attributes? Is that far enough out so that there's no overlap here or concerns about maximizing that value?

Christian Schade

It is far enough out that we're not perspiring about the tax attributes that it generates. But certainly, it's a topic that we will address at due time. And also, would speak to our underlying business that we hope and certainly think will grow enough to burn through these NOLs and to continue to generate the taxable asset side in those years. So we're confident of that.

Brandon Blossman - Tudor, Pickering, Holt & Co. Securities, Inc.

And David, as a follow up, not that anyone wants this to happen, but if there is an exit ramp for STP, can you describe what that looks like? Is there a project to be had at some point in the future, given that this is a particularly attractive development project?

David Crane

Well, Brandon, I guess, what I would say, on a few fronts. I mean it sort of depends on which exit ramp you're talking about. And I'm just speculating on things which of course, we don't hope to happen. I mean from my perspective, I think if something happens during this year that caused the entire project to go away, we would probably finish the licensing process, which is a small fraction of the overall development spend. But we're so far along with the NRC that to stop it this close to the end would not make sense. But beyond that, would the project go forward? I think it depends on which exit ramp it is. And again, I don't mean to speak for the other partners, because I want to emphasize every NRG investor on the call. We do not have the right to kill the STP 3 & 4 project. We just have the right to stop our own financial contribution to it. But I would say, if the exit ramp is that, actually it turns out that there is no loan guarantee in the offing -- I haven't actually asked this question directly, but I think our partners in Japan -- and we would be aligned that there would be, that the project would stop if there's no hope of a federal loan guarantee. If on the other hand, there was a federal loan guarantee, but we were taking the exit ramp because we were unable to lineup the offtake, I don't know what our partners would do in that circumstance. Maybe they would continue with the project, that would be their prerogative to do. I just know that if we don't have that offtake arrangement, then we will stop funding.

Brandon Blossman - Tudor, Pickering, Holt & Co. Securities, Inc.

And that would be not the 1,000 megawatts, but isn't that predicated on the loan guarantee or the loan guarantee predicated on the 1,000 megawatts?

David Crane

It is, but one of the reasons why I don't know -- I don't remember the exact terms, the exact words of the conditional loan guarantee, but I know that we do not have the opportunity at NRG to solve for the offtake arrangement, because I think the condition is offtake agreements with investment grade offtakers. Our Japanese partners who are investment grade would have that opportunity should they so choose to correct that on their own. We don't have that type of power, so that's not a question for us.

Operator

The next question will come from the line of Brian Chin, Citigroup.

Brian Chin - Citigroup Inc

What's the rough range of construction cost estimates in dollar per KW for the solar PV facilities that

you are seeing, and also for the solar thermal side?

Christian Schade

The range, well, I think we would say that the range right now is 3,500 to 4,000 per KW, and I don't know, that would be for the PV -- I can't tell you -- the solar thermal would probably be in the same range.

Brian Chin - Citigroup Inc

And then would it be fair to say that $4 sustaining perpetual natural gas price environment that you'd still see solar generating returns in the double digits as well? And is it higher or lower than nuclear?

David Crane

Well, we haven't compared them side-by-side. I think it's fair to say that like nuclear, the solar projects, at this point, the economics are very heavily driven by the tax benefits. But beyond that, the real difference between the two is that every solar project we're doing is completely not merchant. It's totally PPA. So I don't think -- in fact, when we talk about taking the company's financial performance and sort of de-linking it to natural gas prices, we put renewables together with retail in parts of our EBITDA stream that are not associated with natural gas prices, because of the fact that all of the economics are derived from long-term PPAs.

Brian Chin - Citigroup Inc

Can you talk just a little bit about from your perspective, what the FERC's order in the New York ISO and the capacity market situation up there? What's changed longer-term, and how much of a positive is that for you guys, or is that even material?

Mauricio Gutierrez

Well, I mean it's definitely material. It's difficult to say what is the ultimate impact, because I think the variables are still being flushed out. But the three main changes was the recognition of state taxes and the cost of new entry calculation, inter-connection costs and then the energy offsets. So when you put those three together, you basically have higher cost of new entry, which will push capacity prices for both New York City and the whole state. This will benefit our New York portfolio, but at this point I can't give you the specific mind into it.

Operator

And the next question will come from the line of Anthony Crowdell, Jefferies.

Anthony Crowdell - Jefferies & Co

Just a quick question on the, I guess, the cold stub that hit Texas earlier this month. And it seem like there wasn't much of an impact on the generation side, but was there any impact to the margins that Reliant expected or anything on the quarter?

Jason Few

This is Jason. From the retail side, we actually, faired fairly well through this event. I mean, our hedging strategy and risk policies served as well during the event. We did not see material impact to

our business.

Operator

In interest of time, we have time for two more callers. And the next question will come from the line of Charles Fishman, Pritchard Capital Partners.

Charles Fishman - Pritchard Capital Partners, LLC

Your five-year environmental capital plan, Page 17, I want to make sure I understand this. The $720 million includes your view of what the math might be, which is less than worst-case, number one. And number two is there are no dollars in the $720 million to address once thru cooling. Is that correct?

David Crane

No, actually, there is some dollars for 316(b) through the installation of extremes. We've been very successful in New York, in Arthur Kill and Huntley and Dunkirk to address this issue. So while it addresses the Mercury and asymmetric controls across all our coal assets, it also addresses the 316(b).

Charles Fishman - Pritchard Capital Partners, LLC

And if we do end up with the worst case math, I mean could this number increase 50%? Or do you have any feel for that?

Mauricio Gutierrez

Well, we actually disclosed that on our last earnings call. And I believe it's about $1 billion -- just shy of $1 billion. If it was the worst case scenario, in terms of unit-specific controls, no averaging. And we just don't believe the EPA will go that route. But the rule is going to come out, the proposal is going to come out in about a month, and I think it's just prudent to wait before we make any changes.

Operator

And there are no more questions in queue at this time.

David Crane

Okay, well, good. Well, thank you all very much, and we look forward to talking to you in the next quarter. Thank you, operator.

Operator

And ladies and gentlemen, this concludes today's presentation. Thank you very much for your participation. You may now disconnect, and have a great day.

Executives

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Christian Schade - Chief Financial Officer and Executive Vice President

Mauricio Gutierrez - Chief Operating Officer and Executive Vice President

Nahla Azmy - Vice President of Investor Relations

Jason Few - SVP of Mass Markets and Operations, Reliant Energy, Inc.

Analysts

Anthony Crowdell - Jefferies & Co

Dan Eggers - Crédit Suisse AG

Brandon Blossman - Tudor, Pickering, Holt & Co. Securities, Inc.

Charles Fishman - Pritchard Capital Partners, LLC

Jonathan Arnold - Deutsche Bank AG

Ameet Thakkar - BofA Merrill Lynch

Theodore Durbin - Goldman Sachs Group Inc.

James Dobson - Wunderlich Securities Inc.

Brian Chin - Citigroup Inc

NRG Energy (NRG) Q4 2010 Earnings Call February 22, 2011 9:00 AM ET

Operator

Good day, ladies and gentlemen, and welcome to the Fourth Quarter and Full Year 2010 NRG Energy Earnings Conference Call. My name is Deanna, and I'll be your operator for today. [Operator Instructions] And I would now like to turn the call over to your host for today, Ms. Nahla Azmy, Senior Vice President of Investor Relations. Please proceed.

Nahla Azmy - Vice President of Investor Relations

Thank you, Deanna. Good morning, and welcome to our Fourth Quarter and Full Year 2010 Earnings Call.

This call is being broadcast live over the phone and from our website at www.nrgenergy.com. You can access the call presentation and press release through a link on the Investor Relations page of our website. A replay of the call will also be available on our website. This call, including the formal presentation and the question-and-answer session, will be limited to one hour. In the interest of time, we ask that you please limit yourself to one question with just one follow-up.

And now for the obligatory Safe Harbor statement. During the course of this morning's presentation, management will reiterate forward-looking statements made in today's press release regarding future events and financial performance. These forward-looking statements are subject to material risks and uncertainties that could cause actual results to differ materially from those in the forward-looking statements. We caution you to consider the important risk factors contained in our press release and other filings with the SEC that could cause actual results to differ materially from those in the forward-looking statements in the press release and this conference call.

In addition, please note that the date of this conference call is February 22, 2011, and any forward-looking statements that we make today are based on assumptions that we believe to be reasonable as of this date. We undertake no obligation to update these statements as the result of future events except as required by law.

During this morning's call, we will refer to both GAAP and non-GAAP financial measures of the company's operating financial results. For complete information regarding our non-GAAP financial information, the most directly comparable GAAP measures and a quantitative reconciliation of those figures, please refer to today's press release and this presentation.

And now with that, I'd like to turn the call over to David Crane, NRG's President and Chief Executive Officer.

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Thank you, Nahla, and good morning, everyone, and welcome to our year-end 2010 earnings call. Today, with me, and participating in the presentation is Mauricio Gutierrez, the company's Chief Operating Officer; and Chris Schade, the company's Chief Financial Officer. Also with me today and available to answer questions are Jason Few, who runs NRG's retail company, Reliant; and Chris Moser, who runs the commercial operations function for this company.

So without further ado, to begin -- so ladies and gentlemen, current and perspective shareholders of NRG, as we speak today, it's now been 32 months since natural gas prices began their relentless fall and the economy at large entered into a great recession, the likes of which, I'm sure none of us wish to experience again in our lifetimes, yet the financial performance of NRG during this period has been superb. And that financial performance has been built on the foundation of an equally exceptional

operating performance across all phases of our operations and across all our regions.

In 2010, the second full year of the great recession, our financial performance surpassed all previous years of company results, save for fiscal year 2009, which was of course the first year of the great recession, a year in which we performed spectacularly, achieving both record financial performance and the acquisition of Reliant.

While I am, for the most part, extremely pleased with both the company's financial and its operating performance during 2010, I am acutely mindful of the fact that NRG shareholders did not see any of the benefits of our exceptional performance and share price appreciation during that year. As a management team, we recognize that we have a long way to go in presenting NRG's present value and future potential to the market.

In this presentation and in subsequent presentations that Mauricio, Chris and I will be making during the spring Investor Relations season, we intend to make a concerted effort to explain the NRG value proposition. From the competitive strength of our core businesses, even in a low commodity price environment, to the meaningful and measurable value of our growth opportunities, as well as our effective risk mitigation in areas which we believe to be of concern to the investment community.

So starting with 2010, as summarized on Slide 3, the company continued to generate a very high level of EBITDA in excess of $2.5 billion and also throw off a substantial amount of free cash flow. Indeed, in regard to what should perhaps be the most important metric to shareholders, free cash flow yield, our free cash flow yield for 2010 was a robust 29%, making our seven-year average exceed 23%. And in response to some people who said that we should measure free cash flow for these purposes after both maintenance and environmental CapEx, we have done it in that way but before growth CapEx.

A substantial amount of that free cash flow yield was redeployed back to stakeholders in the form of debt repayment and through our 2010 share buyback program and also into various growth initiatives, which we'll discuss in a minute. But over $650 million of excess free cash flow was returned as cash into the company's coffers, with the result being that our liquidity position at the end of 2010, $4.3 billion of total liquidity with $3 billion of cash on hand, is stronger than it has ever been.

It has always been my position that next to safety, the most important thing that we do as executive management at NRG is capital allocation, and given the amount that we are investing on an annual basis and the record amount that we currently have available either to invest in growth or to return to our equity and debt stakeholders, capital allocation has never been more important than it is now. As such, I'm going to focus the greater part of my remaining remarks on capital, which we expect to invest in our growth initiatives in the months and years to come. Chris will focus a good deal of his comments on capital to be returned to stakeholders.

In terms of the allocation of capital to our growth initiatives, it's important to start with the obvious point that we want to invest the company's capital in assets and initiatives that not only are likely to yield a return significantly in excess of our risk-adjusted weighted average cost of capital, but also in businesses and initiatives which advance the company's strategy.

As depicted on Slide 4, the company's long-term strategy for some time has been twin-tracked. First, to strengthen and enhance our generation to retail business in our core markets through superior operating performance, continued implementation of our first-lean-enabled, long-term hedging program and pursuit of both select acquisitions and the repowering of our older facilities with advantage locations inside load pockets in our core markets. This comply of our strategy which we

have pursued with relentless consistency and a high degree of effectiveness for the past five years was joined a couple years ago with a supplemental strategy that is overtly green and designed to take advantage of the societal trend towards sustainability.

This sustainability trend is, in our opinion, about to accelerate as a result of the emergence of various consumer-oriented disruptive technologies, which will make green energy at the consumer level the focal point of sustainability. We made considerable progress on both strategic fronts during 2010, with substantial advances across every facet of our sustainability initiative.

From our rollout of our eVgo network in Houston, which is centered around an innovative fueling package in approach to electric vehicle infrastructure that is already being replicated in other locations through the smart meter e-Sense applications now being sold by Reliant in quantity, to our unique approach to CCS/EOR being funded in collaboration with the DOE at our Parish facility in Texas. All of these initiatives are exciting and off to a good start. All will, I am confident, return considerable value to NRG to shareholders in the medium term.

You will hear more about these initiatives in the future but not today, because today, consistent with my theme, I want to concentrate my comments on the growth initiatives which are more immediate and which are key priorities for deployment of your investment capital during 2011. This is shown on Slide 6.

By way of background, in 2010, we committed substantial growth capital in four general areas: Zero carbon renewables, with an emphasis on solar; new advanced nuclear development; conventional gas-fired acquisitions and repowerings; and green retail acquisitions in the form of Green Mountain Energy. All four are likely to be areas of additional capital expenditure in 2011 but with very different investment profiles from 2010.

First, we expect an acceleration and significant expansion in our equity capital invested in high-growth, high-return solar projects. At the greater part of our utility scale, solar portfolio should achieve financial close and enter the construction phase during 2011.

Second, investment in conventional generation assets should be relatively flat year-on-year, as spending on GenConn and Cottonwood should give way to spending on El Segundo, but conventional CapEx could increase depending on our development success at Astoria, Saguaro or Encina and also, whether we find any strategic assets that can be acquired at value.

Third, capital invested in green retail should drop precipitously as obviously the big expenditure in this area in 2010 with the acquisition of Green Mountain. The amount of capital that we will be investing in and around Green Mountains business in 2011 or to expand into new geographic markets, bigger customers segments and new complimentary green product offerings is fairly minimal.

And finally, and similarly and perhaps, contrary to popular investor belief, even if the STP nuclear development project stays on course, the development capital projected to be required of NRG in 2011 will be far less than half of what we invested in 2010 and will be a mere fraction of what we will be investing in solar projects and other capital allocation alternatives.

So this is a lot to digest, so let's go through a little bit more slowly, starting on Slide 7 with Green Mountain. Four months ago, we paid $357 million for a business that we expect to contribute $70 million, $80 million of EBITDA in 2011, plus, we expect Green Mountain to continue to deliver on a 20-plus percent compound annual growth rate trajectory that they have delivered for the past decade. But we didn't acquire Green Mountain just to continue with business as usual. We wanted to take

advantage, and we wanted them to take advantage of what we believe are very substantial synergies between Green Mountain and NRG.

Essentially, we want Green Mountain to accelerate the depth and breadth of their growth in close cooperation with us on the same path that they were following on their own, which means expansion into a high retail price Northeast markets, where they start with a natural green-leaning constituency, also, expansion into the larger Commercial segment of the C&I market than they have previously sought to access. And finally, expansion of their value-added product offerings to include distributed green generation.

It's early days yet, but on at least the first two of these, they are already beginning to bear fruit. Green Mountain has established a small but fast-growing footprint in New York Zone J, and in terms of larger C&I customers, they have won landmark business like the Empire State Building. We expect to be reporting on these and many more successes from and with Green Mountain as the year progresses.

Turning to conventional generation on Slide 8. 2010 was an uneven year, with the successful acquisition of Cottonwood and the repowering at Devon and Middletown, balanced by the missed opportunities surrounding Dynegy's California asset. Cottonwood and Devon have been smoothly integrated into our South Central and NEPOOL lineups respectively, and we are very pleased with the results today.

Looking forward to 2011, we're very focused on the successful repowering of El Segundo, an advantage which we hope to derive from having a modern, fast-start, low-heat rate, combined-cycle plant inside the Los Angeles basin load pocket. Beyond El Segundo, we hope to make progress on similar repowering efforts at Astoria in New York City and Encina in San Diego County. Beyond our own Repowering pipeline, the capital we deploy in the acquisition of conventional power plants, obviously, will depend on market conditions and asset availability in our core regions.

While the acquisition market is lumpy, generalities are difficult and predictions are often proved wrong, the optimism I once held at the first half of 2011 would be a buyer's market for CCGTs in the United States has largely dissipated. I see no sign of a flood of assets on the market and the combined cycle of transactions which have been announced recently have been priced at levels significantly above what we could justify to ourselves or explain to our shareholders.

With respect to our nuclear project, while important steps forward have occurred in several areas since our last earnings call, very little of it can be seen with the naked eye. As before, really all critical aspects of the STP 3 & 4 project run off of our receipt of an acceptable conditional loan guarantee from the government. Certainly, it is a challenge for us to complete meaningful discussions about PPAs with potential off-takers, while the loan guarantee application remains pending.

So our exit ramp analysis, which is set forth on Slide 9, remains largely unchanged from the previous quarter. Likewise, our viewpoint with respect to NRG's continued participation in the project remains at the most challenging of these hurdles, which is the long-term off-take requirement, effectively needs to be addressed no later than the third quarter of 2011 before the project enters the substantial pre-construction phase.

As such, we reiterate the view which is clearly articulated in both our 10-K and in today's earnings release, that NRG will be in a position by late this summer to make a final decision on our continued financial participation in this project. At that point, the market should have substantially greater clarity about the prospects for this project and NRG's role in it.

While we understand that there is skepticism amongst some investors that the project can go forward in the current low gas price environment, we nonetheless, believe it might be helpful to you for us to outline as shown on Slide 10 the future capital commitment of NRG in respect to this project, should it stay on track, with NRG continuing to support it financially.

The overall message is that due to a combination of first, the very substantial sum that NRG has previously committed to the project development, particularly during the first half of 2010 after the settlement with CPS. Second, taking into account our expectation of an optimal hold amount in the project for NRG of approximately 40%, which is down from the 67% that we will own if and when TEPCO invests in a project post-loan guarantee award. And third, due to the value ascribed to NRG for its contribution of the site, NRG's cash commitment to the project going forward is less than what otherwise would be suggested by our projected ownership level.

In summary, should the project proceed to financial closing, the total cash commitment for NRG at our 40% hold level should be something just short of $800 million in aggregate, including cash invested to date. Beyond that, we are likely to have an LC commitment to a standby equity crossover line facility that will be fixed. And while that number has not yet been finally fixed, you should be thinking in the range of a few hundred million dollars maximum.

In exchange for this size investment in STP 3 & 4, we expect cash flow from dividends and tax benefits in the range of $500 million a year for the first several years of operations. Obviously, this is a very attractive return but one which we believe is well just justified given the extraordinary challenges of the undertaking.

Now pulling it back from where we hope the project will be in 2016 or 2017 to where we are here in the first quarter of 2011, you should be focused on what happens after announcements of acceptance of the loan guarantee. As the loan guarantee acceptance naturally will trigger certain funding obligations from our partners, NRG's share of cash development spent for the remainder of the development phase should approximate $50 million for all of 2011 and half that for 2012.

While our perspective 2011, 2012 development standard is perhaps substantially less than many in the market were anticipating, it remains a lot of money to us, and we're taking very seriously our commitment to retain our financial discipline around this project and prevent exposure of our balance sheet beyond the specific commitments that I've outlined in this presentation.

Now turning to Slide 11, last but certainly not least, there is the solar pipeline. I've said many times, and I'll repeat here, that in my 20 years in this business, I had never seen investment opportunities in this sector that offer more attractive combination of high returns, low construction risks, long-term PPAs and repeatable business opportunities than the utility-sized solar projects that we currently have in our advanced development portfolio.

As such, we intend to do as much of this business as we can get our hands on, with the result being that by the end of this year, we may well have a total initial equity investment in our solar portfolio that exceeds the total amount that we may ever invest in STP 3 & 4 at very attractive near-term returns. The limiting item for us in terms of these solar investments is our ability on our own to make optimal use of the considerable tax benefits which will be generated by these projects. This is a topic that Chris Schade will discuss in a few minutes.

What I will end by saying is that this extraordinary pipeline of utility-sized solar projects, which our colleagues at NRG Solar have managed to develop or acquire, provides us with a truly unique

opportunity to develop over the next few years a solar portfolio of true scale and significant benefit, even in the context of the larger portfolio of NRG.

Ultimately, however, we fully recognize that the current generation of utility-sized solar and wind projects in the United States is largely enabled by favorable government policies and financial assistance. It seems likely that much of that special assistance is going to be phased out over the next few years, leaving renewable technologies to fend for themselves in the open market.

We do not believe that this will be the end of the flourishing market for solar generation. We do believe it will lead to a stronger and more accelerated transition from an industry that is currently biased towards utility-sized solar plants to one that's focused more on distributed and even residential solar solutions on rooftops and in parking lots.

We are already planning for this transition now within NRG, so that any potential decline in either the availability of utility-sized solar projects or in the attractiveness of the returns being realized on these projects, will be exceeded in aggregate by the increase in the business we are doing on smaller distributed and residential solar projects through our Green Mountain and even our Reliant retail sales channel.

With that, I'll turn it over to Mauricio.

Mauricio Gutierrez - Chief Operating Officer and Executive Vice President

Thank you, David, and good morning, everyone. NRG continued its strong operating and commercial performance during the fourth quarter, making 2010 one of NRG's best years. Slide 13 highlights a few of the key accomplishments achieved in 2010.

Starting with safety, we're particularly pleased with our record performance this year. Our OSHA recordable rate improved 26% over 2009. Our top performance remained strong with 90% availability of our baseload fleet, just shy of our 2009 level. This performance was achieved despite a forced outage event on our STP nuclear plant in November, which I will cover in more detail in the next slide.

On the environmental front, we delivered our second best year, and our FORNRG program far exceeded our 2010 goal. As I mentioned to you on our last call, controlling our cost is a priority, given the challenging economic environment our industry is facing.

Our Commercial Operations Group increased our hedge levels in 2011 and continues to look for opportunities to catch the odd years of favorable prices. We successfully transitioned to the Nodal Market in ERCOT and began integrating Green Mountain Energy and the Cottonwood combined cycle plant into our portfolio.

With respect to our projects under construction, the Indian River Unit 4 environmental back-end control project continues to be on track and on budget to be operational by January 2012. Our Middletown project in Connecticut received all major equipments in the fourth quarter and continues to be on schedule for operation this summer. Finally, the El Segundo Energy Center completed aboveground demolition of two existing units and secured major equipment orders. El Segundo is on track to be operational by the summer of 2013.

Turning to our plant performance metrics on Slide 14. Safety continues to be our number one priority. We are very proud to report that we achieved top decile in the industry, making 2010 our best OSHA

recordable year. We have 25 sites with no injuries and nine sites certified or recertified as OSHA VPP Star worksites.

Net generation decreased by 6% in the fourth quarter due to mild weather across Texas and a 22-day on-plan outage at STP Unit 2 during the month of November. The forced outage event was the result of a breaker failure during routine testing and was extended to repair a reactor coolant pump seal. In order to prevent recurrence, similar electric components were checked in both units. Unit 2 has operated without any issues since it was brought back to service on November 26.

For the full year, net generation was flat from 2009 levels. Increased generation in the Northeast and South Central regions driven by the strong summer weather and the addition of Cottonwood, were offset by lower generation in California and Texas.

For 2010, our coal fleet availability finished the year above the sub-quarter performance level for the industry. WA Parish led the fleet with 92.6% availability factor, and Limestone had the best reliability for the year, with a 1.6% forced outage rate.

Our FORNRG 2.0 program exceeded the 2010 goal by $49 million, and it is on track to achieve our goal of $150 million by 2011, one year earlier than planned. Savings were achieved through a combination of reliability, capacity and efficiency improvements at generating assets and cost savings across our corporate and regional groups.

Turning to our retail operations on Slide 15, we closed out the year with another strong quarter. Volumes and margins were consistent with our forecast, while Operations delivered better-than-expected asset management and lower operational costs.

The Mass segment continues to drive segment improvement in net customer attrition with a 57% reduction in the fourth quarter versus 2009. This result was driven by marketing, sales and introduction of innovative products to meet our customer needs.

In 2010, we led Texas in innovation, enrolling over 175,000 customers on our Reliant e-Sense product and services that utilize smart grid technology. We also introduced new and unique offers like carbon-state [ph] and home protection products, adding not only incremental EBITDA but increased customer stickiness.

We continue to maintain the lowest PUC customer complaint rate while balancing customer counterpricing. Throughout 2010, we aligned to successfully demonstrate that we have stabilized customer attrition and expect to achieve zero net attrition in 2011.

In the C&I segment, both renewal and new deal win rates continue to improve. We have expanded our business in several Northeast states where we can leverage existing energy assets and increase product offerings to include products such as backlog generation. These provides a solid platform to grow our business in 2011.

Business continues to show some fundamentals as you can see on Slide 16. Weather-normalized demand grew by 2% year-on-year and ERCOT set a new winter peak low of 57 kilowatts in February, an increase of almost 2.5% from the previous record. I'd like to take this opportunity to address the events in Texas on February 2.

The men and women of NRG Texas worked very hard to help meet the high demand for electricity due to the extreme cold conditions, increasing our generation by more than 60% from the previous

day. Although we had some operational issues, of the approximately 9,500 megawatts of power we had available in Texas during the low-shed event, we maintained between 97% and 91% of that capacity online. I want to thank all our employees in Texas for their dedication and extraordinary efforts during these events.

Now moving on to reserve volumes in ERCOT, we see a positive feature of our generation portfolio with reserved margins tightening faster than expected. This is to some extent reflected in the forward heat rates, as you can see on the chart on the lower right-hand quarter. We believe this trend will continue, given the robust growth and the expectation that asset retirement will outpace new builds. We have not seen as much coal-to-gas switching in Texas as we have in the Northeast and Southeast regions. In fact, cash generation was down year-on-year due to increases in new coal and wind generation in Texas.

In the Northeast, the back-end market continues to make some news. In New York, the recent FERC order to increase cost of new entry should provide a boost to capacity prices in New York City and rest of state, benefiting our New York portfolio. In PJM, prices remain uncertain until more clarity is given around the minimum offer price rule, the subsidized generation in New Jersey and Maryland and review demand outlook.

Moving on to Slide 17, you can see our detailed plan to control air emissions for each of our coal plants. As stated in our last earnings call, our plan is to invest approximately $720 million through 2015 in environmental projects tailored to comply with future regulations.

Just to remind everyone, the proposed CAIR rule does not require additional capital for compliance. The HAP MACT proposed rule should be released in mid-March, and as you can see in the table, our plant considers mercury controls on all our coal units.

Intake modifications and repowering are expected to meet once for cooling requirements. We only have dry fly ash disposals at our all coal facilities. And finally, in most of our facilities, we burn low sulfur, low chlorine PRB coal.

Moving on to our hedge profile and commodity sensitivities on Slide 18. Our baseload portfolio is now 100% hedged in 2011 and 50% hedged in 2012, providing the protection in the short term where gas prices continue to be weaker given the oversupply situation. Beyond 2012, we choose to remain significantly open.

After two years of low gas prices, we believe the downside risk is limited. Our combination of incremental demand from the power sector, particularly in light of possible coal plant retirements, some signs of the interest rate by producers, indication that drilling to home acreage may be ending, and a move from dry to wet gas production will provide better opportunities to catch our baseload portfolio in the future.

With respect to retail, we have increased our pipe load to 66% in 2011 from 57% in the third quarter. We continue to match as much generation load as possible to start maximum synergies between our retail and wholesale portfolios.

Our power and coal hedges continue to be well managed in 2011 and 2012. Given the shape of the coal curve and steep contango, we have not added any additional occasions since the last quarter. We also remain well hedged in terms of coal transportation now for some time.

Our sensitivity to commodity prices is agreeable for 2011, with 2012 to 2015 largely unchanged from

last quarter. Let me remind you that this sensitivity is around our baseload portfolio. Interest expense, our portfolio is well-positioned to benefit, particularly, in the Texas and South Central regions.

With that, I will turn it over to Chris who will discuss our financial results.

Christian Schade - Chief Financial Officer and Executive Vice President

Thank you, Mauricio, and good morning. Beginning with the financial summary on Slide 20, full-year 2010 adjusted EBITDA was $2.514 billion, just shy of the record 2009 adjusted EBITDA of $2.618 billion and within our previously stated guidance of $2.5 billion to $2.55 billion. As a result of our continued strong operating performance, adjusted cash flow from operations for 2010 was robust at $1.76 billion.

The company's liquidity position at year end, excluding funds deposited by counterparties, stood at nearly $4.3 billion, a $458 million increase from December 31, 2009, liquidity of approximately $3.8 billion. Our cash balance at year end 2010 available for both working capital as well as our 2011 capital allocation program was approximately $2.9 billion.

Now turning to a summary of our 2011 guidance in Capital Allocation Plan. First, we reaffirmed the preliminary 2011 EBITDA guidance range of $1.75 billion to $1.95 billion. Second, and as part of our 2011 capital allocation program, we are planning to repurchase $180 million of common stock, and complete $240 million of term loan debt repayments and $39 million for additional facilities, all of which is consistent with NRG's commitment to return excess capital to its stakeholders. Third, in 2011, in addition to the amount deferred from 2010 as a result of extending the cash grant availability, we are currently planning to commit an additional $640 million of net investment to advance our Repowering and renewable development program, particularly, utility-scale solar.

Now turning to a more detailed review of 2010 adjusted EBITDA result from Slide 21. The company reported near record results of $2.514 billion adjusted EBITDA, only $104 million lower than the 2009 adjusted EBITDA of $2.618 billion. These results were achieved despite the decline in forward prices across all of our regions and clearly benefited from our wholesale generation hedging program and the continued strong performance of Reliant Energy.

During the year, Reliant Energy contributed $711 million of adjusted EBITDA. Comparatively, these results are lower by $158 million from 2009 as we overlined for only eight months of that year. The year-on-year decline was driven by an 18% decline in Mass margins, which were the direct result of price reductions enacted following the acquisition, as well as lower margins on customer renewals and new customer acquisitions reflective of the competitive market. All told, for 2010, Reliant saw net customer attrition rates improve to 0.4% from 0.7% in 2009 with total customers at year end steady at 1.5 million.

The wholesale business meanwhile generated $1.8 billion in adjusted EBITDA, $173 million lower as compared to a record 2009 EBITDA of $1.976 billion. The comparative year-to-date decline is largely explained by a 32% drop in baseload hedge prices in the Northeast, as well as lower margins in Texas, caused by a 60% increase in fuel costs, due largely to higher coal transportation costs at our WA Parish facility. These results were partially offset by an increase in adjusted EBITDA of $28 million from the South Central region due to increases in generation and contracted sales.

Also increasing adjusted EBITDA were our newly acquired assets, including Green Mountain Energy, Cottonwood, Northwind Phoenix, South Trent Wind Farm, as well as the full year of operations from the Blythe solar project.

For the fourth quarter, the company reported adjusted EBITDA results of $444 million, a $45 million decline versus 2009. Reliant Energy contributed $117 million of adjusted EBITDA compared to $104 million for the fourth quarter of 2009. Reliant's quarterly results were favorable $13 million driven by an improvement in operating costs primarily due to better customer payment habits as related to a decrease in bad debt expense.

In the fourth quarter of 2010, our Wholesale Generation business contributed $327 million of adjusted EBITDA, a $58 million decline compared to fourth quarter '09. The change in results can largely be attributed to the following items: In the Northeast region, 35% lower hedge prices and a 25% decrease in generation resulting in a $57 million decline in energy margins quarter-over-quarter. The decrease in generation was largely a result of coal-to-natural gas switching and offsetting this decline in energy margins were favorable year-on-year operating and maintenance expenses of $13 million.

In Texas, the 10% decline in generation at the Limestone and WA Parish facilities due to lower power prices and reduced demand led to a 6% decline in overall generation for the region. Offsetting this decline were favorable year-on-year operating expenses of $17 million that included gain on land sales of $6 million in 2010.

Now turning to Slide 22. As I mentioned a moment ago, total liquidity at year-end 2010 excluding funds deposited by hedged counterparts remained strong at nearly $4.252 billion. Total cash stood at $2.959 billion, an increase of $653 million as compared to the 2009 year-end cash balance of $2.3 billion. The drivers of the cash increase included adjusted cash from operations of $1.76 billion and debt proceeds of $1.317 billion.

These increases were offset by several items: First, five completed acquisitions totaling about $1 billion, which included $507 million for Cottonwood generation station, $357 million for Green Mountain, $100 million for Northwind Phoenix, $32 million for South Trent Wind Farm and for the U.S. solar portfolio, 720 megawatts of development projects in nine states in California and Arizona. Second, debt and fee payments totaling $813 million, including Term Loan B payments of $453 million and a repayment of a common stock fund or CSF of $190 million.

And third, capital expenditures excluding NINA of $445 million, including $199 million of maintenance, $184 million of environmental, primarily related to the Indian River Air Quality Control System project, and $62 million of growth investments. For the full year, we made cash contributions to NINA totaling $170 million primarily in the first half of 2010. And finally, we completed share repurchases of 8.5 million shares, totaling $180 million.

Now turning to 2011 guidance on Slide 23. Our EBITDA guidance remains unchanged from our November 24 range of $1.75 billion to $1.95 billion. Included in this guidance range are wholesale expectations of $1.2 billion to $1.3 billion, retail expectations of $480 million to $570 million, and Green Mountain of $70 million to $80 million. As Mauricio discussed earlier, we are about 100% hedged on our baseload generation for 2011 and are thus comfortable with our forecasted results.

As we look forward to our Wholesale business in 2012, we are currently in excess 50% hedged with a higher average price in 2011 as indicated in our SEC filings. Due to this position and based on the current forward curves, we expect flat to marginally lower year-on-year wholesale results in 2012 from 2011. These results will be supplemented with adjusted EBITDA of $85 million from our repowering and solar investments in 2012 that are not subject to market fluctuations.

For our retail business in 2011, our current expectations, assuming normal weather, are an EBITDA

range of $480 million to $570 million, the decrease in 2011 guidance compared to current 2010 results is largely explained by lower unit margins in Reliant's Mass business. Reliant's C&I business margins are also expected to decline slightly, but be directly offset by higher terawatt-hours served, reflecting our continued dedication to this growing client base in both Texas and PJM.

Finally, we expect Green Mountain Energy to contribute $70 million to $80 million of EBITDA. We are very excited about enhancing the growth prospects for our Green Energy Retail business during the process of integrating the business with our growing renewables portfolio to enhance these future growth prospects.

During our Q3 earnings call, we discussed the 2011 free cash flow guidance of $425 million to $625 million, and we now currently anticipate free cash flow for 2011 to be in a range of $150 million to $350 million. The difference in guidance is largely explained by certain timing of solar projects, due to Congress extending the availability of cash grants for renewable projects through 2011. NRG postponed its large investments in solar projects from 2010 to 2011, resulting in $267 million of solar expenditures pushed into '11 and relates primarily to our Agua Caliente, Ivanpah and CVSR solar projects.

As we often like to emphasize, we are in a strong cash flow position based on Friday's closing stock price of $20.89 and our affirmed outlook. Free cash flow before growth yield currently stands at between 16% to 20%, or $3.36 to $4.17 per share.

Slide 24 shows the company's projected 2011 year-end cash position which we project to be about $2.5 billion. Beginning with the portion of the Capital Allocation Plan that includes share repurchases and debt repayments in 2011, the company intends to repurchase $180 million of common stock, which is within the constraint of the restricted payments basket; repay $240 million of debt related to our Term Loan B agreement; and approximately $39 million in other facilities. It's important to note that the company made a Term Loan B prepayment in November that totaled $200 million.

And finally, complete $907 million of capital allocation in the following projects: $50 million in NINA; $219 million for other Repowering investments including El Segundo, GenConn Middletown, eVgo, Texas Reliability and Princeton Hospital and $638 million for solar projects, net of cash grant proceeds, and including the $267 million of deferred payments from 2010.

During the third quarter conference call, I also mentioned that we usually maintain a minimum cash balance of $700 million largely for working capital margin requirements, the timing of cash payments, of interests, property taxes, as well as equity for projects we have under construction throughout the year. Thus, for 2011, we estimate a balance of just over $1.8 billion to allocate between perhaps additional share repurchases, contingent on the restricted payments basket expansion, further investments of high-growth opportunities and continued opportunistic management of our debt structure.

On January 11, the company issued $1.2 billion of 7 5/8 senior notes due 2018 and announced the simultaneous cash tender for $1.2 billion of the outstanding 7 1/4 senior notes due 2014. As of January 25, nearly 945 million bonds have tendered, and the remaining 250 million will be redeemed by the end of February pursuant to the embedded coal price. As a result, we've improved our debt maturity profile, all of our public debt matures after 2016, and replace the restricted covenant package with one permitting greater efficiency and flexibility to return value to all NRG stakeholders.

On a go forward basis, we will continue to moderately embed in calls in the 2016 and '17 maturities

and be opportunistic about replacing those bonds with less restricted covenant packages, similarly to how we handle the 2014 maturity.

Looking at NRG's combined Repowering and Solar portfolio and our EBITDA contribution on Slide 25, you can clearly see the benefit of the program with nearly $550 million of recurring contribution by 2015.

During the fourth quarter, our El Segundo Repowering project received prior approval from the California Public Utilities Commission for a ten-year Power Purchase Agreement with Southern California Edison. Commercial operation's expected in the summer of 2013.

Our large utility-scale solar projects will also begin to reach commercial operations between the summer of '13 and the first quarter of 2014, and these projects collectively are driving this EBITDA growth. These solar investments are attractive for their high-teens returns, very low construction risks and offtake agreement of 20-plus years with highly rated counterparties. We will continue to provide updates on the progress of these projects as they move into construction and operation.

As we continue to invest and grow our solar portfolio, it's important to highlight a few economic benefits created with these projects. Slide 26 shows how the combination of cash grant, maker's depreciation and strong cash flows from the PPAs for our projects result in a payback for our investments, in some cases by 2014, and retain stable cash flows for the remaining term of the PPAs.

Though we believe there will be a turnaround in commodity markets, we are mindful of our ability to create enough taxable income for us to fully absorb tax benefits created by these solar investments. There is clearly a limit to how much tax efficiency we could absorb in any one year before reducing the total project returns. As such, to both minimize the tax leakage and enhance our returns, in 2011, we will pursue new equity investors for our solar portfolio, who have both the appetite for tax benefits and seek investment to one of the largest utility-scale solar portfolios in the world. New equity investors would not only help to optimize our existing tax position but allow us to continue to invest in future projects with high returns.

We expect to launch this initiative soon and look forward to sharing the progress in the future. Now I'll pass it back to David for final comments.

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Thank you, Chris, and thank you, Mauricio. And so in conclusion, on Slide 28, we put what we think are some of the value drivers around the investment proposition at NRG. And it starts with the fact that 2 1/2 years into the commodity price down cycle, it appears to us that the end is in sight, the bottom of the trough has been reached, and the only way to go is up. When or how quickly gas prices will recover remains open to conjecture, but the case for rising heat rates in our core market of Texas is clear and compelling. And we've positioned our portfolio and our hedge both to benefit from that upturn.

Second, even in a political environment that has turned more conservative in the past year, market mandates for renewable generation and for solar power in particular, remain well supported in both the red and blue states. And the result for us has been a fast-growing portfolio of projects that will contribute substantially to shareholder value creation over the short to medium-term.

Finally, there's the inherent value unique amongst our peer group of Wholesale generation combined

with the leading retail position. While we have executed to such great success in Texas, together with Reliant, we are now in position to replicate with Green Mountain in the fast-growing green and retail energy sector. It's a bright future indeed, and for all of us at NRG, we'll strive to realize its vantage on behalf of the shareholders of NRG.

So Deanna, with that, we'd be happy to take some questions.

Question-and-Answer Session

Operator

[Operator Instructions] The first question will come from the line of Daniel Eggers, Crédit Suisse.

Dan Eggers - Crédit Suisse AG

David, I was just trying to marry up some of the comments made about some of the solar investment opportunities. If I look at Slides 25 and 26, the cash investment and then the earnings contribution you guys show there, is that based on the things that are in hand right now, or is there a assumption of the amount of incremental projects who would have to get signed this year to help get to those numbers?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

I think what we're showing, Chris, correct me if I'm wrong, is the Tier 1, which are projects, which in my personal estimation are ones that have a 90-plus percent chance of achieving financial closure.

Christian Schade - Chief Financial Officer and Executive Vice President

Yes, that's actually correct, Dan.

Dan Eggers - Crédit Suisse AG

So these are things that are already in place, and this would be less contribution than what you said in your comments earlier, David, about having equity investment and solar greater than what you do see in South Texas ultimately?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

I'm sorry. Say it again?

Dan Eggers - Crédit Suisse AG

So this earnings contribution represents an investment less than what you think you can get to from the solar perspective based on your comments earlier in the presentation?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

I mean there are more projects behind this portfolio.

Dan Eggers - Crédit Suisse AG

When do you see the opportunity this year to announce off projects? And how would you see this sell down equity go as far as changing the earnings contribution profile from these projects? And how much could you sell down, do you think?

Christian Schade - Chief Financial Officer and Executive Vice President

Well, we're going to get to how much we can sell down as we move through the process. But very clearly, any amount we sell down will sort of be a pro rata reduction in EBITDA. And so depending on how much we do, we'll certainly let you know. But we do believe that the sell down will allow us to provide incremental more equity into other projects we have yet to announce. But what David said, we're on the bubble given the benefits from the government largesse, which we think still exist but perhaps will run out in the next couple years. And those projects will also be assumed as sort of returns consistent with what we've seen to date.

Dan Eggers - Crédit Suisse AG

And I guess one last question just on South Texas. David, if you could maybe just -- we go through the numbers as far as how much cash you expect to throw off in the project, and then to clarify that, contribution's based on kind of the pricing you'd need it to be able to receive in order to earn economic return on that project?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Well, so you're saying you're -- Dan, you're actually looking forward to 2016 and '17? Yes, I mean, looking at Page 10, I mean, through the first few years, when we've talked about receiving $500 million of cash, that's based on our view on where gas prices go, which is, obviously, some way up from where they are now, sort of into the $6 to $7 range. Having said that, Dan, we've stressed the returns on the nuclear project from an IRR perspective, sort of $4 gas in perpetuity model. And the IRR in the project, it would still be in double digits, but obviously, the higher gas prices, the better we do. But it works, the numbers work even at a $4 gas environment. And the reason that is the case, Dan, is because, obviously, the tax benefits associated with nuclear project, particularly, the production tax credits, meaning that through the first several years of the nuclear project, the economics are more driven actually by the tax benefits than they are by the price of electricity.

Dan Eggers - Crédit Suisse AG

Do you see IRR as working in $4 gas to the equivalent of a mid-30s power price, you would see the plant being economic?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

In a $4 gas, the plant is, yes. I mean, again, it's a low-teen return. I'm not sure that -- it's not the return we're seeking, but it's not a single digit return or a negative return.

Operator

The next question will come from the line of Ameet Thakkar, Bank of America Merrill Lynch.

Ameet Thakkar - BofA Merrill Lynch

Mauricio, you kind of indicated that the path with hedging, despite, I guess, some uptick in heat rates in Texas and you also didn't do much in the way of coal as well. I mean is your expectation that PRB prices should follow gas down? Or are you guys a little bit more neutral on gas at this point?

Mauricio Gutierrez - Chief Operating Officer and Executive Vice President

Well, I mean, if you look at our hedge profile, the next few years, we're pretty well hedged on both sides, so power and coal. We can justify the contango that exists with the coal curve. And given the inventory that we have and the hedge profile, we think that we can weigh to be more opportunistic about when to catch the coal prices. With respect to gas, we continue to see further declines in the front part of the curve, which we've been pretty well insulated. But as I mentioned in my remarks, I mean, I think when you look at 2012 and beyond, and where those price levels are, we see very little downside risk from that. And we think that there are several factors that are converging that could potentially move gas prices, assuming they could be higher than where they are today.

Ameet Thakkar - BofA Merrill Lynch

And then David, real quick on STP. I just want to make sure I understood, I guess, some of your answers to the previous questions. You see returns in kind of the teens area, given the $4 gas for STP?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Yes, so the returns would be in the teens area in the $4, in perpetuity model. Again, this is based on the idea that we're running a model where there's roughly 1,000 megawatts of power sold by long-term contract, and the rest is taken into the merchant market. So the $4 gas would apply to the 2,000 in the merchant market. And yes, you're right, what it shows is a return in the teens, in that sensitivity. I would also tell you, Ameet, both in response to your question and I should say to Dan, also, we run this with no value associated to the zero-carbon aspect of it, so the price on carbon directly or indirectly would be on top of this.

Ameet Thakkar - BofA Merrill Lynch

And then so is like the 1,000 megawatts of PPA cover, I guess, under that analysis, is that really kind of the goal to kind of continue to move forward and not exit, I guess, exit land for on Slide 9?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Well, Ameet, almost as a -- I mean, from the beginning, I think that we have said to our investor base that we, at least, would not proceed with the project unless there was a significant amount of long-term offtake associated with the project. And so, roughly 1,000 megawatts has been something we talked about from the beginning. On top of that, Ameet, the conditional loan guarantee, if and when it's announced, it's called a conditional loan guarantee because there are conditions associated with it. And probably the most substantive condition, the condition we would be focused on is that the government would require us to have approximately that same amount of long-term offtake agreement contracted, which was a condition, again that we were happy to agree with the government on since we had said that we wouldn't go forward with it either. So that's why we would be doing that.

Operator

And the next question will come from the line of Ted Durbin, Goldman Sachs.

Theodore Durbin - Goldman Sachs Group Inc.

If I could just ask a little bit about the capital allocation. You're obviously coming out of 2010 here with a high cash balance. I'm just trying to understand a little bit better the allocation of the capital towards the renewables and whatnot, maybe extending that relative to between cash to stakeholders. Could you just talk a little bit more about that?

Christian Schade - Chief Financial Officer and Executive Vice President

As we said, we're committing to a $180 million stock repurchase, and that's within the confines of our restrictive payment basket. We're also going to be making required debt repayments under our term loan program, Term Loan B program. We've also earmarked potential investment in our solar projects, and these are projects which we had -- some of which we're announced late last year and early this year and would be subject to the cash grant program under the government. So all of those projects and repowering projects from El Segundo and GenConn Middletown. But those are the programs at least that were part of the capital allocation program for this year. That's what we've announced. We have $1.8 billion after which we would be able to deploy into additional repowering should they be available and new solar projects that we see on the horizon, as I've said before, all of which offer us the opportunity for very attractive returns.

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

And just to add, Ted, I think you phrased the question almost as if it was an either/or, and I guess that may be a little different. I mean, given the company's free cash flow generation and the cash we have on hand, we haven't really seen it as an either/or. In terms of returning capital to shareholders through the share buyback, we do as much as we can under the restrictive payment basket. Over the past years, we've constantly evaluated whether or not we could negotiate a way to have more room to do more, but the expense of doing that has always made that impractical. So from our perspective, it has not been an either/or decision. It's been do both.

Theodore Durbin - Goldman Sachs Group Inc.

Does that cost of getting the ability to do more of a buyback, you're still seeing that as not worth the expense of getting that?

Christian Schade - Chief Financial Officer and Executive Vice President

That's right. We think the expense to negotiate with the bondholders is being punitive. And as I said in the prepared remarks, the approach that we took on the 2014 maturity to wait for the calls to come due than to call away and refinance was we felt unattractive and a cost-beneficial way to do it. We have calls coming up in February for the 2016 maturity which we'll keep an eye on. The 2017 are not yet callable, will be so within a year. The high-yield market remains very attractive from financing perspectives, so we'll continue to look at that closely. But just to further what David said, with the excess cash in addition to the $180 million as we said, we'll certainly consider future stock repurchases if it can fall within the confines of hedging expansion we see in our restrictive payments basket throughout the year as well.

Theodore Durbin - Goldman Sachs Group Inc.

I appreciate the commentary on sort of the assets side. It sounds like you're not seeing the values on the CCGT side that you were before, but you did do the Cottonwood transaction. Are there other holes in your portfolio, where you say, "Geez, we'd really like to add some mid-merit assets whether it's more in South Central or whatnot?" And kind of talk about where you'd like to build up the portfolio.

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Well, I think the place where we'd like to build up the portfolio, and again, we've been fairly -- well, it took us six years to execute on the idea that we needed a load following plant in South Central. So just because I say this, I don't want you to think any sort of announcement's around the corner, because I'm actually skeptical that we can achieve anything. But we would definitely like to have some more baseload-following capability in PJM, particularly Eastern PJM. Having said that, we don't have any optimism about anything coming available in that footprint that we would find probably at a reasonable price. But we keep our ear to the ground. I would say that has been our single greatest priority second to backing up Big Cajun, which we've now achieved with Cotton.

Operator

And the next question will come from the line of Jonathan Arnold, Deutsche Bank.

Jonathan Arnold - Deutsche Bank AG

My question is, on STP, you believe the option for the second 10%, the TEPCO would take -- had a May expiration date on it, we recall from the original 8-K. But is there a similar date around the base 10% investment that's contingent on the loan guarantee acceptance? Is May a kind of drop-dead date for that whole arrangement with TEPCO?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

I don't believe there's a drop-dead date. And John, Tokyo Electric well understands the pace of development. I don't want to speak to them, but I think their enthusiasm for participating in this project is unchanged from when we announced the deal a year ago. So I don't remember any sense of date, but I have a very high level of confidence that if the loan guarantee comes that Tokyo Electric will participate in the project.

Jonathan Arnold - Deutsche Bank AG

And can you also give us a sense of -- well, obviously, your contribution is relatively small over this '11, '12 period. What would the $25 million in '12 be absent additional sell downs? And maybe some kind of sense of how much is actually being spent on the project itself during this next couple of years.

Christian Schade - Chief Financial Officer and Executive Vice President

Well, what it would be without the sell down, I'll have to get back to you on that. The amount of money that has to be invested towards in order for us to proceed is it's several hundred million dollars. But Jonathan, it's really hard to put it in those terms. Because like a good portion of it is long lead time materials in Japan which are actually funded with the credit facility from Toshiba. So maybe we can break out and provide it to you or do it next quarter. Just the development spend for now, in order for

us to proceed against the sources of capital, because it's really not useful if you look at it as one-lump sum, because various things are paid for with different buckets of money.

Jonathan Arnold - Deutsche Bank AG

And if I may just on one other topic, what indications are you getting from DOE on these discussions at a level of hedging through PPAs that would be acceptable to them on the project?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Well, I think that the condition is very specific. And I think back, it's the same as I answered to Ameet. It's something just less than 1,000 megawatts.

Operator

The next question will come from the line of Jay Dobson, Wunderlich Securities.

James Dobson - Wunderlich Securities Inc.

I was hoping you could give us some insight into the offtake discussions. The local media's covered some interesting transactions, or at least, proposals that you had. So I'm just wondering if you can give us some insight into where things stand and sort of what your level of optimism is currently.

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

It's a good question, and I think what I would say without -- I mean, it's difficult to comment with discussions that are underway. And in fact, normally, we don't comment on it but since as you said, there's been discussions by the public, I guess I should say some things. I would say, first of all, I think there's an openness, a willingness, and interest on several load-serving entities, large load-serving entities in the Texas market to talk about long-term offtake. And I would also say that the events of early February in Texas, where a part of the reason the state had rolling brownouts or even blackouts is because people couldn't get gas to some power plants, I think has reinforced the idea that having fuel diversity in the state is something that load-serving entities want to have. So there's a fairly high level of interest from various parties, but the big qualifier I always put on this question is, right now, as you say, it's really discussions. I mean, the project isn't really real to off-takers until we have a loan guarantee. So I would describe anything that we're doing with any counterparty at this point is being preliminary. And so that's what I would tell you. And based on what we're being told by the camp, their interest level, I'm guardedly optimistic. But mainly, my main attitude towards all this is, let's wait and see what happens when the loan guarantee's announced, because that's when ourselves and our counterparties are going to have to get down to business, and people are going to have to make commitments on both sides. So that's the main thing, and what we're trying to empathize here is that, that phase, and hopefully that phase will begin within the coming weeks, is something that basically needs to be resolved by the summer so that we can all have clarity as within the company and U.S. investors and analysts as to where we stand vis-à-vis this project.

James Dobson - Wunderlich Securities Inc.

As an unrelated follow-up, on the solar side, I'm not sure if this is good for your or for Chris. I assume in addition to selling an equity stake, you'd consider selling a tax equity there, and how do you

consider those two alternatives?

Christian Schade - Chief Financial Officer and Executive Vice President

Yes, very much so. I think the equity stake that we are contemplating is tax equity, it's a structuring issue. But we're certainly looking to pass off the tax attributes that are generated from this portfolio to tax equity investors. I think, one thing as a follow-up to a question before is that we'd certainly be looking to sell this equity at a premium. The returns that we're seeing perhaps from these investors are below the expected returns that we see in the high-teens, and so that sort of premium or IRR arbitrage gain will certainly benefit us in having development premium for this. But our goal here both is to bring equity into these projects and also, to lay off some of the tax that perhaps, does not necessarily accrue to NRG.

James Dobson - Wunderlich Securities Inc.

And Chris just a last follow-up, the capacity of the RP basket at year end?

Christian Schade - Chief Financial Officer and Executive Vice President

It was about $160 million. So the $180 million that we announced today will be spread out for a couple of quarters.

Operator

The next question will come from the line of Brandon Blossman, Tudor, Pickering Holt & Co.

Brandon Blossman - Tudor, Pickering, Holt & Co. Securities, Inc.

I guess just a follow-up on the tax equity question, probably for Chris. Just to be clear, is the tax equity partner or sell down required to optimize the tax benefits of the current solar portfolio, or is that something you need to do to increase the size of that portfolio?

Christian Schade - Chief Financial Officer and Executive Vice President

I think it's not necessarily required. I think it benefits the returns of the portfolio and allows us to continue to invest in the space. As David said, we're seeing a lot of opportunities elsewhere, and I think when we start to layer on other utility-sized projects in addition to what we have, there is a limit to the capacity of tax attributes that we can assume. So we think it's important. We're seeing a lot of interest and opportunities to invest in this space by sort of nontraditional investors who want to get green, and so we think it's a big opportunity for us, who are certain taxpayers as well. So it's for us to check a lot of boxes along the way. First and foremost to optimize our tax position in appropriate years, as well as to allow us to continue to invest in the space.

Brandon Blossman - Tudor, Pickering, Holt & Co. Securities, Inc.

And how does that dovetail with STP's tax attributes? Is that far enough out so that there's no overlap here or concerns about maximizing that value?

Christian Schade - Chief Financial Officer and Executive Vice President

It is far enough out that we're not perspiring about the tax attributes that it generates. But certainly, it's a topic that we will address at due time. And also, would speak to our underlying business that we

hope and certainly think will grow enough to burn through these NOLs and to continue to generate the taxable asset side in those years. So we're confident of that.

Brandon Blossman - Tudor, Pickering, Holt & Co. Securities, Inc.

And David, as a follow up, not that anyone wants this to happen, but if there is an exit ramp for STP, can you describe what that looks like? Is there a project to be had at some point in the future, given that this is a particularly attractive development project?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Well, Brandon, I guess, what I would say, on a few fronts. I mean it sort of depends on which exit ramp you're talking about. And I'm just speculating on things which of course, we don't hope to happen. I mean from my perspective, I think if something happens during this year that caused the entire project to go away, we would probably finish the licensing process, which is a small fraction of the overall development spend. But we're so far along with the NRC that to stop it this close to the end would not make sense. But beyond that, would the project go forward? I think it depends on which exit ramp it is. And again, I don't mean to speak for the other partners, because I want to emphasize every NRG investor on the call. We do not have the right to kill the STP 3 & 4 project. We just have the right to stop our own financial contribution to it. But I would say, if the exit ramp is that, actually it turns out that there is no loan guarantee in the offing -- I haven't actually asked this question directly, but I think our partners in Japan -- and we would be aligned that there would be, that the project would stop if there's no hope of a federal loan guarantee. If on the other hand, there was a federal loan guarantee, but we were taking the exit ramp because we were unable to lineup the offtake, I don't know what our partners would do in that circumstance. Maybe they would continue with the project, that would be their prerogative to do. I just know that if we don't have that offtake arrangement, then we will stop funding.

Brandon Blossman - Tudor, Pickering, Holt & Co. Securities, Inc.

And that would be not the 1,000 megawatts, but isn't that predicated on the loan guarantee or the loan guarantee predicated on the 1,000 megawatts?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

It is, but one of the reasons why I don't know -- I don't remember the exact terms, the exact words of the conditional loan guarantee, but I know that we do not have the opportunity at NRG to solve for the offtake arrangement, because I think the condition is offtake agreements with investment grade offtakers. Our Japanese partners who are investment grade would have that opportunity should they so choose to correct that on their own. We don't have that type of power, so that's not a question for us.

Operator

The next question will come from the line of Brian Chin, Citigroup.

Brian Chin - Citigroup Inc

What's the rough range of construction cost estimates in dollar per KW for the solar PV facilities that

you are seeing, and also for the solar thermal side?

Christian Schade - Chief Financial Officer and Executive Vice President

The range, well, I think we would say that the range right now is 3,500 to 4,000 per KW, and I don't know, that would be for the PV -- I can't tell you -- the solar thermal would probably be in the same range.

Brian Chin - Citigroup Inc

And then would it be fair to say that $4 sustaining perpetual natural gas price environment that you'd still see solar generating returns in the double digits as well? And is it higher or lower than nuclear?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Well, we haven't compared them side-by-side. I think it's fair to say that like nuclear, the solar projects, at this point, the economics are very heavily driven by the tax benefits. But beyond that, the real difference between the two is that every solar project we're doing is completely not merchant. It's totally PPA. So I don't think -- in fact, when we talk about taking the company's financial performance and sort of de-linking it to natural gas prices, we put renewables together with retail in parts of our EBITDA stream that are not associated with natural gas prices, because of the fact that all of the economics are derived from long-term PPAs.

Brian Chin - Citigroup Inc

Can you talk just a little bit about from your perspective, what the FERC's order in the New York ISO and the capacity market situation up there? What's changed longer-term, and how much of a positive is that for you guys, or is that even material?

Mauricio Gutierrez - Chief Operating Officer and Executive Vice President

Well, I mean it's definitely material. It's difficult to say what is the ultimate impact, because I think the variables are still being flushed out. But the three main changes was the recognition of state taxes and the cost of new entry calculation, inter-connection costs and then the energy offsets. So when you put those three together, you basically have higher cost of new entry, which will push capacity prices for both New York City and the whole state. This will benefit our New York portfolio, but at this point I can't give you the specific mind into it.

Operator

And the next question will come from the line of Anthony Crowdell, Jefferies.

Anthony Crowdell - Jefferies & Co

Just a quick question on the, I guess, the cold stub that hit Texas earlier this month. And it seem like there wasn't much of an impact on the generation side, but was there any impact to the margins that Reliant expected or anything on the quarter?

Jason Few - SVP of Mass Markets and Operations, Reliant Energy, Inc.

This is Jason. From the retail side, we actually, faired fairly well through this event. I mean, our

hedging strategy and risk policies served as well during the event. We did not see material impact to our business.

Operator

In interest of time, we have time for two more callers. And the next question will come from the line of Charles Fishman, Pritchard Capital Partners.

Charles Fishman - Pritchard Capital Partners, LLC

Your five-year environmental capital plan, Page 17, I want to make sure I understand this. The $720 million includes your view of what the math might be, which is less than worst-case, number one. And number two is there are no dollars in the $720 million to address once thru cooling. Is that correct?

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

No, actually, there is some dollars for 316(b) through the installation of extremes. We've been very successful in New York, in Arthur Kill and Huntley and Dunkirk to address this issue. So while it addresses the Mercury and asymmetric controls across all our coal assets, it also addresses the 316(b).

Charles Fishman - Pritchard Capital Partners, LLC

And if we do end up with the worst case math, I mean could this number increase 50%? Or do you have any feel for that?

Mauricio Gutierrez - Chief Operating Officer and Executive Vice President

Well, we actually disclosed that on our last earnings call. And I believe it's about $1 billion -- just shy of $1 billion. If it was the worst case scenario, in terms of unit-specific controls, no averaging. And we just don't believe the EPA will go that route. But the rule is going to come out, the proposal is going to come out in about a month, and I think it's just prudent to wait before we make any changes.

Operator

And there are no more questions in queue at this time.

David Crane - Chief Executive Officer, President, Executive Director and Member of Nuclear Oversight Committee

Okay, well, good. Well, thank you all very much, and we look forward to talking to you in the next quarter. Thank you, operator.

Operator

And ladies and gentlemen, this concludes today's presentation. Thank you very much for your participation. You may now disconnect, and have a great day.

EXHIBIT 3

Campo-Cottonwood Sole Source Aquifer

Designated Area

Notes and Explanation:

The Campo-Cottonwood Sole Source Aquifer was designated under the authority of Section 1424(e) of the Safe Drinking Water Act, Federal Register Citiation-49 FR 2948, Publication Date - 01/24/84. Please contact US EPA Region 9 (Jamelya Curtis, 415-972-3529) for assistance in determining place locations with respect to the project review area.

Map Status and Disclaimer:

Please note that this working map is a computer representation compiled by the Environmental Protection Agency (EPA) from sources which have supplied data or information that may not have been verified by the EPA. This data is offered here as a general representation only, and is not to be used for commercial purposes without verification by an independent professional qualified to verify such data or information. The EPA does not guarantee the accuracy, completeness, or timeliness of the information shown, and shall not be liable for any loss or injury resulting from reliance upon the information shown.

Legend

- Designation Boundary
- Highways
- Major Roads
- Streams
- Tribal Lands
- Cities, Towns

Descanso
Descanso Junction
Los Terrenitos
Guatay
Cuyapaipe
La Posta
Manzanita
La Posta
Live Oak Springs
Campo
Manzanita
Campo
Tierra del Sol
Doghouse Junction
Potrero
Campo
MEXICO

0 1.5 3 6 9 12 Miles

N W E S

EPA
Region 9 GIS Center

WTR0801656.4 Oct. 2008

EXHIBIT 4

Wildlife Conservation and Solar Energy Development in the Desert Southwest, United States

JEFFREY E. LOVICH AND JOSHUA R. ENNEN

Large areas of public land are currently being permitted or evaluated for utility-scale solar energy development (USSED) in the southwestern United States, including areas with high biodiversity and protected species. However, peer-reviewed studies of the effects of USSED on wildlife are lacking. The potential effects of the construction and the eventual decommissioning of solar energy facilities include the direct mortality of wildlife; environmental impacts of fugitive dust and dust suppressants; destruction and modification of habitat, including the impacts of roads; and off-site impacts related to construction material acquisition, processing, and transportation. The potential effects of the operation and maintenance of the facilities include habitat fragmentation and barriers to gene flow, increased noise, electromagnetic field generation, microclimate alteration, pollution, water consumption, and fire. Facility design effects, the efficacy of site-selection criteria, and the cumulative effects of USSED on regional wildlife populations are unknown. Currently available peer-reviewed data are insufficient to allow a rigorous assessment of the impact of USSED on wildlife.

Keywords: solar energy development, Mojave Desert, Sonoran Desert, wildlife, desert tortoises

The United States is poised to develop new renewable energy facilities at an unprecedented rate, including in potentially large areas of public land in the Southwest. This quantum leap is driven by escalating costs and demand for traditional energy sources from fossil fuels and by concerns over global climate change. Attention is focused largely on renewable forms of energy, especially solar energy. The potential for utility-scale solar energy development (USSED) and operation (USSEDO) is particularly high in the southwestern United States, where solar energy potential is high (USDOI and USDOE 2011a) and is already being harnessed in some areas. However, the potential for USSEDO conflicts with natural resources, especially wildlife, is also high, given the exceptional biodiversity (Mittermeier et al. 2002) and sensitivity (Lovich and Bainbridge 1999) of arid Southwest ecosystems, especially the Mojave (Randall et al. 2010) and Sonoran Deserts, which are already stressed by climate and human changes (CBI 2010). In addition, the desert Southwest is identified as a "hotspot" for threatened and endangered species in the United States (Flather et al. 1998). For these reasons, planning efforts should consider ways to minimize USSEDO impacts on wildlife (CBI 2010). Paradoxically, the implementation of large-scale solar energy development as an "environmentally friendly" alternative to conventional energy sources may actually increase environmental degradation on a local and on a regional scale (Bezdek 1993, Abbasi and Abbasi 2000) with concomitant negative effects on wildlife.

A logical first step in evaluating the effects of USSEDO on wildlife is to assess the existing scientific knowledge. As renewable energy development proceeds rapidly worldwide, information is slowly accumulating on the effects of USSEDO on the environment (for reviews, see Harte and Jassby 1978, Pimentel et al. 1994, Abbasi and Abbasi 2000). Gill (2005) noted that although the number of peer-reviewed publications on renewable energy has increased dramatically since 1991, only 7.6% of all publications on the topic covered environmental impacts, only 4.0% included discussions of ecological implications, and less than 1.0% contained information on environmental risks. A great deal of information on USSEDO exists in environmental compliance documents and other unpublished, non-peer-reviewed "gray" literature sources. Published scientific information on the effects on wildlife of any form of renewable energy development, including that of wind energy, is scant (Kuvlesky et al. 2007). The vast majority of the published research on wildlife and renewable energy development has been focused on the effects of wind energy development on birds (Drewitt and Langston 2006) and bats (Kunz et al. 2007) because of their sensitivity to aerial impacts. In contrast, almost no information is available on the effects of solar energy development on wildlife.

From a conservation standpoint, one of the most important species in the desert Southwest is Agassiz's desert

BioScience 61: 982–992. ISSN 0006-3568, electronic ISSN 1525-3244. doi:10.1525/bio.2011.61.12.8

tortoise (*Gopherus agassizii*; figure 1). Distributed north and west of the Colorado River, the species was listed as *threatened* under the US Endangered Species Act in 1990. Because of its protected status, Agassiz's desert tortoise acts as an "umbrella species," extending protection to other plants and animals within its range (Tracy and Brussard, 1994). The newly described Morafka's desert tortoise (*Gopherus morafkai*; Murphy et al. 2011) is another species of significant conservation concern in the desert Southwest, found east of the Colorado River. Both tortoises are important as ecological engineers who construct burrows that provide shelter to many other animal species, which allows them to escape the temperature extremes of the desert (Ernst and Lovich 2009). The importance of these tortoises is thus greatly disproportionate to their intrinsic value as species. By virtue of their protected status, Agassiz's desert tortoises have a significant impact on regulatory issues in the listed portion of their range, yet little is known about the effects of USSEDO on the species, even a quarter century after the recognition of that deficiency (Pearson 1986). Large areas of habitat occupied by Agassiz's desert tortoise in particular have potential for development of USSED (figure 2).

Figure 1. Agassiz's desert tortoise (*Gopherus agassizii*). Large areas of desert tortoise habitat are developed or being evaluated for renewable energy development, including for wind and solar energy. Photograph: Jeffrey E. Lovich.

In this article, we review the state of knowledge about the known and potential effects, both direct and indirect, of USSEDO on wildlife (table 1). Our review is based on information published primarily in peer-reviewed scientific journals for both energy and wildlife professionals. Agassiz's desert tortoise is periodically highlighted in our review because of its protected status, wide distribution in areas considered for USSEDO in the desert Southwest, and well-studied status (Ernst and Lovich 2009). In addition, we identify gaps in our understanding of the effects of USSEDO on wildlife and suggest questions that will guide future research toward a goal of mitigating or minimizing the negative effects on wildlife.

Background on proposed energy-development potential in the southwestern United States

The blueprint for evaluating and permitting the development of solar energy on public land in the region, as is required under the US National Environmental Policy Act (USEPA 2010), began in a draft environmental impact statement (EIS) prepared by two federal agencies (USDOI and USDOE 2011a). The purpose of the EIS is to "develop a new Solar Energy Program to further support utility-scale solar energy development on BLM [US Bureau of Land

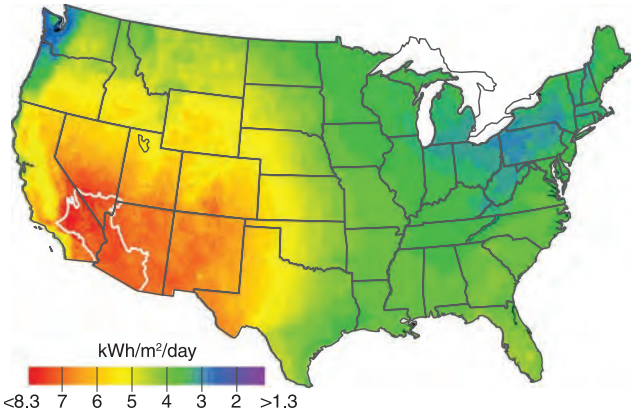


Figure 2. Concentrating solar energy potential (in kilowatt-hours per square meter per day [kWh/m²/day]) of the United States. The map shows the annual average direct normal solar resource data based on a 10-kilometer satellite-modeled data set for the period from 1998 to 2005. Refer to NREL (2011) for additional details and data sources. The white outline defines the approximate composite ranges of Agassiz's (west of the Colorado River) and Morafka's (east of the Colorado River) desert tortoises (Murphy et al. 2011) in the United States, both species of significant conservation concern. This figure was prepared by the National Renewable Energy Laboratory for the US Department of Energy (NREL 2011). The image was authored by an employee of the Alliance for Sustainable Energy, LLC, under Contract no. DE-AC36-08GO28308 with the US Department of Energy. Reprinted with permission from NREL 2011.

Table 1. List of known and potential impacts of utility-scale solar energy development on wildlife in the desert Southwest.

Impacts due to facility construction and decommissioning	Impacts due to facility presence, operation, and maintenance
Destruction and modification of wildlife habitat	Habitat fragmentation and barriers to movement and gene flow
Direct mortality of wildlife	Noise effects
Dust and dust-suppression effects	Electromagnetic field effects
Road effects	Microclimate effects
Off-site impacts	Pollution effects from spills
Destruction and modification of wildlife habitat	Water consumption effects
	Fire effects
	Light pollution effects, including polarized light
	Habitat fragmentation and barriers to movement and gene flow
	Noise effects

Management] -administered lands… and to ensure consistent application of measures to avoid, minimize, or mitigate the adverse impacts of such development" (p. ES-2). As of February 2010, the BLM had 127 active applications for solar facilities on lands that the BLM administers. According to USDOI and USDOE (2011a), all of the BLM-administered land in six states (California, Arizona, Utah, Nevada, New Mexico, and Colorado) was considered initially, for a total of 178 million hectares (ha). Not all of that land is compatible with solar energy development, so three alternative configurations are listed by USDOI and USDOI (2011a) for consideration, ranging from 274,244 to 39,972,558 ha. The larger figure is listed under the *no action alternative* where BLM would continue to use existing policy and guidance to evaluate applications. Of the area being considered under the two action alternatives, approximately 9 million ha meet the criteria established under the BLM's preferred action alternative to support solar development. Twenty-five criteria were used to exclude certain areas of public land from solar development and include environmental, social, and economic factors. The preferred alternative also included the identification of proposed *solar energy zones* (SEZs), defined as "area[s] with few impediments to utility-scale production of solar energy" (USDOI and USDOE 2011a, p. ES-7). By themselves, these SEZs constitute the nonpreferred action alternative of 274,244 ha listed above. Maps of SEZs are available at *http://solareis.anl.gov/documents/dpeis/index.cfm*.

Several sensitive, threatened, or endangered species are being considered within the EIS, but Agassiz's desert tortoise is one of only four species noted whose very presence at a site may be sufficient to exclude USSED in special cases (see table ES.2-2 in USDOI and USDOE 2011a). The potential effects of USSEDO are not trivial for tortoises or other wildlife species. Within the area covered in the draft EIS by USDOI and USDOE (2011a), it is estimated that approximately 161,943 ha of Agassiz's desert tortoise habitat will be directly affected. However, when including direct and indirect impacts on habitat (excluding transmission lines and roads that would add additional impacts; see Lovich and Bainbridge 1999, Kristan and Boarman 2007), it is estimated that approximately 769,230 ha will be affected. Some SEZs are adjacent to critical habitat designated for the recovery of Agassiz's desert tortoise, and this proximity is considered part of the indirect impacts.

On 28 October 2011, while this paper was in press, the BLM and US Department of Energy released a supplement to the EIS (USDOI and USDOE 2011b, 2011c) after receiving more than 80,500 comments. The no action alternative remains the same as in the EIS. The new preferred alternative (slightly reduced to 8,225,179 ha as the modified program alternative) eliminates or adjusts SEZs (now reduced to 115,335 ha in 17 zones as the modified SEZ alternative) to ensure that they are not in high-conflict areas and provides incentives for their use. The new plan also proposes a process to accommodate additional solar energy development outside of SEZs and to revisit ongoing state-based planning efforts to allow consideration of additional SEZs in the future.

The impacts of USSED on wildlife: Effects due to construction and decommissioning

The construction and eventual decommissioning of solar energy facilities will have impacts on wildlife, including rare and endangered species, and on their habitats in the desert (Harte and Jassby 1978). These activities involve significant ground disturbance and direct (e.g., mortality) and indirect (e.g., habitat loss, degradation, modification) impacts on wildlife and their habitat (Kuvlesky et al. 2007). Solar energy facilities require large land areas to harness sunlight and convert it to electrical energy. According to Wilshire and colleagues (2008), photovoltaic panels with a 10% conversion efficiency would need to cover an area of about 32,000 square kilometers, or an area a little smaller than the state of Maryland, to meet the current electricity demands of the United States. Many of the areas being considered for the development of solar energy in the Mojave and Sonoran Deserts are, at present, relatively undisturbed (USDOI and USDOE 2011a).

The extent of surface disturbance of USSED is related to the cooling technology used. Because of the scarcity of water in the desert Southwest region, dry-cooling systems, which consume 90%–95% less water than wet-cooling systems (EPRI 2002), are becoming a more viable option for concentrating solar facilities. Although wet-cooling systems are more economical and efficient, they consume larger amounts of water per kilowatt-hour (Torcellini et al. 2003). Unlike wet-cooling systems, dry-cooling systems use ambient air, instead of water, to cool the exhaust steam from the turbines. However, to achieve a heat-rejection efficiency similar to that in a wet-cooling system, Khalil and colleagues (2006) estimated that a direct dry-cooling system will require a larger footprint and would thus affect more wildlife habitat.

Although we found no information in the scientific literature about the direct effects of USSED on wildlife, the ground-disturbance impacts are expected to be similar to those caused by other human activities in the desert (Lovich and Bainbridge 1999).

Dust and dust suppressants. USSED transforms the landscape substantially through site preparation, including the construction of roads and other infrastructure. In addition, many solar facilities require vegetation removal and grading. These construction activities produce dust emissions, especially in arid environments (Munson et al. 2011), which already have the potential for natural dust emission. Dust can have dramatic effects on ecological processes at all scales (reviewed by Field et al. 2010). At the smallest scale, wind erosion, which powers dust emission, can alter the fertility and water-retention capabilities of the soil. Physiologically, dust can adversely influence the gas exchange, photosynthesis, and water usage of Mojave Desert shrubs (Sharifi et al. 1997). Depending on particle size, wind speed, and other factors, dust emission can physically damage plant species through root exposure, burial, and abrasions to their leaves and stems. The physiological and physical damage to plant species inflicted by dust emissions could ultimately reduce the plants' primary production and could indirectly affect wildlife food plants and habitat quality.

From an operational perspective, dust particles reduce mirror and panel efficiency in converting solar energy into heat or electricity. To combat dust, solar energy facilities apply various dust suppressants to surfaces with exposed soil (e.g., graded areas, areas with vegetation removed, roads). There are eight categories of common dust suppressants used for industrial applications: water, salts and brines, organic nonpetroleum products, synthetic polymers, organic petroleum, electrochemical substances, clay additives, and mulch and fiber mixtures (reviewed in Piechota et al. 2004). In a study conducted in the Mojave Desert in which the hydrological impacts of dust suppressants were compared, Singh and colleagues (2003) reported that changes did occur in the volume, rate, and timing of runoff when dust suppressants were used. In particular, petroleum-based and acrylic-polymer dust suppressants drastically influenced the hydrology of disturbed areas by increasing runoff volume and changing its timing. When it is applied to disturbed desert soils, magnesium chloride ($MgCl_2$), a commonly used salt-based dust depressant, does not increase runoff volume but does, however, increase the total suspended solids loads in runoff (Singh et al. 2003).

Others have highlighted the fact that there is a dearth of scientific research and literature on the effects of dust suppressants on wildlife, including the most commonly used category of dust depressant: brines and salts (Piechota et al. 2004, Goodrich et al. 2008). However, the application of $MgCl_2$ to roads was correlated with a higher frequency of plant damage (Goodrich et al. 2008). Because chloride salts, including $MgCl_2$, are not confined to the point of application but have the ability to be transported in runoff (White and Broadly 2001), the potential exists for a loss of primary production associated with plant damage in the habitats surrounding a solar facility, which could directly affect wildlife habitat.

Mortality of wildlife. We are not aware of any published studies documenting the direct effects of USSED on the survival of wildlife. However, subterranean animals can be affected by USSED, including species that hibernate underground. In the Sonoran Desert portion of California, Cowles (1941) observed that most reptiles in the Coachella Valley hibernated at depths of less than 33 centimeters (cm), with many at considerably shallower depths. Included in his observations were flat-tailed horned lizards (*Phrynosoma mcallii*)—a species of special concern in the region because of solar energy development (USDOI and USDOE 2011a)—and the federally protected Coachella Valley fringe-toed lizard (*Uma inornata*). Even lightweight vehicles like motorcycles are capable of causing greatly increased soil density (soil compaction) at a depth of 30–60 cm as their tires pass over the surface (Webb 1983). These observations suggest that vehicular activities in the desert have the potential to kill or entrap large numbers of subterranean animals (Stebbins 1995) through compressive forces or burrow collapse. Similar or greater impacts would be expected from the heavy equipment associated with the construction activities at an energy facility.

Destruction and modification of wildlife habitat. Despite the absence of published, peer-reviewed information on the effects of USSED on wildlife and their habitats, a considerable body of literature exists on the effects of other ground-disturbing activities on both ecological patterns and processes that are broadly comparable. Ground-disturbing activities affect a variety of processes in the desert, including soil density, water infiltration rate, vulnerability to erosion, secondary plant succession, invasion by exotic plant species, and stability of cryptobiotic soil crusts (for reviews, see Lovich and Bainbridge 1999, Webb et al. 2009). All of these processes have the ability—individually and together—to alter habitat quality, often to the detriment of wildlife. Any disturbance and alteration to the desert landscape, including the construction and decommissioning of utility-scale solar energy facilities, has the potential to increase soil erosion. Erosion can physically and physiologically affect plant species and can thus adversely influence primary production (Sharifi et al. 1997, Field et al. 2010) and food availability for wildlife.

Solar energy facilities require substantial site preparation (including the removal of vegetation) that alters topography and, thus, drainage patterns to divert the surface flow associated with rainfall away from facility infrastructure (Abbasi and Abbasi 2000). Channeling runoff away from plant communities can have dramatic negative effects on water availability and habitat quality in the desert, as was shown by Schlesinger and colleagues (1989). Areas deprived

of runoff from sheet flow support less biomass of perennial and annual plants relative to adjacent areas with uninterrupted water-flow patterns.

The impacts of roads. Roads are required in order to provide access to solar energy infrastructure. Both paved and unpaved roads have well-documented negative effects on wildlife (Forman and Alexander 1998), and similar effects are expected in utility-scale solar energy facilities. Although road mortality is most easily detected on the actual roadway, the effects of roads extend far beyond their physical surface. In a study of the effects of roads on Agassiz's desert tortoise populations in southern Nevada, von Seckendorff Hoff and Marlow (2002) examined transects along roads with traffic volumes varying from 25 to 5000 vehicles per day. Tortoises and tortoise sign (e.g., burrows, shells, scat) decreased with their proximity to a road. On roads with high traffic volumes, tortoises and tortoise sign were reduced as far as 4000 meters from the roadside. Roads with lower traffic volumes had fewer far-reaching effects.

Another effect of roads in the desert is the edge enhancement of plants and arthropod herbivores (Lightfoot and Whitford 1991). Perennial plants along the roadside are often larger than those farther away, and annual plant germination is often greatest along the shoulders of roads. It is possible that increased runoff due to impervious pavement or compacted soil contributes to this heterogeneity of vegetation in relationship to a road. Agassiz's desert tortoises may select locations for burrow construction that are close to roads, perhaps because of this increased productivity of food plants (Lovich and Daniels 2000). Although this situation suggests potentially beneficial impacts for herbivorous species of wildlife, such as tortoises, it increases their chance of being killed by vehicle strikes, as was shown by von Seckendorff Hoff and Marlow (2002).

Off-site impacts. Direct impacts on wildlife and habitat can occur well outside the actual footprint of the energy facility. Extraction of large amounts of raw materials for the construction of solar energy facilities (e.g., aggregate, cement, steel, glass); transportation and processing of those materials; the need for large amounts of water for cooling some installations; and the potential for the production of toxic wastes, including coolants, antifreeze, rust inhibitors, and heavy metals, can affect wildlife adjacent to or far from the location of the facility (Abbasi and Abbasi 2000). Abbasi and Abbasi (2000) summarized data suggesting that the material requirements for large-scale solar facilities exceed those for conventional fossil-fuel plants on a cost-per-unit-of-energy basis. In addition, water used for steam production at one solar energy facility in the Mojave Desert of California contained selenium, and the wastewater was pumped into evaporation ponds that attracted birds that fed on invertebrates. Although selenium toxicity was not considered a threat on the basis of the results of one study, the possibility exists for harmful bioaccumulation of this toxic micronutrient (Herbst 2006). In recognition of the hazard, Pimentel and colleagues (1994) suggested that fencing should be used to keep wildlife away from these toxic ponds.

The impacts of USSED on wildlife: Effects due to operation and maintenance

This category includes the effects related to the presence and operation of the solar facility, not the physical construction and decommissioning of the same. Some of the effects (e.g., mortality of wildlife and impacts caused by roads) are similar to those discussed previously for construction and decommissioning and are not discussed further.

Habitat fragmentation. Until relatively recently, the desert Southwest was characterized by large blocks of continuous and interconnected habitat. Roads and urban development continue to contribute to habitat fragmentation in this landscape. Large-scale energy development has the potential to add to and exacerbate the situation, presenting potential barriers to movement and genetic exchange in wildlife populations, including those of bighorn sheep (*Ovis canadensis*), deer (*Odocoileus* spp.), tortoises, and other species of concern and social significance. Research conducted on the effects of oil and gas exploration and development (OGED) on wildlife in the Intermountain West provides a possible analog to USSEDO, since comparable data are not available for the desert Southwest. The potential effects on mule deer (*Odocoileus hemionus*) and other wildlife species include impediments to free movement, the creation of migration bottlenecks, and a reduction in effective winter range size. Mule deer responded immediately to OGED by moving away from disturbances, with no sign of acclimation during the three years of study by Sawyer and colleagues (2009). Some deer avoidance resulted in their use of less-preferred and presumably less-suitable habitats.

Despite a lack of data on the direct contributions of USSEDO to habitat fragmentation, USSEDO has the potential to be an impediment to gene flow for some species. Although the extent of this impact is, as yet, largely unquantified in the desert, compelling evidence for the effects of human-caused habitat fragmentation on diverse wildlife species has already been demonstrated in the adjacent coastal region of southern California (Delaney et al. 2010).

Noise effects. Industrial noise can have impacts on wildlife, including changes to their habitat use and activity patterns, increases in stress, weakened immune systems, reduced reproductive success, altered foraging behavior, increased predation risk, degraded communication with conspecifics, and damaged hearing (Barber et al. 2009, Pater et al. 2009). Changes in sound level of only a few decibels can elicit substantial animal responses. Most noise associated with USSEDO is likely to be generated during the construction phase (Suter 2002), but noise can also be produced during operation and maintenance activities. Brattstrom and Bondello (1983) documented the effects of noise on Mojave

Desert wildlife on the basis of experiments involving off-highway vehicles. Noise from some of these vehicles can reach 110 decibels—near the threshold of human pain and certainly within the range expected for various construction, operation, and maintenance activities (Suter 2002) associated with USSEDO. This level of noise caused hearing loss in animals, such as kangaroo rats (*Dipodomys* spp.), desert iguanas (*Dipsosaurus dorsalis*), and fringe-toed lizards (*Uma* spp.). In addition, it interfered with the ability of kangaroo rats to detect predators, such as rattlesnakes (*Crotalus* spp.), and caused an unnatural emergence of aestivating spadefoot toads (*Scaphiopus* spp.), which would most likely result in their deaths. Because of impacts on wildlife, Brattstrom and Bondello (1983) recommended that "all undisturbed desert habitats, critical habitats, and all ranges of threatened, endangered, or otherwise protected desert species" (p. 204) should be protected from loud noise.

Although many consider solar energy production a "quiet" endeavor, noise is associated with their operation. For example, facilities at which wet-cooling systems are used will have noises generated by fans and pumps. As for facilities with dry-cooling systems, only noise from fans will be produced during operation (EPRI 2002). Because of the larger size requirements of dry-cooling systems, there will be more noise production associated with an increase in the number of fans.

Electromagnetic field generation. When electricity is passed through cables, it generates electric and magnetic fields. USSEDO requires a large distribution system of buried and overhead cables to transmit energy from the point of production to the end user. Electromagnetic fields (EMFs) produced as energy flows through system cables are a concern from the standpoint of both human and wildlife health, yet little information is available to assess the potential impact of the EMFs associated with USSEDO on wildlife. Concerns about EMFs have persisted for a long time, in part because of controversy over whether they're the actual cause of problems and disagreement about the underlying mechanisms for possible effects. For example, there is presently a lack of widely accepted agreement about the biological mechanisms that can explain the consistent associations between extremely low-frequency EMF exposure from overhead power lines and childhood leukemia, although there is no shortage of theories (Gee 2009).

Some conclude that the effects of EMFs on wildlife will be minor because of reviews of the often conflicting and inconclusive literature on the topic (Petersen and Malm 2006). Others suggest that EMFs are a possible source of harm for diverse species of wildlife and contribute to the decline of some mammal populations. Balmori (2010) listed possible impacts of chronic exposure to athermal electromagnetic radiation, which included damage to the nervous system, disruption of circadian rhythm, changes in heart function, impairment of immunity and fertility, and genetic and developmental problems. He concluded that enough evidence exists to confirm harm to wildlife but suggested that further study is urgently needed. Other authors suggest that the generally inconsistent epidemiological evidence in support of the effects of EMFs should not be cause for inaction. Instead, they argue that the precautionary principle should be applied in order to prevent a recurrence of the "late lessons from early warnings" scenario that has been repeated throughout history (Gee 2009).

Magnetic information is used for orientation by diverse species, from insects (Sharma and Kumar 2010) to reptiles (Perry A et al. 1985). Despite recognition of this phenomenon, the direct effects of USSEDO-produced EMFs on wildlife orientation remains unknown.

Microclimate effects. The alteration of a landscape through the removal of vegetation and the construction of structures by humans not only has the potential of increasing animal mortality but also changes the characteristics of the environment in a way that affects wildlife. The potential for microclimate effects unique to solar facilities was discussed by Pimentel and colleagues (1994) and by Harte and Jassby (1978). It has been estimated that a concentrating solar facility can increase the albedo of a desert environment by 30%–56%, which could influence local temperature and precipitation patterns through changes in wind speed and evapotranspiration. Depending on their design, large concentrating solar facilities may also have the ability to produce significant amounts of unused heat that could be carried downwind into adjacent wildlife habitat with the potential to create localized drought conditions. The heat produced by central-tower solar facilities can burn or incinerate birds and flying insects as they pass through the concentrated beams of reflected light (McCrary et al. 1986, Pimentel et al. 1994, Tsoutsos et al. 2005, Wilshire et al. 2008).

A dry-cooled solar facility—in particular, one with a concentrating-trough system—could reject heated air from the cooling process with temperatures 25–35 degrees Fahrenheit higher than the ambient temperature (EPRI 2002). This could affect the microclimate on site or those in adjacent habitats. To our knowledge, no research is available to assess the effects of USSEDO on temperature or that of any other climatic variable on wildlife. However, organisms whose sex is determined by incubation temperatures, such as both species of desert tortoises, may be especially sensitive to temperature changes, because small temperature changes have the potential to alter hatchling sex ratios (Hulin et al. 2009).

Pollutants from spills. USSEDO, especially at wet-cooled solar facilities, has a potential risk for hazardous chemical spills on site, associated with the toxicants used in cooling systems, antifreeze agents, rust inhibitors, herbicides, and heavy metals (Abbasi and Abbasi 2000, Tsoutsos et al. 2005). Wet-cooling solar systems must use treatment chemicals (e.g., chlorine, bromine, selenium) and acids and bases (e.g., sulfuric acid, sodium hydroxide, hydrated lime) for the prevention of fouling and scaling and for pH control of the water used in their recirculating systems (EPRI 2002).

Solar facilities at which a recirculating system is used also have treatment and disposal issues associated with water discharge, known as *blowdown*, which is water with a high concentration of dissolved and suspended materials created by the numerous evaporation cycles in the closed system (EPRI 2002). These discharges may contain chemicals used to prevent fouling and scaling. The potentially tainted water is usually stored in evaporative ponds, which further concentrates the toxicants (Herbst 2006). Because water is an attraction for desert wildlife, numerous species could be adversely affected. The adverse effects of the aforementioned substances and similar ones on wildlife are well documented in the literature, and a full review is outside the scope of this article. However, with the decreased likelihood of wet-cooling systems for solar facilities in the desert, the risk of hazardous spills and discharges on site will be less in the future, because dry-cooling systems eliminate most of the associated water-treatment processes (EPRI 2002). However, there are still risks of spills associated with a dry-cooling system. More research is needed on the adverse effects of chemical spills and tainted-water discharges specifically related to USSEDO on wildlife.

Water consumption (wet-cooled solar). The southwestern United States is a water-poor region, and water use is highly regulated throughout the area. Because of this water limitation, the type of cooling systems installed at solar facilities is limited as well. For example, a once-through cooling system—a form of wet cooling—is generally not feasible in arid environments, because there are few permanent bodies of water (i.e., rivers, oceans, and lakes) from which to draw cool water and then into which to release hot water. Likewise, other wet-cooling options, such as recirculating systems and hybrid systems, are becoming less popular because of water shortage issues in the arid region. Therefore, the popularity of the less-efficient and less-economical dry-cooling systems is increasing on public lands. Water will also be needed at solar facilities to periodically wash dust from the mirrors or panels. Although there are numerous reports in which the costs and benefits were compared both environmentally and economically (EPRI 2002, Khalil et al. 2006) between wet- and dry-cooled solar facilities, to our knowledge no one has actually quantified the effects of water use and consumption on desert wildlife in relation to the operation of these facilities.

Fire risks. Any system that produces electricity and heat has a potential risk of fire, and renewable energy facilities are no exception. Concentrating solar energy facilities harness the sun's energy to heat oils, gases, or liquid sodium, depending on the system design (e.g., heliostat power, trough, dish). With temperatures reaching more than 300 degrees Celsius in most concentrated solar systems, spills and leaks from the coolant system increase the risk of fires (Tsoutsos et al. 2005). Even though all vegetation is usually removed from the site during construction, which reduces the risk of a fire propagating on and off site, the increase of human activity in a desert region increases the potential for fire, especially along major highways and in the densely populated western Mojave Desert (Brooks and Matchett 2006).

The Southwest deserts are not fire-adapted ecosystems: fire was historically uncommon in these regions (Brooks and Esque 2002). However, with the establishment of numerous flammable invasive annual plants in the desert Southwest (Brown and Minnich 1986), coupled with an increase in anthropogenic ignitions, fire has become more common in the deserts, which adversely affects wildlife (Esque et al. 2003). For Agassiz's desert tortoise, fire can translate into direct mortality at renewable energy facilities (Lovich and Daniels 2000) and can cause reductions in food and habitat quality. To our knowledge, however, there is no scientific literature related to the effects of USSEDO-caused fire on wildlife.

Light pollution. Two types of light pollution could be produced by solar energy facilities: ecological light pollution (ELP; Longcore and Rich 2004) and polarized light pollution (PLP; Horváth et al. 2009). The latter, PLP, could be produced at high levels at facilities using photovoltaic solar panels, because dark surfaces polarize light. ELP can also be produced at solar facilities in the form of reflected light. The reflected light from USSEDO has been suggested as a possible hazard to eyesight (Abbasi and Abbasi 2000). ELP could adversely affect the physiology, behavior, and population ecology of wildlife, which could include the alteration of predation, competition, and reproduction (for reviews, see Longcore and Rich 2004, Perry G et al. 2008). For example, the foraging behavior of some species can be adversely affected by light pollution (for a review, see Longcore and Rich 2004). The literature is limited regarding the impact of artificial lighting on amphibians and reptiles (Perry G et al. 2008), and, to our knowledge, there are no published studies in which the impacts on wildlife of light pollution produced by USSEDO have been assessed. However, light pollution is considered by G. Perry and colleagues (2008) to be a serious threat to reptiles, amphibians, and entire ecological communities that requires consideration during project planning. G. Perry and colleagues (2008) further recommended the removal of unnecessary lighting so that the lighting conditions of nearby habitats would be as close as possible to their natural state.

Numerous anthropogenic products—usually those that are dark in color (e.g., oil spills, glass panes, automobiles, plastics, paints, asphalt roads)—can unnaturally polarize light, which can have adverse effects on wildlife (for a review, see Horváth et al. 2009). For example, numerous animal species use polarized light for orientation and navigation purposes (Horváth and Varjú 2004). Therefore, the potential exists for PLP to disrupt the orientation and migration abilities of desert wildlife, including those of sensitive species. In the review by Horváth and colleagues (2009), which was focused mostly on insects but included a few avian references, they highlighted the fact that anthropogenic products that produce PLP can appear to be water bodies to wildlife and can become ecological traps for insects and, to a lesser degree, avian species. Therefore,

utility-scale solar energy facilities at which photovoltaic technology is used in the desert Southwest could create a direct effect on insects (i.e., ecological trap), which could have profound but unquantified effects on the ecological community surrounding the solar facility. In addition, there may be indirect effects on wildlife through the limitation of plant food resources, especially if pollinators are negatively affected. As was stated by Horváth and colleagues (2009), the population- and community-level effects of PLP can only be speculated on because of the paucity of data.

Unanswered questions and research needs

In our review of the peer-reviewed scientific literature, we found only one peer-reviewed publication on the specific effects of utility-scale solar energy facility operation on wildlife (McCrary et al. 1986) and none on utility-scale solar energy facility construction or decommissioning. Although it is possible that we missed other peer-reviewed publications, our preliminary assessment demonstrates that very little critically reviewed information is available on this topic. The dearth of published, peer-reviewed scientific information provides an opportunity to identify the fundamental research questions for which resource managers need answers. Without those answers, resource managers will be unable to effectively minimize the negative effects of USSEDO on wildlife, especially before permitting widespread development of this technology on relatively undisturbed public land.

Before-and-after studies. Carefully controlled studies are required in order to tease out the direct and indirect effects of USSEDO on wildlife. Pre- and postconstruction evaluations are necessary to identify the effects of renewable energy facilities and to compare results across studies (Kunz et al. 2007). In their review of wind energy development and wildlife, with an emphasis on birds, Kuvlesky and colleagues (2007) noted that experimental designs and data-collection standards were typically inconsistent among studies. This fact alone contributes measurably to the reported variability among studies or renders comparisons difficult, if not impossible. Additional studies should emphasize the need for carefully controlled before-after-control-impact (BACI) studies (Kuvlesky et al. 2007) with replication (if possible) and a detailed description of site conditions. The potential payoff for supporting BACI studies now could be significant: They could provide answers for how to mitigate the negative impacts on wildlife in a cost-effective and timely manner.

What are the cumulative effects of large numbers of dispersed or concentrated energy facilities? Large portions of the desert Southwest have the potential for solar energy development. Although certain areas are targeted for large facilities because of resource availability and engineering requirements (e.g., their proximity to existing transmission corridors), other areas may receive smaller, more widely scattered facilities. A major unanswered question is what the cumulative impacts of these facilities on wildlife are. Would it be better for wildlife if development is concentrated or if it is scattered in smaller, dispersed facilities? Modeling based on existing data would be highly suspect because of the deficiency of detailed site-level published information identified in our analysis. Except for those on habitat destruction and alteration related to other human endeavors, there are no published articles on the population genetic consequences of habitat fragmentation related to USSED, which makes this a high priority for future research.

What density or design of development maximizes energy benefits while minimizing negative effects on wildlife? We are not aware of any published peer-reviewed studies in which the impacts on wildlife of different USSED densities or designs have been assessed. For example, would it benefit wildlife to leave strips of undisturbed habitat between rows of concentrating solar arrays? Research projects in which various densities, arrays, or designs of energy-development infrastructure are considered would be extremely valuable. BACI studies would be very useful for addressing this deficiency.

What are the best sites for energy farms with respect to the needs of wildlife? The large areas of public land available for renewable energy development in the desert Southwest encompass a wide variety of habitats. Although this provides a large number of choices for USSED, not all areas have the same energy potential because of resource availability and the limitations associated with engineering requirements, as was noted above. Detailed information on wildlife distribution and habitat requirements are crucially needed for proper site location and for the design of renewable energy developments (Tsoutsos et al. 2005). Public-resource-management agencies have access to rich geospatial data sets based on many years of inventories and resource-management planning. These data could be used to identify areas of high value for both energy development and wildlife. Areas with overlapping high values could be carefully studied through risk assessment when it appears that conflicts are likely. Previously degraded wildlife habitats, such as old mine sites, overgrazed pastures, and abandoned crop fields, may be good places to concentrate USSED to minimize its impacts on wildlife (CBI 2010).

Can the impacts of solar energy development on wildlife be mitigated? The construction of solar energy facilities can cause direct mortality of wildlife. In addition, building these facilities results in the destruction and fragmentation of wildlife habitat and may increase the possibility of fire, as was discussed above. Beyond these effects, essentially nothing is known about the operational effects of solar energy facilities on wildlife. Current mitigation strategies for desert tortoises and other protected species include few alternatives other than translocation of the animals from the footprint of the development into other areas. Although this strategy may be appealing at first glance, animal translocation has a checkered history of success, especially for reptiles and amphibians (Germano and Bishop 2008, CBI 2010). Translocation

has yet to be demonstrated as a viable long-term solution that would mitigate the destruction of Agassiz's desert tortoise habitat (Ernst and Lovich 2009, CBI 2010).

Conclusions

All energy production has associated social and environmental costs (Budnitz and Holdren 1976, Bezdek 1993). In their review of the adverse environmental effects of renewable energy development, Abbasi and Abbasi (2000) stated that "renewable energy sources are not the panacea they are popularly perceived to be; indeed, in some cases, their adverse environmental impacts can be as strongly negative as the impacts of conventional energy sources" (p. 121). Therefore, responsible, efficient energy production requires both the minimization of environmental costs and the maximization of benefits to society—factors that are not mutually exclusive. Stevens and colleagues (1991) and Martín-López and colleagues (2008) suggested that the analyses of costs and benefits should include both wildlife use and existence values. On the basis of our review of the existing peer-reviewed scientific literature, it appears that insufficient evidence is available to determine whether solar energy development, as it is envisioned for the desert Southwest, is compatible with wildlife conservation. This is especially true for threatened species such as Agassiz's desert tortoise. The many other unanswered questions that remain after reviewing the available evidence provide opportunities for future research, as was outlined above.

The shift toward renewable energy is widely perceived by the public as a "green movement" intended to reduce greenhouse-gas emissions and acid rain and to curb global climate change (Abbasi and Abbasi 2000). However, as was noted by Harte and Jassby (1978), just because an energy technology is simple, thermodynamically optimal, renewable, or inexpensive does not mean that it will be benign from an ecological perspective. The issue of wildlife impacts is much more complex than is widely appreciated, especially when the various scales of impact (e.g., local, regional, global) are considered. Our analysis shows that, on a local scale, so little is known about the effects USSEDO on wildlife that extrapolation to larger scales with any degree of confidence is currently limited by an inadequate amount of scientific data. Therefore, without additional research to fill the significant information void, accurate assessment of the potential impacts of solar energy development on wildlife is largely theoretical but needs to be empirical and well-founded on supporting science.

Acknowledgments

Earlier versions of the manuscript benefited from comments offered by Linda Gundersen, Marijke van Heeswijk, John Mathias, Misa Milliron, Ken Nussear, Mary Price, Mark Sogge, Linda Spiegel, and Brian Wooldridge. Special thanks to Emily Waldron and Caleb Loughran for their assistance with literature searches. The research was generously supported by a grant from the California Energy Commission, Research Development and Demonstration Division, Public Interest Energy Research program (contract # 500-09-020). Special thanks to Al Muth for providing accommodations at the Philip L. Boyd Deep Canyon Research Center of the University of California, Riverside, during the development of the manuscript. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the US government.

References cited

Abbasi SA, Abbasi N. 2000. The likely adverse environmental impacts of renewable energy sources. Applied Energy 65: 121–144.

Balmori A. 2010. The incidence of electromagnetic pollution on wild mammals: A new "poison" with a slow effect on nature? Environmentalist 30: 90–97.

Barber JR, Crooks KR, Fristrup KM. 2009. The costs of chronic noise exposure for terrestrial organisms. Trends in Ecology and Evolution 25: 180–189.

Bezdek RH. 1993. The environmental, health, and safety implications of solar energy in central station power production. Energy 18: 681–685.

Brattstrom BH, Bondello MC. 1983. Effects of off-road vehicle noise on desert vertebrates. Pages 167–206 in Webb RH, Wilshire HG, eds. Environmental Effects of Off-road Vehicles: Impacts and Management in Arid Regions. Springer.

Brooks ML, Esque TC. 2002. Alien plants and fire in desert tortoise (*Gopherus agassizii*) habitat of the Mojave and Colorado Deserts. Chelonian Conservation and Biology 4: 330–340.

Brooks ML, Matchett JR. 2006. Spatial and temporal patterns of wildfires in the Mojave Desert, 1980–2004. Journal of Arid Environments 67: 148–164.

Brown DE, Minnich RA. 1986. Fire and changes in creosote bush scrub of the western Sonoran Desert, California. American Midland Naturalist 116: 411–422.

Budnitz RJ, Holdren JP. 1976. Social and environmental costs of energy systems. Annual Review of Energy 1: 553–580.

[CBI] Conservation Biology Institute. 2010. Recommendations of Independent Science Advisors for the California Desert Renewable Energy Conservation Plan (DRECP). CBI. (6 July 2011; *www.energy.ca.gov/2010publications/DRECP-1000-2010-008/DRECP-1000-2010-008-F.PDF*)

Cowles RB. 1941. Observations on the winter activities of desert reptiles. Ecology 22: 125–140.

Delaney KS, Riley SPD, Fisher RN. 2010. A rapid, strong, and convergent genetic response to urban habitat fragmentation in four divergent and widespread vertebrates. PLoS ONE 5: e12767. doi:10.1371/journal.pone.0012767

Drewitt AL, Langston RHW. 2006. Assessing the impacts of wind farms on birds. Ibis 148: 29–42.

[EPRI] Electric Power Research Institute. 2002. Comparison of alternate cooling technologies for California power plants: economic, environmental, and other tradeoffs. California Energy Commission. Report no. 500–02–079F.

Ernst CH, Lovich JE. 2009. Turtles of the United States and Canada, 2nd ed. Johns Hopkins University Press.

Esque TC, Schwalbe CR, DeFalco LA, Duncan RB, Hughes TJ. 2003. Effects of desert wildfires on desert tortoise (*Gopherus agassizii*) and other small vertebrates. Southwestern Naturalist 48: 103–111.

Field JP, Belnap J, Breshears DD, Neff JC, Okin GS, Whicker JJ, Painter TH, Ravi S, Reheis MC, Reynolds RL. 2010. The ecology of dust. Frontiers in Ecology and the Environment 8: 423–430.

Flather CH, Knowles MS, Kendall IA. 1998. Threatened and endangered species geography. BioScience 48: 365–376.

Forman RTT, Alexander LE. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29: 207–231.

Gee D. 2009. Late lessons from early warnings: Towards realism and precaution with EMF. Pathophysiology 16: 217–231.

Germano JM, Bishop PJ. 2008. Suitability of amphibians and reptiles for translocation. Conservation Biology 23: 7–15.

Gill AB. 2005. Offshore renewable energy: ecological implications of generating electricity in the coastal zone. Journal of Applied Ecology 42: 605–615.

Goodrich BA, Koski RD, Jacobi WR. 2008. Roadside vegetation health condition and magnesium chloride ($MgCl_2$) dust suppressant use in two Colorado, U.S. counties. Arboriculture and Urban Forestry 34: 252–259.

Harte J, Jassby A. 1978. Energy technologies and natural environments: The search for compatibility. Annual Review of Energy 3: 101–146.

Herbst DB. 2006. Salinity controls on trophic interactions among invertebrates and algae of solar evaporation ponds in the Mojave Desert and relation to shorebird foraging and selenium risk. Wetlands 26: 475–485.

Horváth G, Varjú D. 2004. Polarized Light in Animal Vision: Polarization Pattern in Nature. Springer.

Horváth G, Kriska G, Malik P, Robertson B. 2009. Polarized light pollution: A new kind of ecological photopollution. Frontiers in Ecology and the Environment 7: 317–325.

Hulin V, Delmas V, Girondot M, Godrey MH, Guillon JM. 2009. Temperature-dependent sex determination and global change: Are some species at greater risk? Oecologia 160: 493–506.

Khalil I, Sahm A, Boehm R. 2006. Wet or dry cooling? Pages 55–62 in Proceedings of ISEC 2006: International Solar Energy Conference; July 18–13, 2006, Denver, Co. Paper no. ISEC 2006-99082. doi:10.1115/ISEC2006-99082

Kristan WB III, Boarman WI. 2007. Effects of anthropogenic developments on common raven nesting biology in the west Mojave Desert. Ecological Applications 17: 1703–1713.

Kunz TH, Arnett EB, Erickson WP, Hoar AR, Johnson GD, Larkin RP, Strickland MD, Thresher RW, Tuttle MD. 2007. Ecological impacts of wind energy development on bats: Questions, research needs, and hypotheses. Frontiers in Ecology and the Environment 5: 315–324.

Kuvlesky WP Jr, Brennan LA, Morrison ML, Boydston KK, Ballard BM, Bryant FC. 2007. Wind energy development and wildlife conservation: Challenges and opportunities. Journal Wildlife Management 71: 2487–2498.

Lightfoot DC, Whitford WG. 1991. Productivity of creosotebush foliage and associated canopy arthropods along a desert roadside. American Midland Naturalist 125: 310–322.

Longcore T, Rich C. 2004. Ecological light pollution. Frontiers in Ecology and the Environment 2: 191–198.

Lovich JE, Bainbridge D. 1999. Anthropogenic degradation of the southern California desert ecosystem and prospects for natural recovery and restoration. Environmental Management 24: 309–326.

Lovich JE, Daniels R. 2000. Environmental characteristics of desert tortoise (*Gopherus agassizii*) burrow locations in an altered industrial landscape. Chelonian Conservation and Biology 3: 714–721.

Martín-López B, Montes C, Benayas J. 2008. Economic valuation of biodiversity conservation: The meaning of numbers. Conservation Biology 22: 624–635.

McCrary MD, McKernan RL, Schreiber RW, Wagner WD, Sciarrotta TC. 1986. Avian mortality at a solar energy power plant. Journal of Field Ornithology 57: 135–141.

Mittermeier R, Mittermeier CG, Robles Gil P, Fonseca G, Brooks T, Pilgrim J, Konstant WR, eds. 2002. Wilderness: Earth's Last Wild Places. Conservation International.

Munson SM, Belnap J, Okin GS. 2011. Responses of wind erosion to climate-induced vegetation changes on the Colorado Plateau. Proceedings of the National Academy of Sciences 108: 3854–3859.

Murphy RW, Berry KH, Edwards T, Leviton AE, Lathrop A, Riedle JD. 2011. The dazed and confused identity of Agassiz's land tortoise, *Gopherus agassizii* (Testudines, Testudinidae) with the description of a new species, and its consequences for conservation. ZooKeys 113: 39–71.

[NREL] National Renewable Energy Laboratory. 2011. Dynamic maps, GIS data and analysis tools: Solar maps. NREL. (6 July 2011; *www.nrel.gov/gis/solar.html*)

Pater LL, Grubb TG, Delaney DK. 2009. Recommendations for improved assessment of noise impacts on wildlife. Journal of Wildlife Management 73: 788–795.

Pearson DC. 1986. The desert tortoise and energy development in southeastern California. Herpetologica 42: 58–59.

Perry A, Bauer GB, Dizon AE. 1985. Magnetoreception and biomineralization of magnetite in amphibians and reptiles. Pages 439–453 in Kirschvink JL, Jones DS, MacFarland BJ, eds. Magnetite Biomineralization and Magnetoreception in Organisms: A New Biomagnetism. Plenum Press.

Perry G, Buchanan BW, Fisher RN, Salmon M, Wise SE. 2008. Effects of artificial night lighting on reptiles and amphibians in urban environments. Pages 239–256 in Jung RE, Mitchell JC, eds. Urban Herpetology. Society for the Study of Amphibians and Reptiles.

Petersen JK, Malm T. 2006. Offshore windmill farms: Threats to or possibilities for the marine environment. Ambio 35: 75–80.

Piechota T, van Ee J, Batista J, Stave K, James D, eds. 2004. Potential and environmental impacts of dust suppressants: "Avoiding another Times Beach." US Environmental Protection Agency. Panel Summary no. EPA/600/R-04/031. (6 July 2011; *www.epa.gov/esd/cmb/pdf/dust.pdf*)

Pimentel D, et al. 1994. Renewable energy: economic and environmental issues. BioScience 44: 536–547.

Randall JM, Parker SS, Moore J, Cohen B, Crane L, Christian B, Cameron D, MacKenzie JB, Klausmeyer K, Morrison S. 2010. Mojave Desert Ecoregional Assessment. The Nature Conservancy. (6 July 2011; *http://conserveonline.org/workspaces/mojave/documents/mojave-desert-ecoregional-2010/@@view.html*)

Sawyer H, Kauffman MJ, Nelson RM. 2009. Influence of well pad activity on winter habitat selection patterns on mule deer. Journal of Wildlife Management 73: 1052–1061.

Schlesinger WH, Fonteyn PJ, Reiner WA. 1989. Effects of overland flow on plant water relations, erosion, and soil water percolation on a Mojave Desert landscape. Soil Science Society of America Journal 53: 1567–1572.

Sharifi MR, Gibson AC, Rundel PW. 1997. Surface dust impacts on gas exchange in Mojave Desert shrubs. Journal of Applied Ecology 34: 837–846.

Sharma VP, Kumar NR. 2010. Changes in honeybee behaviour and biology under the influence of cellphone radiations. Current Science 98: 1376–1378.

Singh V, Piechota TC, James D. 2003. Hydrologic impacts of disturbed lands treated with dust suppressants. Journal of Hydrologic Engineering 8: 278–286.

Stebbins RC. 1995. Off-road vehicle impacts on desert plants and animals. Pages 467–480 in Latting J, Rowlands PG, eds. The California Desert: An Introduction to Natural Resources and Man's Impact, vol. 2. June Latting Books.

Stevens TH, Echeverria J, Glass RJ, Hager T, More TA. 1991. Measuring the existence value of wildlife: What do CVM estimates really show. Land Economics 67: 390–400.

Suter AH. 2002. Construction noise: Exposure, effects, and the potential for remediation; a review and analysis. American Industrial Hygiene Association Journal 63: 768–789.

Torcellini P, Long N, Judkoff R. 2003. Consumptive Water Use for U.S. Power Production. National Renewable Energy Laboratory. Report no. NREL/TP-550-33905.

Tracy CR, Brussard PF. 1994. Preserving biodiversity: Species in landscapes. Ecological Applications 4: 205–207.

Tsoutsos T, Frantzeskaki N, Gekas V. 2005. Environmental impacts from solar energy technologies. Energy Policy 33: 289–296.

[USDOI and USDOE] US Department of the Interior, US Department of Energy. 2011a. Draft Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States. US Department of Energy. Report no. DOE/EIS-0403. (19 September 2011; *http://solareis.anl.gov/documents/dpeis/index.cfm*)

———. 2011b. Supplement to the Draft Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States. (2 November 2011; *http://solareis.anl.gov/news/index.cfm*)

———. 2011c. Notice of availability of the supplement to the draft programmatic environmental impact statement for solar energy development in six southwestern states and notice of public meetings. Federal Register 76: 66958–66960.

[USEPA] US Environmental Protection Agency. 2010. National Environmental Policy Act. USEPA. (5 July 2011; *www.epa.gov/oecaerth/basics/nepa.html#oversight*)

Von Seckendorff Hoff K, Marlow RW. 2002. Impacts of vehicle road traffic on desert tortoise populations with consideration of conservation of tortoise habitat in southern Nevada. Chelonian Conservation and Biology 4: 449–456.

Webb RH. 1983. Compaction of desert soils by off-road vehicles. Pages 51–79 in Webb RH, Wilshire HG, eds. Environmental Effects of Off-road Vehicles: Impacts and Management in Arid Regions. Springer.

Webb RH, Fenstermaker LF, Heaton JS, Hughson DL, McDonald EV, Miller DM, eds. 2009. The Mojave Desert: Ecosystem Processes and Sustainability. University of Nevada Press.

White PJ, Broadley MR. 2001. Chloride in soils and its uptake and movement within the plant: A review. Annals of Botany 88: 967–988.

Wilshire HG, Nielson JE, Hazlett RW. 2008. The American West at Risk: Science, Myths, and Politics of Land Abuse and Recovery. Oxford University Press.

Jeffrey E. Lovich (jeffrey_lovich@usgs.gov) is a research ecologist, and Joshua R. Ennen (josh.ennen@maryvillecollege.edu) was a wildlife biologist, both with the US Geological Survey, Southwest Biological Science Center. Ennen is now with Maryville College in Tennessee. The authors are studying the effects of utility-scale renewable energy development on terrestrial vertebrates, especially Agassiz's desert tortoise.

EXHIBIT 5

SAN DIEGO COUNTY

CAL FIRE FRAP
Fire and Resource Assessment Program
California Department of Forestry and Fire Protection

VERY HIGH FIRE HAZARD SEVERITY ZONES IN LRA

As Recommended By CAL FIRE

RIVERSIDE COUNTY

IMPERIAL COUNTY

MEXICO

PACIFIC OCEAN

Oceanside
Vista
Carlsbad
San Marcos
Escondido
Encinitas
Solana Beach
Del Mar
Pala Mesa
Rincon
Oak Grove
Lake Henshaw
Morettis Junction
Borrego Springs
Ocotillo Wells
Lake Sutherland
Santa Ysabel
Ramona
Lake Poway
Lake Cuyamaca
Mesquite Oasis
San Vicente Res.
El Capitan Lake
Moreno
Mount Laguna
Pine Valley
Lake Loveland Res.
Dos Cabezas
Santee
El Cajon
La Mesa
Lemon Grove
SAN DIEGO
Sweetwater Reservoir
Lower Otay Lake
Manzanita
Chula Vista
Potrero
Imperial Beach

FIRE HAZARD SEVERITY ZONES

Local Responsibility Area	State or Federal Responsibility Area
VHFHSZ	VHFHSZ
Non-VHFHSZ	Non-VHFHSZ
Incorporated Cities	

Government Code 51175-89 directs the California Department of Forestry and Fire Protection (CAL FIRE) to identify areas of very high fire hazard severity zones within Local Responsibility Areas (LRA). Mapping of the areas, referred to as Very High Fire Hazard Severity Zones (VHFHSZ), is based on data and models of, **potential** fuels over a 30-50 year time horizon and their associated expected fire behavior, and expected burn probabilities to quantify the likelihood and nature of vegetation fire exposure (including firebrands) to buildings. Details on the project and specific modeling methodology can be found at http://frap.fire.ca.gov/projects/hazard/fhz.html. Local Responsibility Area VHFHSZ maps were initially developed in the mid-1990s and are now being updated based on improved science, mapping techniques, and data.

In late 2005 to be effective in 2008, the California Building Commission adopted California Building Code Chapter 7A requiring new buildings in VH FHSZs to use ignition resistant construction methods and materials. These new codes include provisions to improve the ignition resistance of buildings, especially from firebrands. The updated very high fire hazard severity zones will be used by building officials for new building permits in LRA. The updated zones will also be used to identify property whose owners must comply with natural hazards disclosure requirements at time of property sale and 100 foot defensible space clearance. It is likely that the fire hazard severity zones will be used for updates to the safety element of general plans.

This specific map is based on a geographic information system dataset that depicts final CAL FIRE recommendations for Very High FHSZs within the local jurisdiction. The process of finalizing these boundaries involved an extensive local review process, the details of which are available at http://frap.cdf.ca.gov/projects/hazard/threat/ (click on "Continue as guest without logging in"). Local government has 120 days to designate, by ordinance, very high fire hazard severity zones within its jurisdiction after receiving the recommendation. Local government can add additional VHFHSZs. There is no requirement for local government to report their final action to CAL FIRE when the recommended zones are adopted. Consequently, users are directed to the appropriate local entity (county, city, fire department, or Fire Protection District) to determine the status of the local fire hazard severity zone ordinance.

0 5 Miles
0 10 Kilometers

Projection Albers, NAD 1927
Scale 1: 150,000
at 46" x 34"
June 12, 2009

Obtain FRAP maps, data, metadata and publications on the Internet at http://frap.cdf.ca.gov
For more information, contact CAL FIRE-FRAP, PO Box 944246, Sacramento, CA 94244-2460, (916) 327-3939.

Arnold Schwarzenegger, Governor,
State of California
Mike Chrisman, Secretary for Resources,
The Natural Resources Agency
Del Walters, Director,
Department of Forestry and Fire Protection

MAP ID: FHSZL_MAP

DATA SOURCES
CAL FIRE Fire Hazard Severity Zones (FHSZL06_3)
CAL FIRE State Responsibility Areas (SRA05_5)
CAL FIRE Incorporated Cities (Incorp07_3)
PLSS (1:100,000 USGS, Land Grants with CAL FIRE grid)

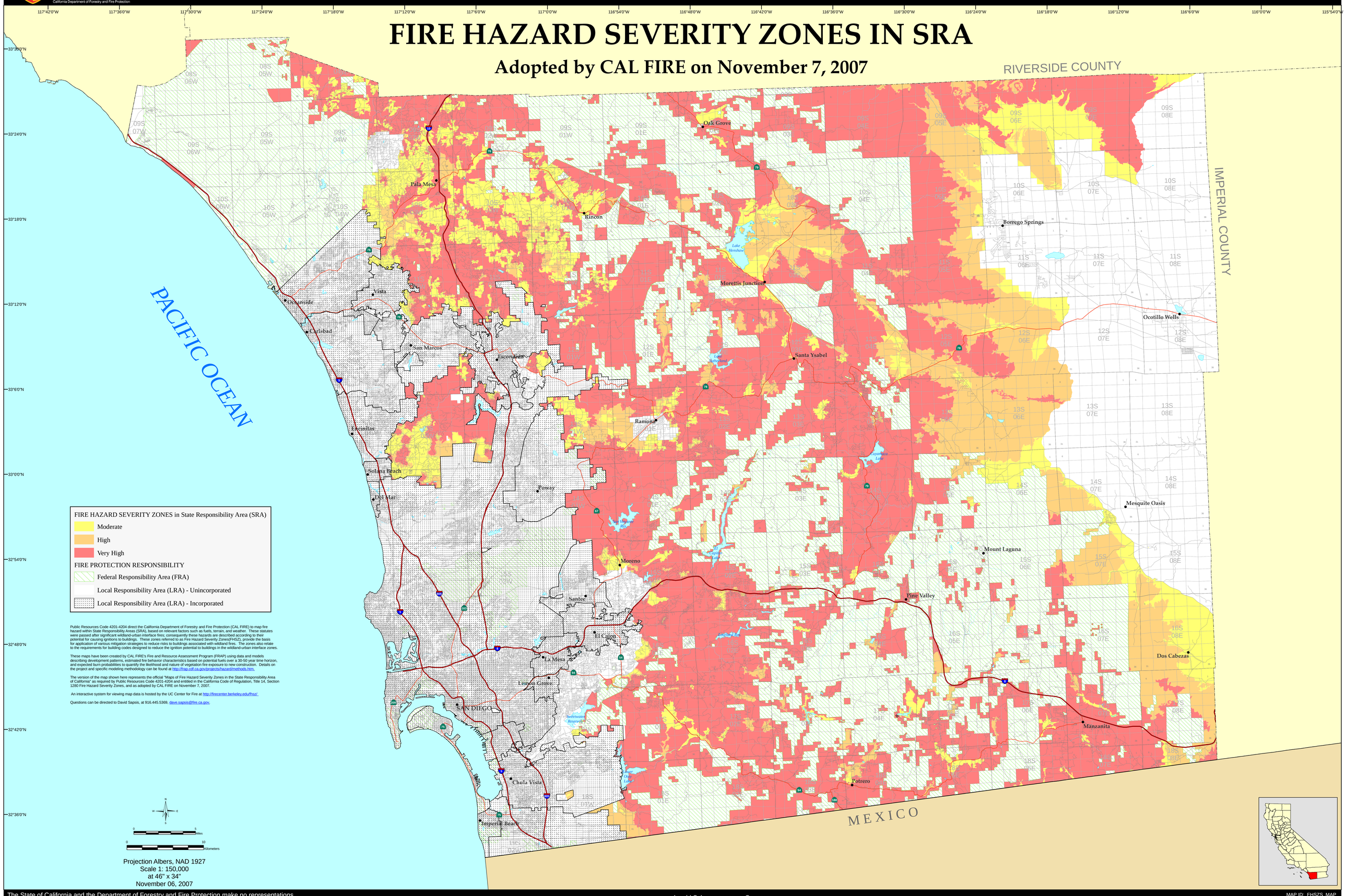
EXHIBIT 6

SAN DIEGO COUNTY

CAL FIRE FRAP
Fire and Resource Assessment Program
California Department of Forestry and Fire Protection

FIRE HAZARD SEVERITY ZONES IN SRA

Adopted by CAL FIRE on November 7, 2007



FIRE HAZARD SEVERITY ZONES in State Responsibility Area (SRA)

- Moderate
- High
- Very High

FIRE PROTECTION RESPONSIBILITY

- Federal Responsibility Area (FRA)
- Local Responsibility Area (LRA) - Unincorporated
- Local Responsibility Area (LRA) - Incorporated

Public Resources Code 4201-4204 direct the California Department of Forestry and Fire Protection (CAL FIRE) to map fire hazard within State Responsibility Areas (SRA), based on relevant factors such as fuels, terrain, and weather. These statutes were passed after significant wildland-urban interface fires; consequently these hazards are described according to their potential for causing ignitions to buildings. These zones referred to as Fire Hazard Severity Zones(FHSZ), provide the basis for application of various mitigation strategies to reduce risks to buildings associated with wildland fires. The zones also relate to the requirements for building codes designed to reduce the ignition potential to buildings in the wildland-urban interface zones.

These maps have been created by CAL FIRE's Fire and Resource Assessment Program (FRAP) using data and models describing development patterns, estimated fire behavior characteristics based on potential fuels over a 30-50 year time horizon, and expected burn probabilities to quantify the likelihood and nature of vegetation fire exposure to new construction. Details on the project and specific modeling methodology can be found at http://frap.cdf.ca.gov/projects/hazard/methods.htm.

The version of the map shown here represents the official "Maps of Fire Hazard Severity Zones in the State Responsibility Area of California" as required by Public Resources Code 4201-4204 and entitled in the California Code of Regulation, Title 14, Section 1280 Fire Hazard Severity Zones, and as adopted by CAL FIRE on November 7, 2007.

An interactive system for viewing map data is hosted by the UC Center for Fire at http://firecenter.berkeley.edu/fhsz/

Questions can be directed to David Sapsis, at 916.445.5369, dave.sapsis@fire.ca.gov.

0 5 Miles
0 10 Kilometers

Projection Albers, NAD 1927
Scale 1: 150,000
at 46" x 34"
November 06, 2007

Obtain FRAP maps, data, metadata and publications on the Internet at http://frap.cdf.ca.gov
For more information, contact CAL FIRE-FRAP, PO Box 944246, Sacramento, CA 94244-2460, (916) 327-3939.

Arnold Schwarzenegger, Governor,
State of California
Mike Chrisman, Secretary for Resources,
The Resources Agency
Ruben Grijalva, Director,
Department of Forestry and Fire Protection

MAP ID: FHSZS_MAP

DATA SOURCES
CAL FIRE Fire Hazard Severity Zones (FHSZS06_3)
CAL FIRE State Responsibility Areas (SRA05_5)
CAL FIRE Incorporated Cities (Incorp07_3)
PLSS (1:100,000 USGS, Land Grants with CAL FIRE grid)

EXHIBIT 7

STEPHAN C. VOLKER (CSB #63093)
JOSHUA A.H. HARRIS (CSB #226898)
STEPHANIE L. ABRAHAMS (CSB #257961)
JAMEY M.B. VOLKER (CSB # 273544)
LAW OFFICES OF STEPHAN C. VOLKER
436 14th Street, Suite 1300
Oakland, California 94612
Tel: 510/496-0600
Fax: 510/496-1366

Attorneys for Plaintiffs
BACKCOUNTRY AGAINST DUMPS, et al.

IN THE UNITED STATES DISTRICT COURT

FOR THE SOUTHERN DISTRICT OF CALIFORNIA

BACKCOUNTRY AGAINST DUMPS, et al., Plaintiffs, v. JIM ABBOTT, in his official capacity as California State Director of the United States Bureau of Land Management, et al., Defendants, and SAN DIEGO GAS & ELECTRIC CO., Intervenor-Defendant.	Civ. No. **3:10-CV-01222-AJB-BGS** **DECLARATION OF MARK OSTRANDER IN SUPPORT OF PLAINTIFFS' MOTION FOR PRELIMINARY INJUNCTION AND APPLICATION FOR TEMPORARY RESTRAINING ORDER** Hearing: May 6, 2011 Time: 2:00 p.m. Court: 12 Judge: Hon. Anthony J. Battaglia

I, Mark Ostrander, declare as follows:

1. I am a recently retired Battalion Chief with the California Department of Forestry and Fire Protection ("Cal Fire") with 36 years' experience working in the field of wildfire suppression throughout Southern California.[1] I submit this declaration in support of the plaintiffs' motion for a preliminary injunction to prevent construction of the Sunrise Powerlink project. I make this declaration based on my personal knowledge and extensive

[1] I make this declaration in my capacity as an independent wildfire suppression expert. The views expressed herein are not intended to reflect the official views of the California Department of Forestry and Fire Protection.

professional expertise in the field of wildfire suppression.

BACKGROUND AND EXPERIENCE

2. I was employed by Cal Fire for the period 1974 through 2010. During the entire period of my employment by Cal Fire – an all risk fire response agency – I worked in the field of wildfire suppression, performing numerous essential tasks including both "hands-on" fire suppression activities in the field and later, in a supervisorial capacity as a manager of wildfire response campaigns on major conflagrations. I have worked on over 2,000 fires – including 12 of the 20 largest wildfires in California history – during my 36 years of employment with Cal Fire.

3. I started work with Cal Fire as a Firefighter and as a Firefighter I learned the use of the primary tools for construction of fire lines, including the Pulaski, the McCloud, double-bitted axe and, of course, shovels, rakes and grub hoes. I also became proficient in the removal of "ladder fuels" that give rise to "crown fires" in heavy timber, and as a feller, in the removal of trees that either had caught fire or were in imminent danger of doing so, in order to help prevent the rapid spread of wildfires. I was promoted to the position of Heavy Fire Equipment Operator in 1985, where my duties included construction of fire lines utilizing heavy equipment such as D-6C Caterpillar tractors. After 15 years, I became proficient in all these hands-on areas of fire suppression, and was promoted to Fire Station Captain. My responsibilities as Captain included management of a Fire Station and supervision of the personnel assigned to the Station. Our Station responded to all types of emergencies including the highly hazardous first phase, or "initial attack" on wildland fires for which I assumed management responsibility as Incident Commander until a Chief Officer arrived on scene.

4. In addition to my responsibilities as a Fire Station Captain, I also worked as a Crew Captain from 1996 to 2008. In this capacity, I led fire suppression crews numbering from 14 to 17 inmate men under extremely hazardous conditions in the initial attack on wildland fires where we quickly built fire lines to contain and ultimately control wildfires. As a Crew Captain, my tasks included training, supervising, and disciplining of Inmate

Firefighters. In addition to supervising and directing Inmate Fire Crews on wildland fires, I also kept them in a high state of readiness to respond to wildfires, floods, and earthquakes.

5. During my employment as a Fire Captain, I supervised Cal Fire's fire suppression response to approximately 200 plus fires, including the large, recent Harris and Pines fires. I was responsible for the supervision of 600 or more fire suppression personnel. Over time, as I became more proficient as a Fire Captain, my responsibilities grew to include the positions of Respiratory Protection Administrator for San Diego Cal Fire, Facility Safety Program Manager, Cal Fire San Diego Safety Committee Member, and Administrative Captain and Project Manager for the McCain Valley Conservation Camp.

6. After 23 years as a Fire Captain, I was promoted to the position of Battalion Chief for the Campo Battalion in eastern San Diego County. In that capacity I supervised operations for 7 fire stations, 1 Conservation Camp, and the San Diego Unit's Dozer and Heavy Equipment Program. I served as Incident Commander for Multi-Causality Incidents, Structure Fires, Hazardous Materials Incidents and Cal Fire wildfire suppression response to all wildfires on state or private land in eastern San Diego County. I also assisted in the supervision of fire suppression responses by the United States Forest Service and the U.S. Bureau of Land Management on lands managed by those federal agencies. I was Logistic Section Chief for Cal Fire's suppression response to the Cedar fire in 2003, a fire that engulfed 285,000 plus acres of land throughout central San Diego County. This fire ultimately burned 3000 plus structures and resulted in serious injuries or death to 14 people. I also managed the following additional major wildfire response campaigns as part of a Major Incident Command Team, Cal Fire Team 8: Saw Tooth, Eagle, Border 50, Shekel, Martin, Esperanza, among others. Our Team was also Certified in Complex Incident Management.

PROFESSIONAL OPINION

7. As a result of my 36 years' experience as a fire suppression specialist with Cal Fire, I have developed substantial expertise in understanding the causes of wildfire ignition and spread. At the same time, I have developed substantial expertise in the areas of

wildfire prevention, containment and control. Based on my nearly 4 decades of training and hands-on experience in these areas, I have formed the professional opinion that the Sunrise Powerlink project poses an extremely hazardous impediment to effective wildfire suppression in eastern San Diego County. I base this conclusion on my thorough familiarity with the Sunrise Powerlink project, which I have studied and on which I have submitted comments to the responsible agencies on numerous occasions.

8. The Sunrise Powerlink project will, if built, prevent effective fire suppression response for three reasons. First, modern fire suppression response depends heavily on retardant and water drops by large aircraft and helicopters as close as possible to the leading edge of wildfires. To be effective, retardant and water drops must be made as close to the surface as possible, and as quickly following ignition as possible. Delay in the delivery of retardant or water drops, or failure to deliver retardant or water directly to the leading edge of a wildfire, allows the fire to build momentum, size and speed. Once a wildfire has reached a critical size, temperature and speed, it is extremely difficult to contain much less control. Construction of the Sunrise Powerlink project will prevent the delivery of retardant and water drops along the many ridgelines and valley crossings that this powerline will span. Over 110 miles of high tension powerline located upwards of several hundred feet above the terrain will effectively create a large zone in which low flying aircraft cannot operate for the purpose of making retardant and water drops. This zone will increase in width when wildfires create smoky conditions in which low level flying is at best difficult, and in the face of potential ensnarement by high tension powerlines, completely impossible. The resulting inability to deliver retardant and water drops with speed and pinpoint accuracy onto the many ridges and exposed valleys that the Sunrise Powerlink project would span will cause a severe impairment of our fire suppression abilities.

9. Second, competent fire suppression leading to containment and ultimate control of fires requires construction of mineral earth fire lines by skilled fire crews deploying, where possible, heavy equipment. The deployment of fire crews within 100 to

1000 feet (depending on conditions) of high tension power lines is a serious safety concern and requires altering Strategies and Tactics which generally means the fire will get larger as we wait for it to pass thru the power line area to a safer distance to work the fire. These are well-established safety practices and procedures by all of the major fire suppression agencies, including Cal Fire. The reason for this is that wildfires can cause high tension powerlines to snap, either due to heat or wind. A powerline that has snapped not only can cause severe physical injury from the powerlines' whiplash motion to any crew member within several hundred yards of the line but also heavy smoke around the lines can cause phase-to-ground arcing due to the carbon in the smoke which reduces the air resistance allowing a path to ground. This increases the risk for electrocution or serious injury to fire personnel caused by the arcing and grounding of a "hot" electrical line. For this reason, construction of the Sunrise Powerlink project will prevent effective hand crew and heavy equipment fire suppression response, including the essential construction of fire lines needed to contain and control wildfires, within a 2,000-foot wide swath of land underlying the Sunrise Powerlink's designated route.

10. Third, powerlines cause the ignition of wildfires. Several of the worst conflagrations in San Diego County history, including the Pines and Witch fires, were ignited by powerlines. Although it is true that high tension powerlines such as the Sunrise Powerlink are less likely to ignite wildfires than smaller powerlines located closer to the ground, it is nonetheless true that high tension lines pose a very significant threat of wildfire ignition. This threat is exacerbated by the location of the Sunrise Powerlink project in remote areas of eastern San Diego County where inaccessibility by fire suppression response vehicles would allow the wildfires to grow into major conflagrations before effective suppression activities could commence.

11. For the foregoing reasons, I strongly urge this Court to halt construction of the Sunrise Powerlink project on federal land pending consideration of alternatives that would not pose such severe wildfire hazards to public and private land and to the health and safety of San Diego's citizens and wildlife.

I declare, under penalty of perjury, that the foregoing is true and correct based on my personal knowledge, and that this declaration was executed on April 14, 2011 in Jacumba, California.

Mark Ostrander

EXHIBIT 8

Attention Deficit Hyperactivity Disorder and Dirty Electricity

To the Editor:

In February 2010, while studying a cancer cluster in teachers at a California elementary school, a fourth-grade teacher complained that her students were hyperactive and unteachable. The classroom levels of high-frequency voltage transients (dirty electricity) in the radio frequencies (RF) between 4 and 100 kHz measured in the outlets of her classroom with a Graham/Stetzer Microsurge meter were very high. Dirty electricity is a term coined by the electrical utilities to describe electrical pollution contaminating the 60 Hz electricity on the electrical grid. A cell phone tower on campus a few feet from this classroom and unshielded fluorescent lights both contributed to the electrical pollution in this room. Cell tower transmitters, like most modern electrical equipment, operate on direct current. The electrical current brought to the tower is alternating current that needs to be changed to direct current. This is done by a switching power supply. These devices interrupt the alternating current and are the likely major source of the dirty electricity in the classroom.

On a Friday afternoon after school, I filtered the 5 outlets in this room with Graham/Stetzer plug-in capacitive filters, reducing the measured dirty electricity in the room wiring from more than 5000 Graham/Stetzer units to less than 50 units. With no change in either the lighting or the cell tower radiation, the teacher reported an immediate dramatic improvement in the behavior of her students in the following week. They were calmer, paid more attention, and were teachable all week except for Wednesday when they spent part of the day in the library.

In his 1973 book, Health and Light,[1] John N. Ott described a 1973 study of 4 first-grade classrooms in a windowless Sarasota, Florida school. Two of the rooms had standard white fluorescent lighting and the other two had full-spectrum fluorescent lighting with a grounded aluminum wire screen to remove the RF radiation produced by fluorescent bulbs and ballasts. Concealed time-lapse cameras recorded student behavior in classrooms for 4 months.[2] In the unshielded rooms, the first graders developed, "... nervous fatigue, irritability, lapses of attention, and hyperactive behavior." "... students could be observed fidgeting to an extreme degree, leaping from their seats, flailing their arms, and paying little attention to their teachers." In the RF-shielded rooms, "Behavior was entirely different. Youngsters were calmer and far more interested in their work."

The Old Order Amish live without electricity. A pediatric group practice in Jasper, Indiana, which cares for more than 800 Amish families has not diagnosed a single child with attention deficit hyperactivity disorder (ADHD).[3] Dozens of cases of childhood ADHD have been "cured" with no further need for drugs by simply changing their electrical environments (Stetzer D, personal communication [www.Stetzerelectric.com]). AQ:A

Before children are treated with drugs for ADHD, the dirty electricity levels in their homes and school environments should first be examined and reduced if needed.

I present the epidemiologic evidence linking dirty electricity to the other diseases of civilization in a recent book.[4,5] AQ:B

Disclosure: The authors declare no conflict of interest. AQ:C

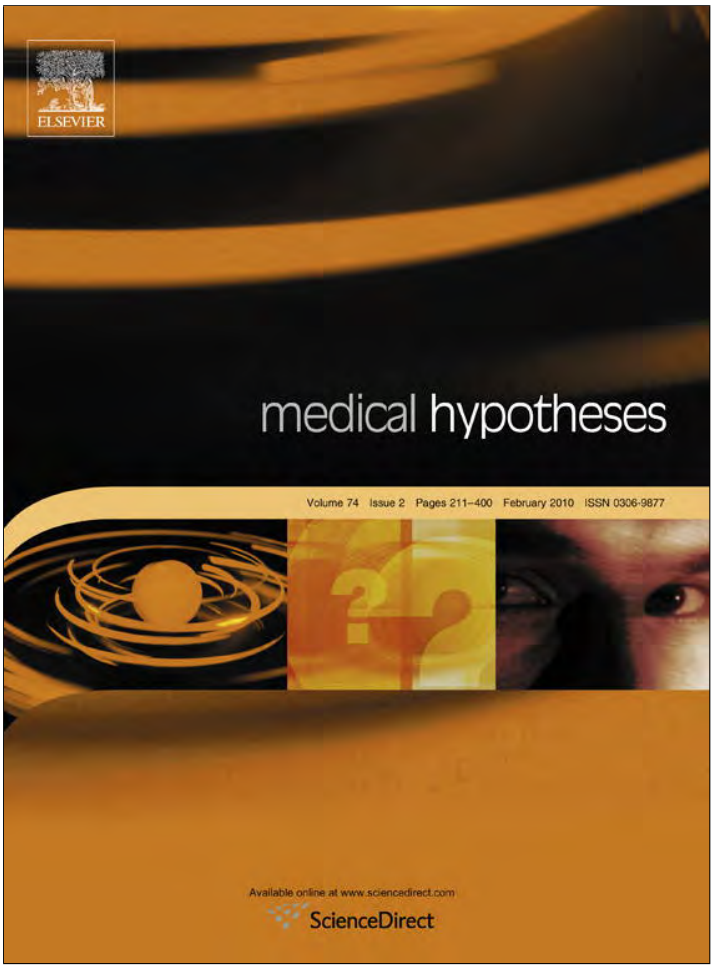
Samuel Milham, MD, MPH AQ:D
Washington State Health Department
Tumwater, WA

REFERENCES

1. Ott JN. Afterword. In: *Health and Light.* Columbus, OH; Atlanta, GA: Ariel Press; 1973:200–205. AQ:E
2. Ott JN. *Exploring the Spectrum: The Effects of Natural and Artificial Light on Living Organisms* [DVD]; 2008.
3. Ruff ME. Attention deficit disorder and stimulant use: an epidemic of modernity. *Clin Pediatr (Phila).* 2005;44:557–563.
4. Milham S. *Dirty Electricity.* Bloomington, IN: iUniverse; 2010. AQ:F
5. www.sammilham.com.

IN PRESS: JOURNAL OF DEVELOPMENTAL AND BEHAVIORAL PEDIATRICS

EXHIBIT 9



Medical Hypotheses 74 (2010) 337–345

Contents lists available at ScienceDirect

Medical Hypotheses

journal homepage: www.elsevier.com/locate/mehy

Historical evidence that electrification caused the 20th century epidemic of "diseases of civilization" ☆

Samuel Milham *

Washington State Department of Health, Olympia, WA, USA

ARTICLE INFO

Article history:
Received 14 August 2009
Accepted 18 August 2009

SUMMARY

The slow spread of residential electrification in the US in the first half of the 20th century from urban to rural areas resulted by 1940 in two large populations; urban populations, with nearly complete electrification and rural populations exposed to varying levels of electrification depending on the progress of electrification in their state. It took until 1956 for US farms to reach urban and rural non-farm electrification levels. Both populations were covered by the US vital registration system. US vital statistics tabulations and census records for 1920–1960, and historical US vital statistics documents were examined. Residential electrification data was available in the US census of population for 1930, 1940 and 1950. Crude urban and rural death rates were calculated, and death rates by state were correlated with electrification rates by state for urban and rural areas for 1940 white resident deaths. Urban death rates were much higher than rural rates for cardiovascular diseases, malignant diseases, diabetes and suicide in 1940. Rural death rates were significantly correlated with level of residential electric service by state for most causes examined. I hypothesize that the 20th century epidemic of the so called diseases of civilization including cardiovascular disease, cancer and diabetes and suicide was caused by electrification not by lifestyle. A large proportion of these diseases may therefore be preventable.

Background

In 2001, Ossiander and I [1] presented evidence that the childhood leukemia mortality peak at ages 2–4 which emerged in the US in the 1930s was correlated with the spread of residential electrification in the first half of the 20th century in the US. While doing the childhood leukemia study, I noticed a strong positive correlation between level of residential electrification and the death rate by state due to some adult cancers in 1930 and 1940 vital statistics. At the time, a plausible electrical exposure agent and a method for its delivery within residences was lacking. However, in 2008 I coauthored a study of a cancer cluster in school teachers at a California middle school [2] which indicated that high frequency voltage transients (also known as dirty electricity), were a potent universal carcinogen with cancer risks over 10.0 and significant dose–response for a number of cancers. They have frequencies between 2 and 100 kHz. These findings are supported by a large cancer incidence study in 200,000 California school employees which showed that the same cancers and others were in excess in California teachers statewide [3]. Power frequency magnetic fields (60 Hz) measured at the school were low and not related to cancer incidence, while classroom levels of high frequency voltage transients measured at the electrical outlets in the classrooms accurately predicted a teacher's cancer risk. These fields are potentially present in all wires carrying electricity and are an important component of ground currents returning to substations especially in rural areas. This helped explain the fact that professional and office workers, like the school teachers, have high cancer incidence rates. It also explained why indoor workers had higher malignant melanoma rates, why melanoma occurred on part of the body which never are exposed to sunlight, and why melanoma rates are increasing while the amount of sunshine reaching earth is stable or decreasing due to air pollution. A number of very different types of cancer had elevated risk in the La Quinta school study, in the California school employees study, and in other teacher studies. The only other carcinogenic agent which acts like this is ionizing radiation.

Among the many devices which generate the dirty electricity are compact fluorescent light bulbs, halogen lamps, wireless routers, dimmer switches, and other devices using switching power supplies. Any device which interrupts current flow generates dirty electricity. Arcing, sparking and bad electrical connections can also generate the high frequency voltage transients. Except for the dimmer switches, most of these devices did not exist in the first half of the 20th century. However, early electric generating equipment

☆ Supported by a small grant from Children with Leukemia.

* Address: 2318 Gravelly Beach Loop NW, Olympia, WA 98502-8837, USA. Tel.: +1 360 866 0256.
E-mail address: smilham2@comcast.net

0306-9877/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mehy.2009.08.032

and electric motors used commutators, carbon brushes, and split rings, which would inject high frequency voltage transients into the 60 Hz electricity being generated and distributed.

With a newly recognized electrical exposure agent and a means for its delivery, I decided to examine whether residential electrification in the US in the first half of the last century was related to any other causes of death. Most cancers showed increasing mortality in this period, and many are still increasing in incidence in the developed world.

Thomas Edison began electrifying New York City in 1880, but by 1920, only 34.7% of all US dwelling units and 1.6% of farms had electric service (Table 1). By 1940, 78% of all dwelling units and 32% of farms had electric service [4]. This means that in 1940 about three quarters of the US population lived in electrified residences and one quarter did not. By 1940, the US vital registration system was essentially complete, in that all the 48 contiguous United States were included. Most large US cities were electrified by the turn of the century, and by 1940, over 90% of all the residences in the northeastern states and California were electrified. In 1940 almost all urban residents in the US were exposed to electromagnetic fields (EMFs) in their residences and at work, while rural residents were exposed to varying levels of EMFs, depending on the progress of rural electrification in their states. In 1940, only 28% of residences in Mississippi were electrified, and five other southern states had less than 50% of residences electrified (Table 2). Eleven states, mostly in the northeast had residential electrification rates above 90%. In the highly electrified northeastern states and in California, urban and rural residents could have similar levels of EMF exposure, while in states with low levels of residential electrification, there were potentially great differences in EMF exposure between urban and rural residents. It took the first half of the 20th century for these differences to disappear. I examined US mortality records by urban and rural residence by percent of residences with electric service by state.

Hypothesis

The diseases of civilization or lifestyle diseases include cardiovascular disease, cancer and diabetes and are thought to be caused by changes in diet, exercise habits, and lifestyle which occur as countries industrialize. I think the critical variable which causes the radical changes in mortality accompanying industrialization is electrification. Beginning in 1979, with the work of Wertheimer and Leeper [5], there has been increasing evidence that some facet of electromagnetic field exposure is associated epidemiologically with an increased incidence of leukemia, certain other cancers and non-cancers like Alzheimer's disease, amyotrophic lateral sclerosis, and suicide. With the exception of a small part of the electromagnetic spectrum from infra red through visible light, ultraviolet light and cosmic rays, the rest of the spectrum is man-made and foreign to human evolutionary experience. I suggest that from the time that Thomas Edison started his direct current electrical distribution system in the 1880s in New York City until now, when most of the world is electrified, the electricity carried high frequency voltage transients which caused and continue to cause what are considered to be the normal diseases of civilization. Even today, many of these diseases are absent or have very low incidence in places without electricity.

Table 1
Growth of residential electric service US 1920–1956 percent of dwelling units with electric service.

Year	All		Urban and rural non-farm
	Dwellings	Farm	
1920	34.7	1.6	47.4
1925	53.2	3.9	69.4
1930	68.2	10.4	84.8
1935	68.0	12.6	83.9
1940	78.7	32.6	90.8
1945	85.0	48.0	93.0
1950	94.0	77.7	96.6
1956	98.8	95.9	99.2

Table 2
Percent of residences with electric lighting 1930 and 1940 by state.

Code	State	1930	1940
AL	Alabama	33.9	43.3
AZ	Arizona	68.8	70.5
AR	Arkansas	25.3	32.8
CA	California	93.9	96
CO	Colorado	69.6	77.6
CT	Connecticut	95.3	96.5
DE	Delaware	78.4	81.8
FL	Florida	60.9	66.5
GA	Georgia	35.5	46.6
ID	Idaho	64.5	79.1
IL	Illinois	86.1	89.9
IN	Indiana	74.8	84
IA	Iowa	65.6	76.7
KS	Kansas	62	71.5
KY	Kentucky	44.2	54.2
LA	Louisiana	42.2	48.9
ME	Maine	76.1	80.4
MD	Maryland	81.8	85.9
MA	Massachusetts	97.1	97.6
MI	Michigan	84.8	92.1
MN	Minnesota	65.9	75.8
MS	Mississippi	19.4	28.3
MO	Missouri	65.5	70.6
MT	Montana	58.2	70.7
NE	Nebraska	61	70.5
NV	Nevada	76.2	80.8
NH	New Hampshire	84.9	87
NJ	New Jersey	95.8	96.6
NM	New Mexico	39.8	49.2
NY	New York	94.5	96.4
NC	North Carolina	40.8	54.4
ND	North Dakota	41.6	53.8
OH	Ohio	85.2	90.6
OK	Oklahoma	45.3	55.1
OR	Oregon	79.5	85.8
PA	Pennsylvania	89.5	92.3
RI	Rhode Island	97.3	97.7
SC	South Carolina	34.3	46.2
SD	South Dakota	44.4	56.6
TN	Tennessee	42	50.9
TX	Texas	*	59
UT	Utah	88.4	93.9
T	Vermont	71.9	80.2
VA	Virginia	50.5	60.6
WA	Washington	86.3	90.9
WV	West Virginia	63.4	69.1
WI	Wisconsin	74.5	83.9
WY	Wyoming	60	70.9

*No data.

Evaluation of the hypothesis

To evaluate the hypothesis, I examined mortality in US populations with and without residential electrification. Vital statistics tabulations of deaths [6], US census records for 1920–1970 [7], and historical US documents [8,9] were examined in hard copy or downloaded from the internet. The same state residential electrification data used in the childhood leukemia study [1] was used in this study. Crude death rates were calculated by dividing number of deaths by population at risk, and death rates by state were then correlated with electrification rates by state using downloaded software [10]. Time trends of death rates for selected causes

of death by state were examined. Most rates were calculated by state for urban and rural residence for whites only in 1940 deaths, since complete racial data was available by urban/rural residence by state for only 13 of 48 states. Data was available for 48 states in the 1940 mortality tabulations. District of Columbia was excluded because it was primarily an urban population. Excel graphing software [11] and "Create a Graph" [12] software was used.

I had hoped to further test this hypothesis by studying mortality in individual US farms with and without electrification, when the 1930 US census 70 year quarantine expired in 2000. Unfortunately, the 1930 US farm census schedules had been destroyed.

Findings

Rural residential electrification did not reach urban levels until 1956 (Table 1). Table 2 shows the level of residential electrification for each state for 1930 and 1940. In 1930 and 1940 only 9.5% and 13%, respectively, of all generated electricity was used in residences. Most electricity was used in commercial and industrial applications.

Figs. 1–4 were copied and scanned from "Vital statistics rates in the United States 1940–1960", by Robert Grove Ph.D. and Alice M. Henzel. This volume was published in 1968. Fig. 1 shows a gradual decline in the all causes death rate from 1900 to 1960 except for a spike caused by the 1918 influenza pandemic. Death rates due to tuberculosis, typhoid fever, diphtheria, dysentery, influenza and pneumonia and measles all fell sharply in this period, and account for most of the decline in the all causes death rate. Figs. 2–4 show that in the same time period when the all causes death rate was declining, all malignant neoplasms (Fig. 2), cardiovascular diseases (Fig. 3), and diabetes (Fig. 4) all had gradually increasing death rates. In 1900, heart disease and cancer were 4th and 8th in a list of 10 leading causes of death. By 1940 heart disease had risen to first and cancer to second place, and have maintained that position ever since. Table 3 shows that for all major causes of death examined, except motor vehicle accidents, there was a sizable urban excess in 1940 deaths. The authors of the extensive 69 page introduction to the 1930 mortality statistics volume noted that the cancer rates for cities were 58.2% higher than those for rural areas. They speculated that some of this excess might have been due to rural residents dying in urban hospitals. In 1940, deaths by place of residence and occurrence are presented in separate volumes. In 1940 only 2.1% of all deaths occurred to residents of one state dying in another state. Most non-resident deaths were residents of other areas of the same state. Table 4 presents correlation coefficients for the relationship between death rates by urban rural areas of each state and the percent of residences in each state with

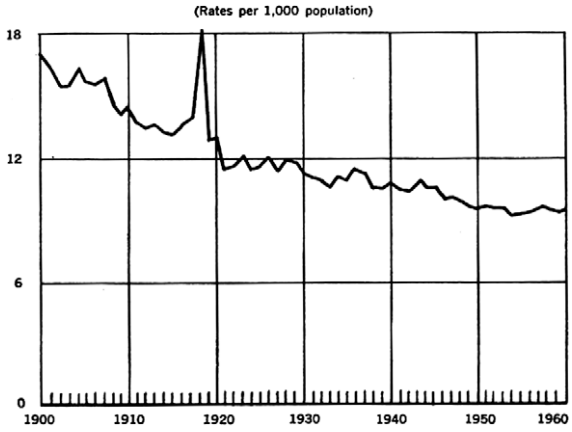


Fig. 1. Death rates: death registration states, 1900–32, and United States, 1933–60.

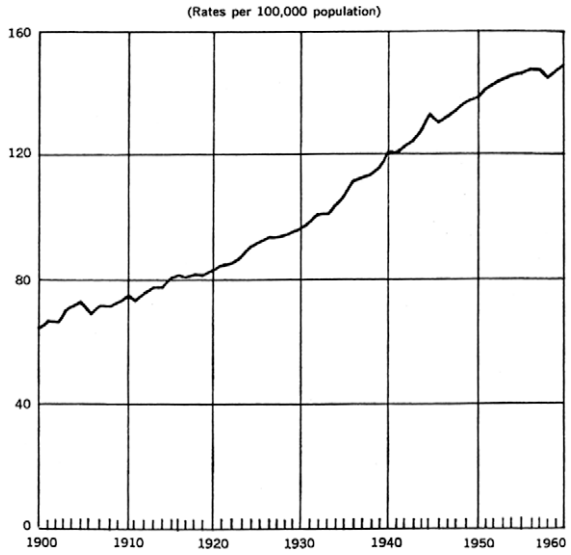


Fig. 2. Death rates for malignant neoplasms: death registration states, 1900–32, and United States, 1933–60.

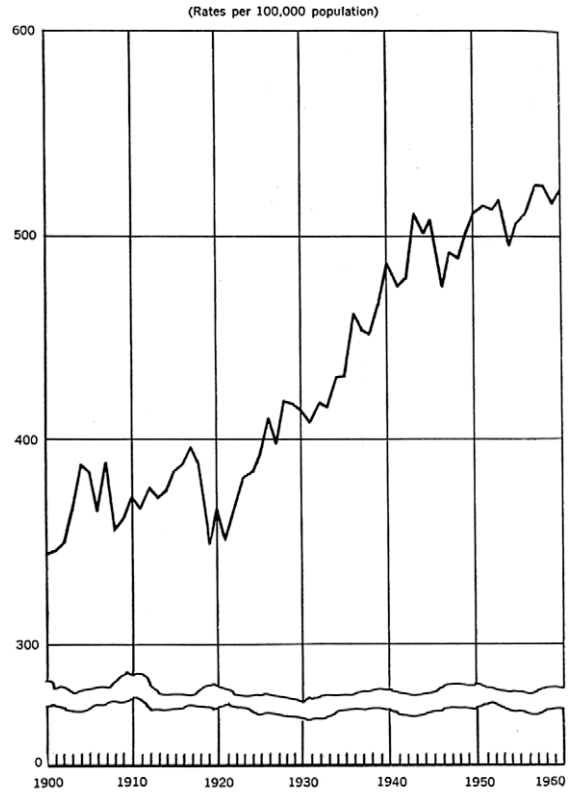


Fig. 3. Death rates for major cardiovascular renal diseases: death registration states, 1900–32, and United States, 1933–60.

electric service. In 1940 urban and rural residence information was not available for individual cancers as it was in 1930, but death rates for each cancer were available by state. They were used to calculate correlations between electric service by state and respiratory cancer, breast cancer and leukemia mortality.

All causes of death

There was no correlation between residential electrification and total death rate for urban areas, but there was a significant

correlation for rural areas ($r = 0.659$, $p = <0.0001$). Fig. 5 shows the 1940 resident white death rates for urban and rural areas of states having greater than 96% of residences electrified and states having less than 50% of residences electrified. In the highly electrified states, urban and rural death rates were similar, but in low electrification states, the urban death rates were systematically higher than the rural death rates. The urban death rates were similar in both high and low electrification states.

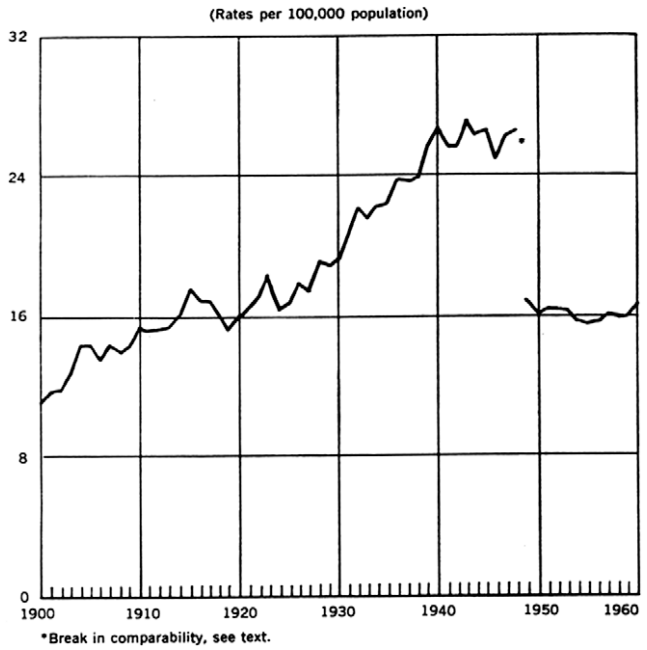


Fig. 4. Death rates for diabetes mellitus: death registration states, 1900–32, and United States, 1933–60.

All malignant neoplasms

In 1940, the urban total cancer rate was 49.2% higher than the rural rate. Both urban and rural cancer deaths rates were significantly correlated with residential electrification. Fig. 6 shows the 1940 resident white total cancer rates for urban and rural areas of states having greater than 96% of residences electrified and states having less than 50% of residences electrified. Four of the five high electrification states had similar urban and rural total cancer rates, while all the low electrification states had urban rates about twice as high as rural rates. Both urban and rural total cancer rates were lower in low electrification states than in high electrification states. Fig. 7 shows the time trend of the total cancer rate between 1920 and 1960 for Massachusetts (1940 electrification rate = 97.6%) and Louisiana (1940 electrification rate = 48.9%). The Massachusetts cancer rate was about twice that of Louisiana between 1920 and 1945. The Massachusetts rate leveled off in 1945, but the Louisiana rate increased steadily between 1920 and 1960. A declining urban–rural gradient for cancer is still evident in 1980–1990 US cancer incidence data [13]. Swedish investigators [14] have reported increasing cancer mortality and incidence time trend breaks in the latter half of the 20th century.

Table 3
1940 US white resident crude death rates per 100,000 by urban/rural residence.

Cause of death	ICD No.[a]	Urban rate	Rural rate	(%) Urban excess
All	1-200	1124.1	929.5	20.9
All cancers	47-55	145.8	97.7	49.2
Coronary disease	94	92.4	69.1	33.7
Other diseases of heart	90b,91,92a,d,e 93a,b,d,e 95a,c	217.0	162.8	33.3
Diabetes	61	33.2	20.0	66.0
Suicide	163-164	17.1	13.2	29.5
Motor vehicle accidents	170	26.6	26.3	1.1

[a] 1938 Revision International classification of disease.

Table 4
Correlation coefficients (r) 1940 crude US death rates by state by electrification for white resident deaths.

Cause	ICD No.[A]	Residence	r	r^2	p One tailed	Slope	Y intercept
All causes	1-200	Urban	0.083	0.007	0.285	0.007	11.114
		Rural	0.659	0.434	<0.0001	0.070	4.185
All cancers	45-55	Urban	0.667	0.445	<0.0001	0.883	75.970
		Rural	0.758	0.575	<0.0001	1.502	−10.040
Respiratory cancer[B]	47	State	0.611	0.374	<0.0001	0.071	1.020
Breast cancer female	50	State	0.794	0.630	<0.0001	0.170	−1.506
Diabetes	61	Urban	0.666	0.444	<0.0001	0.278	8.168
		Rural	0.693	0.480	<0.0001	0.366	−6.184
Leukemia[B]	72a	State	0.375	0.140	0.0042	0.021	1.980
Coronary artery	94	Urban	0.400	0.160	0.0024	0.494	61.570
Disease		Rural	0.781	0.610	<0.0001	1.252	25.319
Other diseases of the heart	90b, 91	Urban	0.449	0.202	0.0006	1.236	100.35
	92a,d,e 93a,b,d,e 95a,c	Rural	0.799	0.639	0.0001	2.887	−48.989
Suicide	163-4	Urban	0.077	0.006	0.2993	0.028	16.235
		Rural	0.729	0.532	<0.0001	0.181	0.299
Motor vehicle	170	Urban	−0.254	0.064	0.0408	−0.171	44.572
Accidents		Rural	0.451	0.203	0.0006	0.195	12.230

[A] International classification of diseases 1938 revision.
[B] Age adjusted death rate both sexes.

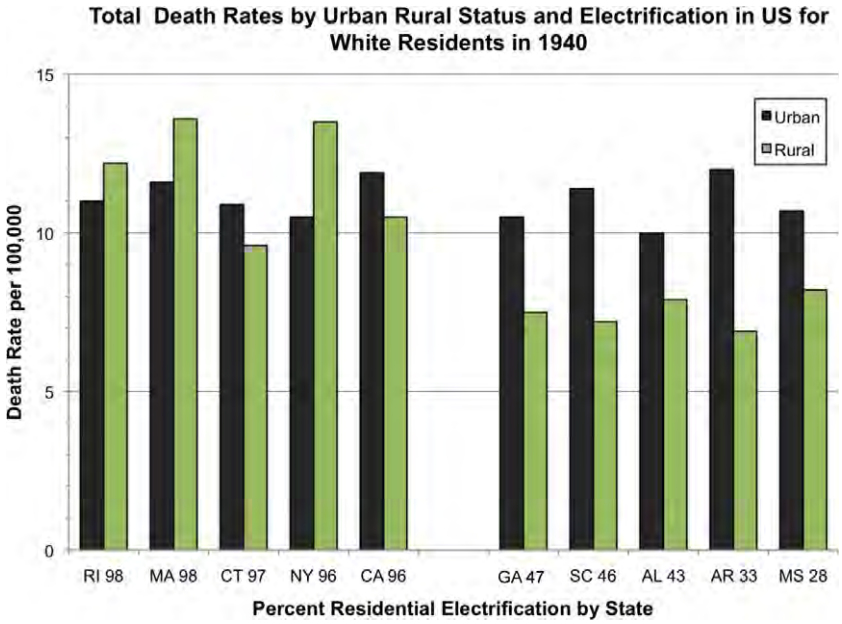


Fig. 5. All causes death rates by urban rural status and electrification in the US for white residents in 1940.

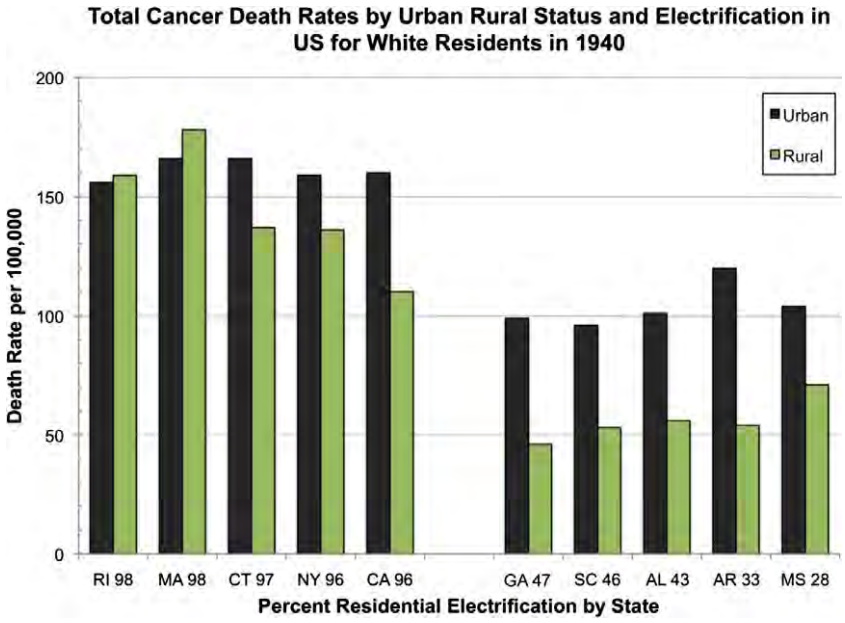


Fig. 6. Total cancer death rates by urban rural status and electrification in the US for white residents in 1940.

Respiratory cancer

No urban rural information was available for respiratory cancer, but the correlation between residential electrification and state death rates was $r = 0.611$; $p = <0.0001$. This cancer is etiologically strongly related to cigarette smoking, so the correlation with electrification is surprising. A large electrical utility worker cohort study found a high respiratory cancer incidence related to high frequency EMF transient exposure independent of cigarette smoking with a significant dose–response relationship [15].

Breast cancer

Although urban/rural information was not available for breast cancer, the 1940 state breast cancer death rates have a correlation of $r = 0.794$; $p = <0.0001$ with residential electrification. Fig. 8 shows the typical time trend of breast cancer death rates for a state with a high level of electrification (96%) and one with a low level of electrification (<50) in 1940. The California breast cancer death rate increased from 1920 to 1940, and then gradually decreased until 1960. The Tennessee breast cancer death rate is less than half of the California rate in 1920 and continues a steady increase until 1960.

Diabetes

This cause has a 66% urban excess. In spite of this, the correlation coefficients for urban and rural areas are similar at $r = 0.66$; $p = <0.0001$. There is some animal and human evidence that EMFs can effect insulin production and blood glucose levels [16]. Fig. 9

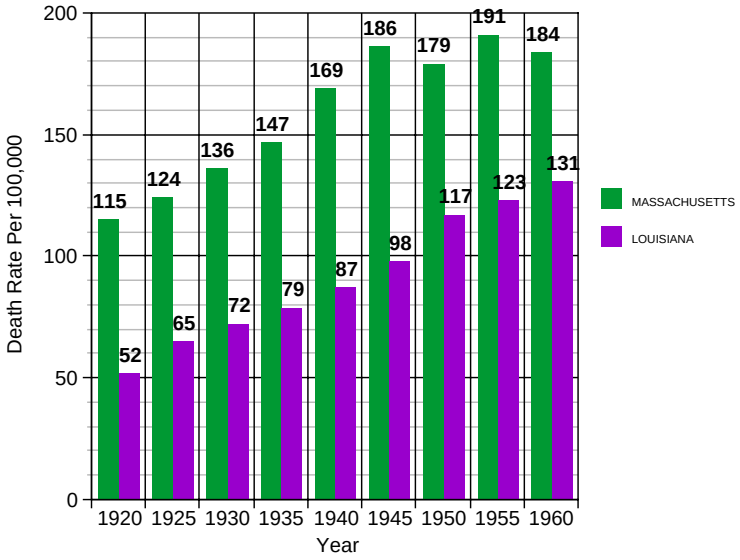


Fig. 7. US white resident total cancer death rates for Massachusetts (97.6% elect.) and Louisiana (48.9% elect.) by year.

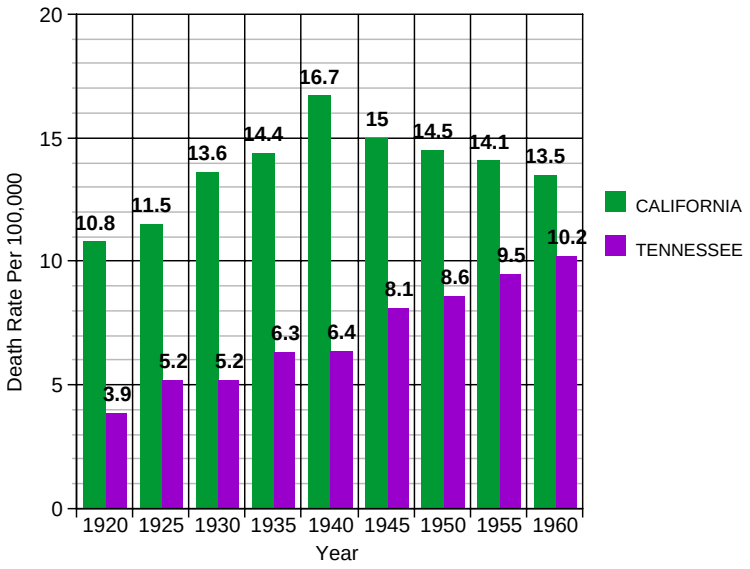


Fig. 8. US white resident breast cancer death rates for California (96% elect.) and Tennessee (50% elect.) by year.

shows that in states with low levels of electrification in 1940, the urban diabetes death rates are consistently higher than the rural rates, but are always lower than the urban and rural rates in the high electrification states.

Leukemia

Since the childhood leukemia age peak is strongly associated with residential electrification, it was interesting that the all leukemia death rate correlation was $r = 0.375$; $p = 0.0042$. Most of these deaths are in adults and are of different types of leukemia. A study of amateur radio operators showed a selective excess only of acute myelogenous leukemia [17].

Coronary artery disease and other heart disease

These two cause groups had the same percentage urban excess (33%), and very similar patterns of urban and rural correlation coefficients with residential electrification. The urban correlations were about $r = 0.4$ and rural deaths had correlations of 0.78 and 0.79, respectively. Fig. 10 shows the 1940 resident white coronary artery disease death rates for urban and rural areas of states having greater than 96% of residences electrified and states having less than 50% of residences electrified. Four of the five high electrification states had similar urban and rural total cancer rates, while all the low electrification states had urban rates about twice as high as rural rates. Urban and rural coronary artery death rates were lower in low electrification states than in high electrification states.

Suicide

The urban suicide death rate is about 30% higher than the rural rate. The urban suicide rate is not correlated with residential electrification ($r = 0.077$; $p = 0.299$), but the rural death rate is correlated with 1940 state residential electrification levels ($r = 0.729$; $p = <0.0001$). Fig. 11 shows the 1940 resident white suicide for

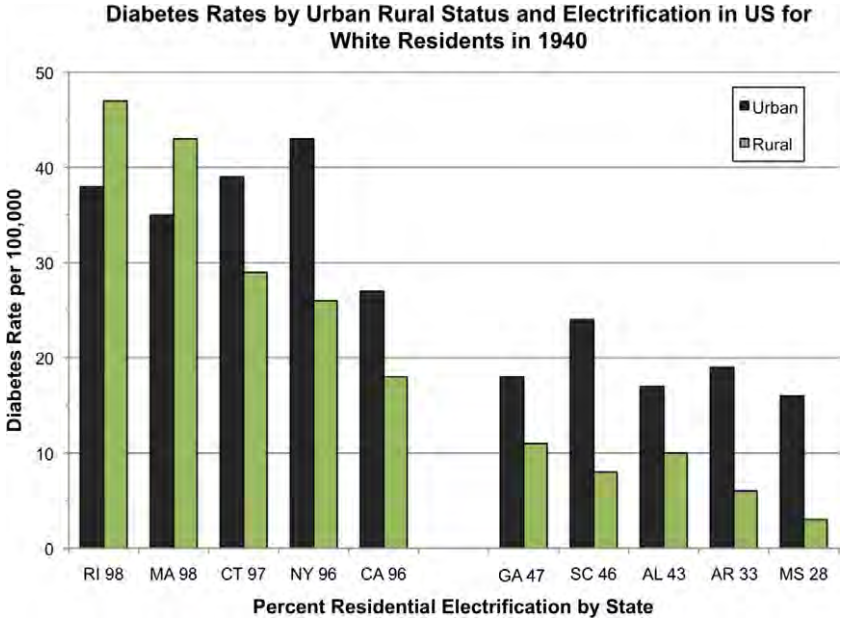


Fig. 9. Total diabetes rates by urban rural status and electrification in the US for white residents in 1940.

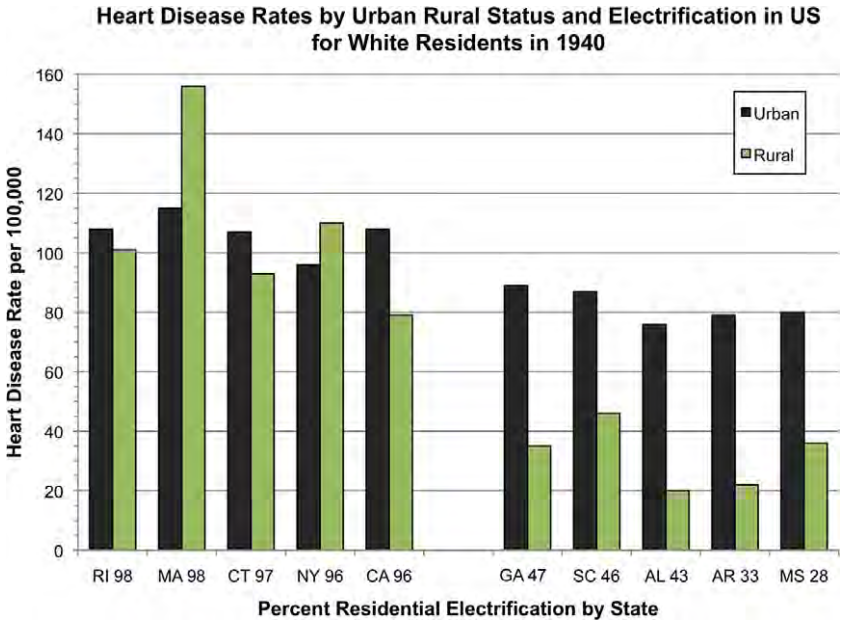


Fig. 10. Total heart disease rates by urban rural status and electrification in the US for white residents in 1940.

urban and rural areas of states having greater than 96% of residences electrified and states having less than 50% of residences electrified. In four of five high electrification states, rural suicide rates are higher than the urban rates. In all of the low electrification states, the urban rate is higher. The rural rates in the high electrification states are higher than the rural rates in the low electrification states. Fig. 12 shows X Y scatter plots for urban and rural suicide by electrification for 48 states. Suicide has been associated with both residential [18] and occupational [19] EMF exposure. Suicide is probably the visible peak of the clinical depression iceberg.

Motor vehicle accidents

Although the mortality rates are similar in urban and rural areas, the correlations with residential electrification levels are different. There is a slight negative correlation ($r = -0.254$) in urban areas and a positive correlation ($r = 0.451$) in rural areas. Since motor vehicle fatality is related to access to a vehicle and to speed. It may be that in the larger cities it was difficult to go fast enough for a fatal accident, and in rural areas especially on farms, a farmer who could afford electrification could also afford a car.

Discussion

When Edison and Tesla opened the Pandora's box of electrification in the 1880s, the US vital registration system was primitive at best, and infectious disease death rates were falling rapidly. City residents had higher mortality rates and shorter life expectancy than rural residents [8]. Rural white males in 1900 had an expectation of life at birth of over 10 years longer than urban residents.

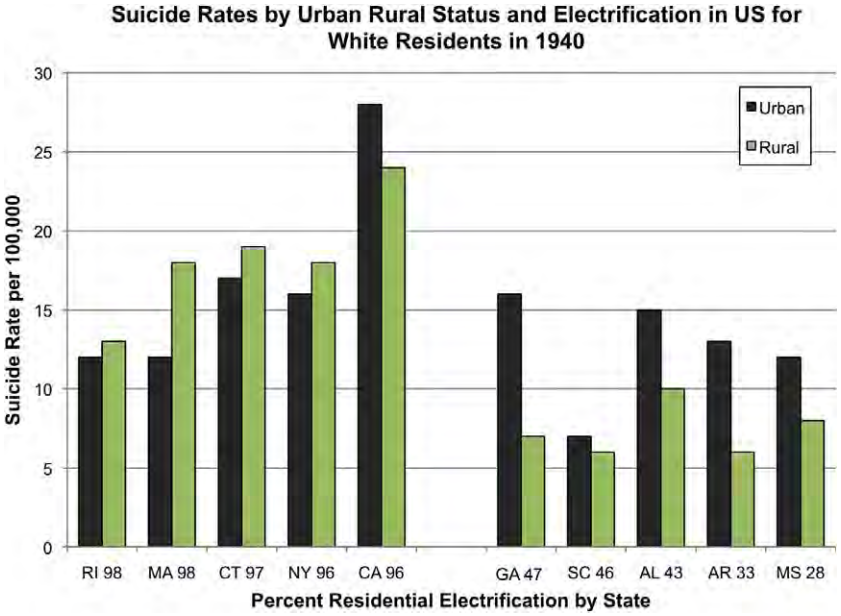


Fig. 11. Total suicide death rates by urban rural status and electrification in the US for white residents in 1940.

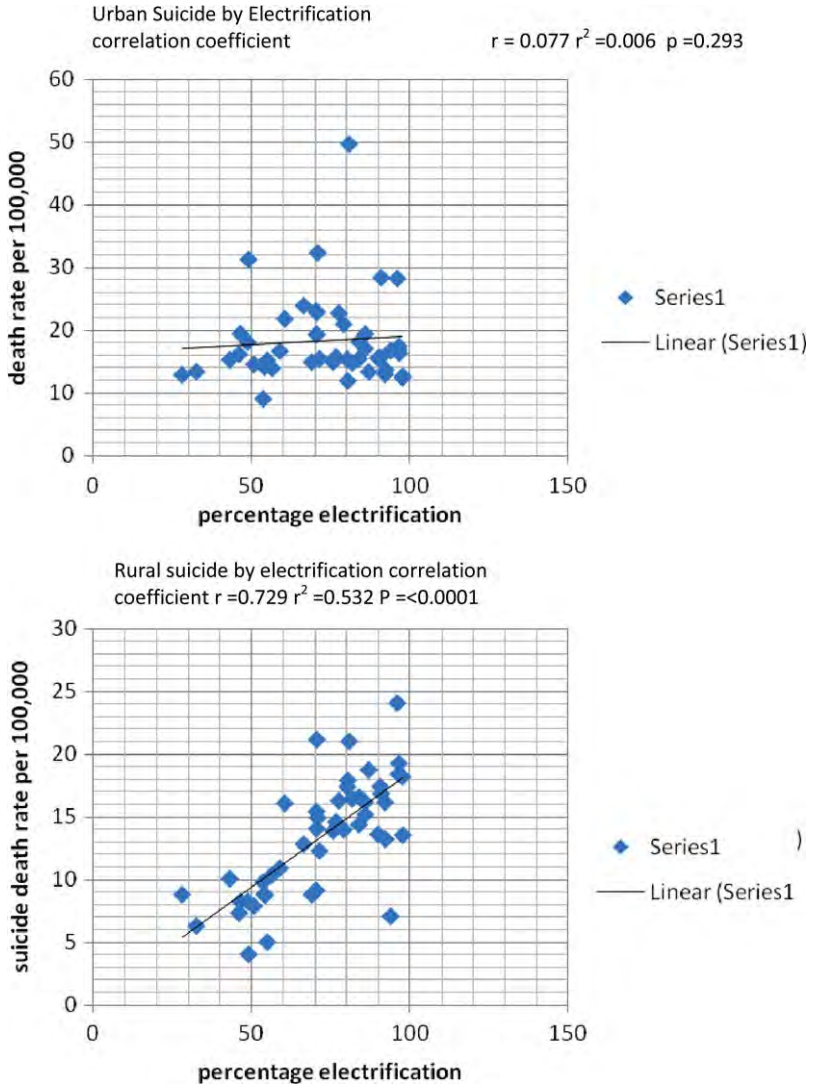


Fig. 12. 1940 US white resident urban rural suicide death rates by state and electrification.

Although the authors of the 1930 US vital statistics report noted a 58.2% cancer mortality excess in urban areas, it raised no red flags. The census bureau residential electrification data was obviously not linked to the mortality data. Epidemiologists in that era were still concerned with the communicable diseases.

Court Brown and Doll reported [20] the appearance of the childhood leukemia age peak in 1961, forty years after the US vital statistics mortality data on which it was based was available. I reported a cluster of childhood leukemia [21] a decade after it occurred, only because I looked for it. Real time or periodic analysis of national or regional vital statistics data is still only rarely done in the US.

The real surprise in this data set is that cardiovascular disease, diabetes and suicide, as well as cancer seem to be strongly related to level of residential electrification. A community-based epidemiologic study of urban rural differences in coronary heart disease and its risk factors was carried out in the mid 1980s in New Delhi, India and in a rural area 50 km away [22]. The prevalence of coronary heart disease was three times higher in the urban residents, despite the fact that the rural residents smoked more and had higher total caloric and saturated fat intakes. Most cardiovascular disease risk factors were two to three times more common in the urban residents. Rural electrification projects are still being carried out in parts of the rural area which was studied.

It seems unbelievable that mortality differences of this magnitude could go unexplained for over 70 years after they were first reported and 40 years after they were noticed. I think that in the early part of the 20th century nobody was looking for answers. By the time EMF epidemiology got started in 1979 the entire population was exposed to EMFs. Cohort studies were therefore using EMF-exposed population statistics to compute expected values, and case-control studies were comparing more exposed cases to less exposed controls. The mortality from lung cancer in two pack a day smokers is over 20 times that of non-smokers but only three times that of one pack a day smokers. After 1956, the EMF equivalent of a non-smoker ceased to exist in the US. An exception to this is the Amish who live without electricity. Like rural US residents in the 1940s, Amish males in the 1970s had very low cancer and cardiovascular disease mortality rates [23].

If this hypothesis and findings outlined here are even partially true, the explosive recent increase in radiofrequency radiation, and high frequency voltage transients sources, especially in urban areas from cell phones and towers, terrestrial antennas, wi-fi and wi-max systems, broadband internet over power lines, and personal electronic equipment, suggests that like the 20th century EMF epidemic, we may already have a 21st century epidemic of morbidity and mortality underway caused by electromagnetic fields. The good news is that many of these diseases may be preventable by environmental manipulation, if society chooses to.

Conflicts of interest statement

None declared.

References

[1] Milham S, Ossiander EM. Historical evidence that residential electrification caused the emergence of the childhood leukemia peak. Med Hypotheses 2001;56(3):290–5.

[2] Milham S, Morgan LL. A new electromagnetic field exposure metric: high frequency voltage transients associated with increased cancer incidence in teachers in a California school. Am J Ind Med 2008;51(8):579–86.

[3] Reynolds P, Elkin EP, Layefsky ME, Lee JM. Cancer in California school employees. Am J Ind Med 1999;36:271–8.

[4] US bureau of the Census. The statistical history of the United States from colonial times to the present. New York: Basic Books; 1976.

[5] Wertheimer N, Leeper E. Electrical wiring configurations and cancer. Am J Epidemiol 1979;109(3):273–84.

[6] Vital statistics of the United States (annual volumes 1930, 1940). Washington, DC: US Government Printing Office.

[7] US Census Bureau. Washington, DC: US Department of Commerce; 2009. <www.census.gov>.

[8] Vital statistics rates in the US 1940–1960, National Center for Health Statistics. Washington, DC: US Government Printing Office.

[9] Historical statistics of the United States colonial times to 1970. US Bureau of the Census. Washington, DC: US Commerce Department.

[10] Vassar statistical computation web site. Authored by Richard Lowry, Emeritus professor of psychology. Vassar College, Poughkeepsie NY, USA; 2009. <http://faculty.vassar.edu/lowry/VassarStats.html>.

[11] Microsoft Excel 2007. Microsoft Corporation. One Microsoft Way, Redmond, WA, 98052-6399.

[12] National Center for Education Statistics (NCES) web site. US Department of Education. Washington, DC: Institute of Educational Sciences; 2009. <http://nces.ed.gov/nceskids/createAgraph/>.

[13] Howe HL, Keller JE, Lehnherr M. The relation of population density and cancer incidence. Illinois 1986–1990. Am J Epidemiol 1993;138:29–36.

[14] Hallberg O, Johannson O. Cancer trends during the 20th century. J Aust College Nutr Environ Med 2002;21(1):3–8.

[15] Armstrong B, Theriault G, Guenel P, Deadman J, Goldgerg M, Heroux P. Association between exposure to pulsed electromagnetic fields and cancer in electric utility workers in Quebec, Canada, and France. Am J Epidemiol 1994;140(9):805–20.

[16] Navakatikian MA, Tomashevskaya LA. Phasic behavior and endocrine effects of microwaves of nonthermal intensity. In: Carpenter DO, editor. Biological effects of magnetic fields, vol. 1. San Diego, CA: Academic Press; 1994. p. 333–42.

[17] Milham S. Increased mortality in amateur radio operators due to lymphatic and hematopoietic malignancies. Am J Epidemiol 1988;127(1):50–4.

[18] Perry S, Reichmanis M, Marino AA, Becker RO. Environmental power-frequency fields and suicide. Health Phys 1981;41(2):267–77.

[19] van Wijngaarden E, Savitz DA, Kleckner RC, Cai J, Loomis D. Exposure to electromagnetic fields and suicide among electric utility workers: a nested case-control study. West J Med 2000;173(2):94–100.

[20] Court Brown WM, Doll R. Leukemia in childhood and young adult life: Trends in mortality in relation to aetiology. BMJ 1961;26:981–8.

[21] Milham S. Leukemia clusters. Lancet 1963;23(7317):1122–3.

[22] Chadna SL, Gopinath N, Shekhawat S. Urban-rural difference in the prevalence of coronary heart disease and its risk factors. Bull World Health Org 1997;75(1):31–8.

[23] Hamman RF, Barancik JJ, Lilienfeld AM. Patterns of mortality in the Old Order Amish. Am J Epidemiol 1981;114(6):345–61.

EXHIBIT 10

A New Electromagnetic Exposure Metric: High Frequency Voltage Transients Associated With Increased Cancer Incidence in Teachers in a California School

Samuel Milham, MD, MPH*,† and L. Lloyd Morgan, BS‡

Background *In 2003 the teachers at La Quinta, California middle school complained that they had more cancers than would be expected. A consultant for the school district denied that there was a problem.*

Objectives *To investigate the cancer incidence in the teachers, and its cause.*

Method *We conducted a retrospective study of cancer incidence in the teachers' cohort in relationship to the school's electrical environment.*

Results *Sixteen school teachers in a cohort of 137 teachers hired in 1988 through 2005 were diagnosed with 18 cancers. The observed to expected (O/E) risk ratio for all cancers was 2.78 ($P = 0.000098$), while the O/E risk ratio for malignant melanoma was 9.8 ($P = 0.0008$). Thyroid cancer had a risk ratio of 13.3 ($P = 0.0098$), and uterine cancer had a risk ratio of 9.2 ($P = 0.019$). Sixty Hertz magnetic fields showed no association with cancer incidence. A new exposure metric, high frequency voltage transients, did show a positive correlation to cancer incidence. A cohort cancer incidence analysis of the teacher population showed a positive trend ($P = 7.1 \times 10^{-10}$) of increasing cancer risk with increasing cumulative exposure to high frequency voltage transients on the classroom's electrical wiring measured with a Graham/Stetzer (G/S) meter. The attributable risk of cancer associated with this exposure was 64%. A single year of employment at this school increased a teacher's cancer risk by 21%.*

Conclusion *The cancer incidence in the teachers at this school is unusually high and is strongly associated with high frequency voltage transients, which may be a universal carcinogen, similar to ionizing radiation.* Am. J. Ind. Med. 2008. © *2008 Wiley-Liss, Inc.*

KEY WORDS: high frequency voltage transients; electricity; dirty power; cancer; school teachers; carcinogen

BACKGROUND

Since the 1979 Wertheimer–Leeper study [Wertheimer and Leeper, 1979] there has been concern that exposure to power frequency (50/60 Hz) EMFs, especially magnetic fields, may contribute to adverse health effects including cancer. Until now, the most commonly used exposure metric has been the time-weighted average of the power-frequency magnetic field. However, the low risk ratios in most studies suggest that magnetic fields might be a surrogate for a more important metric. In this paper we present evidence that a

Abbreviations: EMF, electromagnetic fields; O, observed cases; E, expected cases; O/E, risk ratio; p, probability; Hz, Hertz or cycles per second; OSHA, Occupational Safety and Health Administration; OCMAP, occupational mortality analysis program; AM, amplitude modulation; GS units, Graham/Stetzer units; G/S meter, Graham/Stetzer meter; MS II, Microsurge II meter; mG, milligauss; EKG, electrocardiogram; LQMS, La Quinta Middle School.

Washington State Department of Health, Tumwater, Washington
†Retired.
‡Retired Electronic Engineer.
*Correspondence to: Samuel Milham, 2318 Gravelly Beach Loop NW, Olympia, WA 98502. E-mail: smilham2@comcast.net

Accepted 29 April 2008
DOI 10.1002/ajim.20598. Published online in Wiley InterScience (www.interscience.wiley.com)

new exposure metric, high frequency voltage transients existing on electrical power wiring, is an important predictor of cancer incidence in an exposed population.

The new metric, GS units, used in this investigation is measured with a Graham/Stetzer meter (G/S meter) also known as a Microsurge II meter (MS II meter), which is plugged into electric outlets [Graham, 2005]. This meter displays the average rate of change of these high frequency voltage transients that exist everywhere on electric power wiring. High frequency voltage transients found on electrical wiring both inside and outside of buildings are caused by an interruption of electrical current flow. The electrical utility industry has referred to these transients as "dirty power."

There are many sources of "dirty power" in today's electrical equipment. Examples of electrical equipment designed to operate with interrupted current flow are light dimmer switches that interrupt the current twice per cycle (120 times/s), power saving compact fluorescent lights that interrupt the current at least 20,000 times/s, halogen lamps, electronic transformers and most electronic equipment manufactured since the mid-1980s that use switching power supplies. Dirty power generated by electrical equipment in a building is distributed throughout the building on the electric wiring. Dirty power generated outside the building enters the building on electric wiring and through ground rods and conductive plumbing, while within buildings, it is usually the result of interrupted current generated by electrical appliances and equipment.

Each interruption of current flow results in a voltage spike described by the equation $V = L \times di/dt$, where V is the voltage, L is the inductance of the electrical wiring circuit and di/dt is the rate of change of the interrupted current. The voltage spike decays in an oscillatory manner. The oscillation frequency is the resonant frequency of the electrical circuit. The G/S meter measures the average magnitude of the rate of change of voltage as a function of time (dV/dT). This preferentially measures the higher frequency transients. The measurements of dV/dT read by the meter are defined as GS (Graham/Stetzer) units.

The bandwidth of the G/S meter is in the frequency range of these decaying oscillations. Figure 1 shows a two-channel oscilloscope display. One channel displays the 60 Hz voltage on an electrical outlet while the other channel with a 10 kHz hi-pass filter between the oscilloscope and the electrical outlet, displays the high frequency voltage transients on the same electrical outlet [Havas and Stetzer, 2004, reproduced with permission].

Although no other published studies have measured high frequency voltage transients and risk of cancer, one study of electric utility workers exposed to transients from pulsed

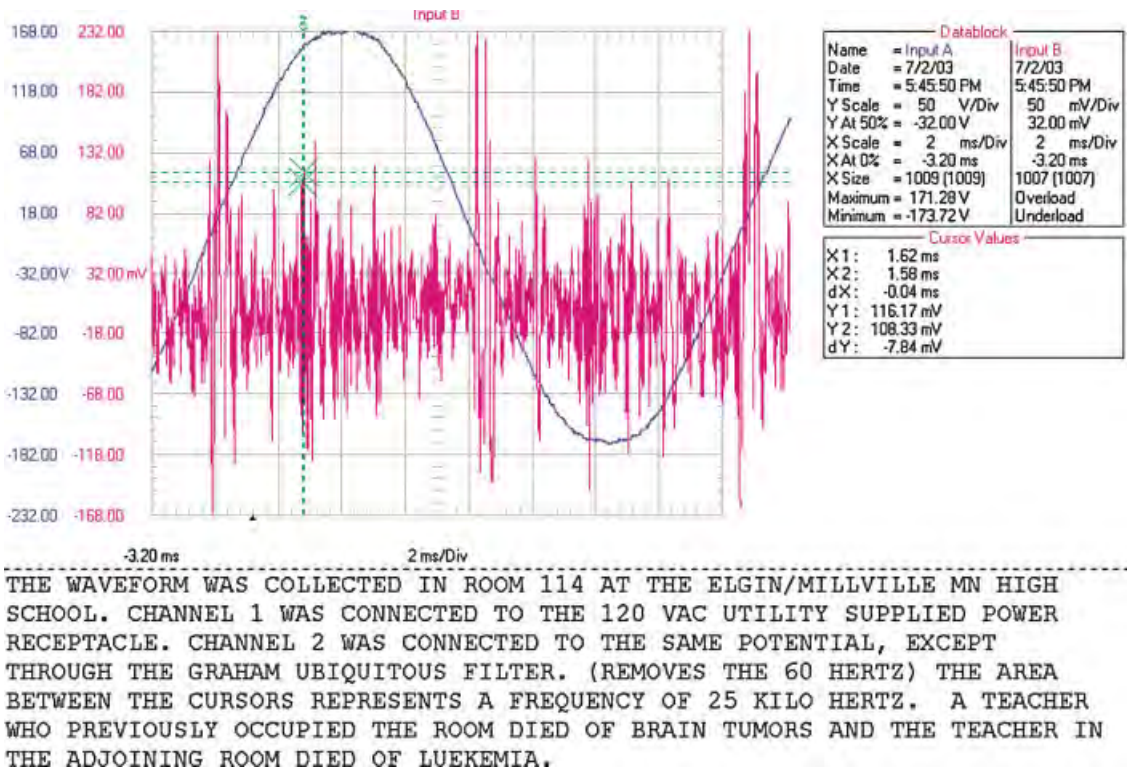


FIGURE 1. Oscilloscope display of dirty power: 60 Hz electrical power (channel 1) with concurrent high frequency voltage transients (channel 2). A 10 kHz hi-pass filter was used on channel 2 in order to filter out the 60 Hz voltage and its harmonics. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

electromagnetic fields found an increased incidence of lung cancer among exposed workers [Armstrong et al., 1994].

INTRODUCTION

In February 2004, a Palm Springs, California newspaper, The Desert Sun, printed an article titled, ''Specialist discounts cancer cluster at school,'' in which a local tumor registry epidemiologist claimed that there was no cancer cluster or increased cancer incidence at the school [Perrault, 2004]. An Internet search revealed that the teacher population at La Quinta Middle School (LQMS) was too small to generate the 11 teachers with cancer who were reported in the article. The school was opened in 1988 with 20 teachers hired that year. For the first 2 years, the school operated in three temporary buildings, one of which remains. In 1990, a newly constructed school opened. In 2003, the teachers complained to school district management that they believed that they had too many cancers. Repeated requests to the school administration for physical access to the school and for teachers' information were denied. We contacted the teachers, and with their help, the cancers in the group were characterized. One teacher suggested using yearbooks to develop population-at-risk counts for calculating expected cancers. We were anxious to assess the electrical environment at the school, since elevated power frequency magnetic field exposure with a positive correlation between duration of exposure and cancer incidence had been reported in first floor office workers who worked in strong magnetic fields above three basement-mounted 12,000 V transformers [Milham, 1996]. We also wanted to use a new electrical measurement tool, the Graham/Stetzer meter, which measures high frequency voltage transients.

The Graham/Stetzer Microsurge II meter measures the average rate of change of the transients in Graham/Stetzer units (GS units). Anecdotal reports had linked dirty power exposure with a number of illnesses [Havas and Stetzer, 2004]. We decided to investigate whether power frequency magnetic field exposure or dirty power exposure could explain the cancer increase in the school teachers.

METHODS

After the school administration (Desert Sands Unified School District) had refused a number of requests to assist in helping us evaluate the cancers reported by the teachers, we were invited by a teacher to visit the school after hours to make magnetic field and dirty power measurements. During that visit, we noted that, with the exception of one classroom near the electrical service room, the classroom magnetic field levels were uniformly low, but the dirty power levels were very high, giving many overload readings. When we reported this to Dr. Doris Wilson, then the superintendent of schools (retired December, 2007), one of us (SM) was threatened with prosecution for ''unlawful.. trespass,'' and the teacher who had invited us into the school received a letter of reprimand. The teachers then filed a California OSHA complaint which ultimately lead to a thorough measurement of magnetic fields and dirty power levels at the school by the California Department of Health Services which provided the exposure data for this study. They also provided comparison dirty power data from residences and an office building, and expedited tumor registry confirmation of cancer cases.

Classrooms were measured at different times using 3 meters: an FW Bell model 4080 tri-axial Gaussmeter, a Dexsil 310 Gaussmeter, and a Graham-Stetzer (G/S) meter. The Bell meter measures magnetic fields between 25 and 1,000 Hz. The Dexsil meter measures magnetic fields between 30 and 300 Hz. The G/S meter measures the average rate of change of the high frequency voltage transients between 4 and 150 KHz.

All measurements of high frequency voltage transients were made with the G/S meter. This meter was plugged into outlets, and a liquid crystal display was read. All measurements reported were in GS units. The average value was reported where more than one measurement was made in a classroom.

We measured seven classrooms in February 2005 using the Bell meter and the G/S meter. Later in 2005, the teachers measured 37 rooms using the same meters. On June 8, 2006, electrical consultants for the school district and the California Department of Health Services (Dr. Raymond Neutra) repeated the survey using the G/S meter and a Dexsil 320 Gaussmeter, measuring 51 rooms. We used results of this June 8, 2006 sampling in our exposure calculations, since all classrooms were sampled, multiple outlets per room were sampled, and an experienced team did the sampling. Additionally, GS readings were taken at Griffin Elementary school near Olympia, Washington, and Dr. Raymond Neutra provided GS readings for his Richmond California office building and 125 private California residences measured in another Northern California study.

All the cancer case information was developed by personal, telephone, and E-mail contact with the teachers or their families without any assistance from the school district. The local tumor registry verified all the cancer cases with the exception of one case diagnosed out of state and the two cases reported in 2007. The out-of state case was verified by pathologic information provided by the treating hospital. The teachers gathered population-at-risk information (age at hire, year of hire, vital status, date of diagnosis, date of death, and termination year) from yearbooks and from personal contact. The teachers also provided a history of classroom assignments for all teachers from annual classroom assignment rosters (academic years 1990–1991 to 2006–2007) generated by the school administration. The school administration provided a listing of school employees, including

the teachers, to the regional tumor registry after the teachers involved the state health agency by submitting an OSHA complaint. The information we obtained anecdotally from the teachers, yearbooks, and classroom assignment rosters was nearly identical to that given to the tumor registry. None of the cancer cases were ascertained initially through the cancer registry search.

Published cancer incidence rates by age, sex, and race for all cancers, as well as for malignant melanoma, thyroid, uterine, breast, colon, ovarian cancers, and non-Hodgkin's lymphoma (NHL) were obtained from a California Cancer Registry publication [Kwong et al., 2001]. We estimated the expected cancer rate for each teacher by applying year, age, sex, and race-specific cancer incidence rates from hire date until June 2007, or until death. We then summed each teacher's expected cancer rate for the total cohort.

Using the California cancer incidence data, the school teacher data, and the GS exposure data, we calculated cancer incidence and risks. A replicate data set was sent to Dr. Gary Marsh and to Mike Cunningham at the University of Pittsburgh School of Public Health for independent analysis using OCMAP software. We calculated cancer risk ratios by duration of employment and by cumulative GS unit-years of exposure. We calculated an attributable risk percent using the frequencies of total observed and expected cancers, and performed trend tests [Breslow and Day, 1987] for cancer risk versus duration of employment and cumulative GS unit-years of exposure. Poisson *P* values were calculated using the Stat Trek website (Stat Trek, 2007). We also performed a linear regression of cancer risk by duration of employment in years and by time-weighted exposure in GS unit-years.

Since neither author had a current institutional affiliation, institutional review board approval was not possible. The teachers requested the study, and their participation in the study was both voluntary and complete. All the active teachers at the school signed the Cal OSHA request. The authors fully explained the nature of the study to study participants and offered no remuneration to the teachers for participation in the study. The authors maintained strict confidentiality of all medical and personal information provided to us by the teachers, and removed personal identifiers from the data set which was analyzed by the University of Pittsburgh. Possession of personal medical information was limited to the two authors. No patient-specific information was obtained from the tumor registry. With the individual's permission we provided the registry with case information for a teacher with malignant melanoma diagnosed out of state. The exposure information was provided by the California Department of Health Services. The basic findings of the study were presented to the Desert Sands Unified School District School Board and at a public meeting arranged by the teachers.

RESULTS

Electrical Measurements

In our seven-room survey of the school in 2005, magnetic field readings were as high as 177 mG in a classroom adjacent to the electrical service room. A number of outlets had overload readings with the G/S meter. Magnetic fields were not elevated ($>$3.0 mG) in the interior space of any of the classrooms except in the classroom adjacent to the electrical service room, and near classroom electrical appliances such as overhead transparency projectors. There was no association between the risk of cancer and 60 Hz magnetic field exposures in this cohort, since the classroom magnetic field exposures were the same for teachers with and without cancer (results not shown).

This school had very high GS readings and an association between high frequency voltage transient exposure in the teachers and risk of cancer. The G/S meter gives readings in the range from 0 to 1,999 GS units. The case school had 13 of 51 measured rooms with at least one electrical outlet measuring ''overload'' ($\geq$2,000 GS units). These readings were high compared to another school near Olympia Washington, a Richmond California office building, and private residences in Northern California (Table I). Altogether, 631 rooms were surveyed for this study. Only 17 (2.69%) of the 631 rooms had an ''overload'' (maximum, $\geq$2,000 GS units) reading. Applying this percentage to the 51 rooms surveyed at the case school, we would expect 1.4 rooms at the school to have overload GS readings ($0.0269 \times 51 = 1.37$). However, thirteen rooms (25%) measured at the case school had ''overload'' measurements above the highest value (1,999 GS units) that the G/S meter can

TABLE I. Graham/Stetzer Meter Readings: Median Values in Schools, Homes and an Office Building

Place	Homes	Office bldg	Olympia WA School	LQMS	Total
No. of rooms surveyed	500	39	41	51	531
Median GS units	159	210	160	750	<270[a]
Rooms with overload GS units ($\geq$2,000)	4	0	0	13*	17

[a]Excludes homes as specific room data was not available.
*$P = 3.14 \times 10^{-9}$.

TABLE II. Risk of Cancer by Type Among Teachers at La Quinta Middle School

Cancer	Observed	Expected	Risk ratio (O/E)	*P*-value
All cancers	18	6.51	2.78*	0.000098
Malignant melanoma	4	0.41	9.76*	0.0008
Thyroid cancer	2	0.15	13.3*	0.011
Uterus cancer	2	0.22	9.19*	0.019
Female breast cancer	2	1.5	1.34	0.24
All cancers less melanoma	14	6.10	2.30*	0.0025

*$P \leq 0.05$.

measure. This is a highly statistically significant excess over expectation (Poisson $P = 3.14 \times 10^{-9}$).

We noticed AM radio interference in the vicinity of the school. A teacher also reported similar radio interference in his classroom and in the field near his ground floor classroom. In May 2007, he reported that 11 of 15 outlets in his classroom overloaded the G/S meter. An AM radio tuned off station is a sensitive detector of dirty power, giving a loud buzzing noise in the presence of dirty power sources even though the AM band is beyond the bandwidth of the G/S meter.

Cancer Incidence

Three more teachers were diagnosed with cancer in 2005 after the first 11 cancer diagnoses were reported, and another former teacher (diagnosed out-of-state in 2000) was reported by a family member employed in the school system. One cancer was diagnosed in 2006 and two more in 2007. In the years 1988–2005, 137 teachers were employed at the school. The 18 cancers in the 16 teachers were: 4 malignant melanomas, 2 female breast cancers, 2 cancers of the thyroid, 2 uterine cancers and one each of Burkitt's lymphoma (a type of non-Hodgkins lymphoma), polycythemia vera, multiple myeloma, leiomyosarcoma and cancer of the colon, pancreas, ovary and larynx. Two teachers had two primary cancers each: malignant melanoma and multiple myeloma, and colon and pancreatic cancer. Four teachers had died of cancer through August 2007. There have been no non-cancer deaths to date.

The teachers' cohort accumulated 1,576 teacher-years of risk between September 1988 and June 2007 based on a 12-month academic year. Average age at hire was 36 years. In 2007, the average age of the cohort was 47.5 years.

When we applied total cancer and specific cancer incidence rates by year, age, sex, race, and adjusted for cohort ageing, we found an estimate of 6.5 expected cancers, 0.41 melanomas, 0.15 thyroid cancers, 0.22 uterine cancers, and 1.5 female breast cancers (Table II). For all cancers, the risk ratio (Observed/Expected = 18/6.5) was 2.78 ($P = 0.000098$, Poisson test); for melanoma, (O/E = 4/0.41) was 9.8 ($P = 0.0008$, Poisson test); for thyroid cancer (O/E = 2/0.15) was 13.3 ($P = 0.0011$, Poisson test); for uterine cancer (O/E = 2/0.22), was 9.19 ($P = 0.019$, Poisson test).

Table III shows the cancer risk among the teachers by duration of employment. Half the teachers worked at the school for less than 3 years (average 1.52 years). The cancer risk increases with duration of employment, as is expected when there is exposure to an occupational carcinogen. The cancer risk ratio rose from 1.7 for less than 3 years, to 2.9 for 3–14 years, to 4.2 for 15+ years of employment. There was a positive trend of increasing cancer incidence with increasing duration of employment ($P = 4.6 \times 10^{-10}$). A single year of employment at this school increases a teacher's risk of cancer by 21%.

Using the June 8, 2006 survey data (Table IV), the cancer risk of a teacher having ever worked in a room with at least one outlet with an overload GS reading ($\geq$2000 GS units) and employed for 10 years or more, was 7.1 ($P = 0.00007$, Poisson test). In this group, there were six teachers diagnosed

TABLE III. Cancer Risk by Duration of Employment

Time at school	Average time	Teachers	% of teachers	Cancer observed	Cancer expected	Risk ratio (O/E)	Poisson p
<3 years	1.52 years	68	49.6	4	2.34	1.72	0.12
3–14 years	7.48 years	56	40.9	9	3.14	2.87*	0.0037
15+ years	16.77 years	12	8.8	5	1.02	4.89*	0.0034
Total		137	100	18	6.51	2.78*	0.000098

Positive trend test (Chi square with one degree of freedom = 38.8, $P = 4.61 \times 10^{-10}$).
*$P \leq 0.05$.

TABLE IV. Cancer in Teachers Who Ever Taught in Classrooms With at Least One Overload GS Reading (≥2000 GS Units) by Duration of Employment

Ever in a room >2,000 GS units	Employed 10 + years	Total teachers	Cancers observed	Cancers expected	Risk ratio (O/E)	Poisson p
Yes	Yes	10	7[a]	0.988	7.1*	0.00007
Yes	No	30	3[a]	0.939	3.2	0.054
Total		40	10	1.93	5.1*	0.00003
No	Yes	19	2	1.28	1.6	0.23
No	No	78	6	3.25	1.8	0.063
Total		97	8	4.56	1.8*	0.047
Grand total		137	18	6.49	2.8*	0.000098

[a]One teacher had two primary cancers.
*$P < 0.05$.

with a total of seven cancers, and four teachers without a cancer diagnosis, who were employed for 10 or more years and who ever worked in one of these rooms. Five teachers had one primary cancer and one teacher had two primary cancers. These teachers made up 7.3% of the teachers' population (10/137) but had 7 cancers or 39% (7/18) of the total cancers. The 10 teachers who worked in an overload classroom for 10 years or more had 7 cancers when 0.99 would have been expected ($P = 6.8 \times 10^{-5}$ Poisson test). The risk ratio for the 8 teachers with cancer and 32 teachers without cancer, who ever worked in a room with an overload GS reading, regardless of the time at the school, was 5.1 ($P = 0.00003$, Poisson test). The risk ratio for 8 teachers with cancer and 89 teachers without cancer who never worked in a room with an overload G-S reading was 1.8 ($P = 0.047$, Poisson test). Teachers who never worked in an overload classroom also had a statistically significantly increased risk of cancer.

A positive dose-response was seen between the risk of cancer and the cumulative GS exposure (Table V). Three categories of cumulative GS unit-years of exposure were selected: <5,000, 5,000 to 10,000, and more than 10,000 cumulative GS unit-years. We found elevated risk ratios of 2.0, 5.0, and 4.2, respectively, all statistically significant, for each category. There was a positive trend of increasing cancer incidence with increasing cumulative GS unit-years of exposure ($P = 7.1 \times 10^{-10}$). An exposure of 1,000 GS unit-years increased a teacher's cancer risk by 13%. Working in a room with a GS overload (≥2,000 GS units) for 1 year increased cancer risk by 26%.

An attributable risk percentage was calculated: (observed cancers-expected cancers)/observed cancers = $(18-6.51)/18 = 63.8\%$.

The fact that these cancer incidence findings were generated by a single day of G/S meter readings made on June 8, 2006 suggests that the readings were fairly constant over time since the school was built in 1990. For example, if the 13 classrooms which overloaded the meter on June 8, 2006 were not the same since the start of the study and constant throughout, the cancer risk of teachers who ever worked in the overload rooms would have been the same as the teachers who never worked in an overload room.

Although teachers with melanoma and cancers of the thyroid, and uterus, had very high, statistically significant risk ratios, there was nothing exceptional about their age at hire, duration of employment, or cumulative GS exposure. However, thyroid cancer and melanoma had relatively short latency times compared to the average latency time for all 18 cancers. The average latency time between start of

TABLE V. Observed and Expected Cancers by Cumulative GS Exposure (GS Unit-Years)

Exposure group	<5,000 GS unit-years	5,000 to 10,000	>10,000 GS unit-years	Total
Average GS unit-years	914	7,007	15,483	
Cancers obs.	9	4	5	18
Cancers exp.	4.507	0.799	1.20	6.49
Risk ratio (O/E)	2.01*	5.00*	4.17*	2.78*
Poisson p	0.0229	0.0076	0.0062	0.000098

Positive trend test (Chi square with one degree of freedom = 38.0, $P = 7.1 \times 10^{-10}$).
*$P < 0.05$.

employment at the school and diagnosis for all cancers was 9.7 years. The average latency time for thyroid cancer was 3.0 years and for melanoma it was 7.3 years (with three of the four cases diagnosed at 2, 5, and 5 years).

An independent analysis of this data set by the University of Pittsburgh School of Public Health using OCMAP software supported our findings.

DISCUSSION

Because of access denial, we have no information about the source, or characterization of the high frequency voltage transients. We can assume, because the school uses metal conduit to contain the electrical wiring, that any resultant radiated electric fields from these high frequency voltage transients would radiate mainly from the power cords and from electrical equipment using the power cords within a classroom.

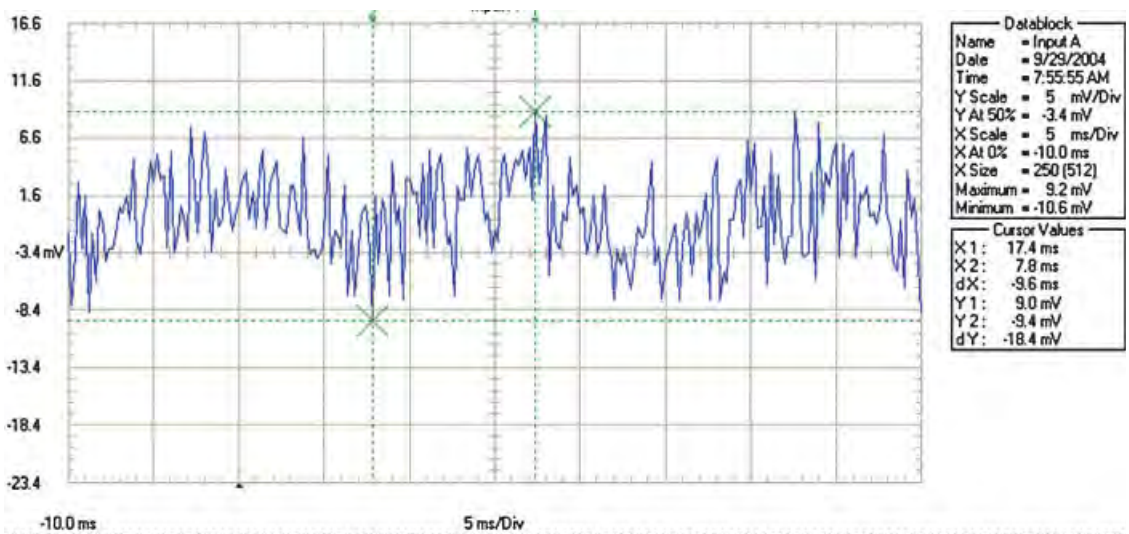
The school's GS readings of high frequency voltage transients are much higher than in other tested places (Table I). Also, teachers in the case school who were employed for over 10 years and who had ever worked in a room with an overload GS reading had a much higher rate of cancer. They made up 7.3% of the cohort but experienced 39% of all cancers.

The relatively short latency time of melanoma and thyroid cancers suggests that these cancers may be more sensitive to the effects of high frequency voltage transients than the other cancers seen in this population.

In occupational cohort studies, it is very unusual to have a number of different cancers with an increased risk. An exception to this is that cohorts exposed to ionizing radiation show an increased incidence of a number of different cancers. The three cancers in this cohort with significantly elevated incidence, malignant melanoma, thyroid cancer and uterine cancer, also have significantly elevated incidence in the large California school employees cohort [Reynolds et al., 1999].

These cancer risk estimates are probably low because 23 of the 137 members of the cohort remain untraced. Since exposure was calculated based on 7 days a week for a year, this will overstate the actual teachers' exposure of 5 days a week for 9 months a year.

We could not study field exposures in the classrooms since we were denied access to the school. We postulate that the dirty power in the classroom wiring exerted its effect by capacitive coupling which induced electrical currents in the



The waveform was recorded between 2 EKG patches placed on the ankles of XXXXXX XXXXXXXXX standing in front of his kitchen sink at his home near Bright Ontario. It shows a distorted 60 cycle sine wave containing high frequencies applied to each foot, allowing high frequency current to freely oscillate up one leg and down the other. XXXXXX has been diagnosed with prostrate cancer since moving to the house in less than a year. He was standing with feet shoulder width apart, wearing shoes, at the time of the readings. The amplitude increased as the feet were placed farther apart.

FIGURE 2. Oscilliscope display of 60 Hz current distorted with high frequencies taken between EKG patches applied to the ankles of a man standing with shoes on at a kitchen sink. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

teachers' bodies. The energy that is capacitively coupled to the teachers' bodies is proportional to the frequency. It is this characteristic that highlights the usefulness of the G/S meter. High frequency dirty power travels along the electrical distribution system in and between buildings and through the ground. Humans and conducting objects in contact with the ground become part of the circuit. Figure 2 [Havas and Stetzer, 2004, reproduced with permission] shows an oscilloscope tracing taken between EKG patches on the ankles of a man wearing shoes, standing at a kitchen sink. The 60 Hz sine wave is distorted by high frequencies, which allows high frequency currents to oscillate up one leg and down the other between the EKG patches.

Although not demonstrated in this data set, dirty power levels are usually higher in environments with high levels of 60 Hz magnetic fields. Many of the electronic devices which generate magnetic fields also inject dirty power into the utility wiring. Magnetic fields may, therefore, be a surrogate for dirty power exposures. In future studies of the EMF-cancer association, dirty power levels should be studied along with magnetic fields.

The question of cancer incidence in students who attended La Quinta Middle School for 3 years has not been addressed.

CONCLUSION

The cancer incidence in the teachers at this school is unusually high and is strongly associated with exposure to high frequency voltage transients. In the 28 years since electromagnetic fields (EMFs) were first associated with cancer, a number of exposure metrics have been suggested. If our findings are substantiated, high frequency voltage transients are a new and important exposure metric and a possible universal human carcinogen similar to ionizing radiation.

ACKNOWLEDGMENTS

The authors would like to thank The La Quinta, California middle school teachers, especially Gayle Cohen. Thanks also to Eric Ossiander, Dr. Raymond Neutra, Dr. Gary Marsh and Mike Cunningham and Dr. Louis Slesin. LM thanks Diana Bilovsky for editorial assistance.

REFERENCES

Armstrong B, Theriault G, Guenel P, Deadman J, Goldberg M, Heroux P. 1994. Association between exposure to pulsed electromagnetic fields and cancer in electric utility workers in Quebec, Canada, and France. Am J Epidemiol 140(9):805–820.

Breslow NE, Day NE. 1987. Statistical Methods in Cancer Research, Vol. II—The Design and Analysis of Cohort Studies. IARC Scientific Publication No. 82, International Agency for Research on Cancer, Lyon France, 1987.96 (equation 3.12).

Graham MH. 2005. Circuit for Measurement of Electrical Pollution on Power Line. United States Patent 6,914,435 B2.

Havas M, Stetzer D. 2004. Dirty electricity and electrical hypersensitivity: Five case studies. World Health Organization Workshop on Electrical Hypersensitivity. 25–26 October, Prague, Czech Republic, available online at: http://www.stetzerelectric.com/filters/research/havas_stetzer_who04.pdf.

Kwong SL, Perkins CI, Morris CR, Cohen R, Allen M, Wright WE. 2001. Cancer in California 1988–1999. Sacramento CA: California Department of Health Services, Cancer Surveillance Section.

Milham S. 1996. Increased incidence of cancer in a cohort of office workers exposed to strong magnetic fields. Am J Ind Med 30(6):702–704.

Perrault M. 2004. Specialist Discounts Cancer Cluster at School. The Desert Sun (Palm Springs, CA), 22 February, A1.

Reynolds P, Elkin EP, Layefsky ME, Lee JM. 1999. Cancer in California school employees. Am J Ind Med 36:271–278.

Stat Trek http://stattrek.com/tables/poisson.aspx (accessed August 2007).

Wertheimer N, Leeper E. 1979. Electrical wiring configurations and childhood cancer. Am J Epidemiol 109(3):273–284.

EXHIBIT 11

Perception-based protection from low-frequency sounds may not be enough

Alec N. Salt[a)]
Jeffery T. Lichtenhan[b)]
Department of Otolaryngology, Washington University School of Medicine, St. Louis, MO, 63110, USA.

Hearing and perception in the mammalian ear are mediated by the inner hair cells (IHC). IHCs are fluid-coupled to mechanical vibrations and have been characterized as velocity-sensitive, making them quite insensitive to low-frequency sounds. But the ear also contains more numerous outer hair cells (OHC), which are not fluid coupled and are characterized as displacement sensitive. The OHCs are more sensitive than IHCs to low frequencies and respond to very low-frequency sounds at levels below those that are perceived. OHC are connected to the brain by type II afferent fibers to networks that may further attenuate perception of low frequencies. These same pathways are also involved in alerting and phantom sounds (tinnitus). Because of these anatomic configurations, low-frequency sounds that are not perceived may cause influence in ways that have not yet been adequately studied. We present data showing that the ear's response to low-frequency sounds is influenced by the presence of higher-frequency sounds such as those in the speech frequency range, with substantially larger responses generated when higher-frequency components are absent. We conclude that the physiological effects of low-frequency sounds are more complex than is widely appreciated. Based on this knowledge, we have to be concerned that sounds that are not perceived are clearly transduced by the ear and may still affect people in ways that have yet to be fully understood.

1 INTRODUCTION

The manner in which the inner ear responds to very low-frequency sounds is still not well characterized. The pertinent anatomy and physiology is diagrammed in Figure 1. When sounds enter the cochlea they stimulate different regions, depending on the frequency, or tone, of the sound. The basilar membrane has a low-pass filter characteristic, such that the basal turn can respond to all frequencies while higher frequency components are progressively filtered out towards the apex. The apical regions are where mechanical-to-electrical transduction occurs for

[a)]email: salta@ent.wustl.edu
[b)] email: lichtenhanj@ent.wustl.edu

only the low-frequency components of acoustic sound. Superimposed on the passive mechanical filtering are cochlear hair cells that amplify low-level sounds for detection. This mechanical amplification is performed by the outer hair cells (OHC) so that the signal can be detected by the inner hair cells (IHC) that are the true sensory cells of the ear. The IHCs are densely innervated by type I primary afferent fibers, which is why it is generally accepted that hearing and perception are mediated by IHC activity. An important feature of the IHCs is that their sensory stereocilia ("hairs") do not contact the overlying tectorial membrane. They are therefore fluid coupled to the mechanical vibrations and have been characterized as velocity-sensitive, or ac-coupled[1]. That is to say, high-frequency vibrations stimulate IHCs but low-frequency vibration is attenuated, making IHCs insensitive to very low-frequency sounds. This contributes to the insensitivity of mammalian hearing to very low-frequency sounds and infrasound, requiring high levels to be heard. However, this is not to say that the ear itself is insensitive to very low-frequency sounds and infrasound. The stereocilia of the OHC are directly coupled to the tectorial membrane so they receive mechanical input in a displacement-sensitive manner. In early studies, Békésy[2] showed that displacements of the basilar membrane by trapezoidal stimuli generated trapezoidal response potentials that were sustained for the duration of the stimulus. The OHCs are thus dc-coupled to input and therefore highly sensitive to low-frequency stimulation. The OHC are, in part, connected to the brain by the type II afferents which make up approximately 5% of the afferent fibers in the auditory nerve. Each type II fiber contacts multiple OHC. Although no one has ever reported recordings from type II fibers with infrasound stimulation, Schermuly and Klinke[3] have shown that similar fibers in the bird, that innervate multiple hair cells, are highly sensitive to infrasound input.

Studies have suggested that the perception of low-frequency sounds by humans is influenced by the presence of higher-frequency sounds. Krahé[4,5] found that the perception of low-frequency noise alone was rated to be more annoying than low-frequency noise presented with higher-frequency sounds. These studies suggest that the perceptual consequences of low-frequency sounds should not be studied without considering the combined effects of higher-frequency sounds such as those in the range of speech.

Here we report objective measures from the low-frequency regions of the cochlea. They offer support for hypotheses that the influence of high-frequency sounds on the perception of low-frequency sounds is rooted in a cochlear mechanism in which the OHCs near the apex are stimulated by low frequency sounds more intensely than previously understood.

2 METHODS

Stimulus generation and response acquisition were performed using Tucker-Davis System 3 hardware controlled by custom-written software on a personal computer. Sound stimuli were delivered in a closed system using a hollow ear bar between the transducers and the external ear canal of anesthetized guinea pigs. Full details of stimulus delivery and presentation are given elsewhere[6]. Cochlear responses were measured from 500 mM KCl-filled glass pipettes inserted into endolymph of the cochlear third turn and connected through a high-input impedance electrometer. All procedures were approved by the Animal Studies Committee of Washington University under protocols 20070147 and 20100135.

3 RESULTS

3.1 Suppression of Infrasonic-Tone-Response by a Higher-Frequency Tone

The response of the apical, low-frequency regions of the cochlea to low-frequency sounds is complex. Responses are large when the sound is dominated by low frequencies and become smaller when higher-frequency sounds are present. In Figure 2, the response to an infrasonic (5Hz, 90 dB SPL) tone was recorded from endolymph of the third cochlear turn while a higher frequency (500 Hz) tone was superimposed after 1 second. As the level of the 500 Hz tone was increased from 50 to 80 dB SPL, the response to the 5 Hz stimulus was dramatically suppressed. Suppression of the infrasound response occurred at stimulus levels well below those that saturate the mechanical-to-electrical hair cell transducers of the inner ear (Figure 2, lower left panel), meaning that the suppression is not a result of transducer saturation.

3.2 Low-Pass Noise: A Variant of Infrasonic-Tone-Response Suppression

Responses to low-pass filtered noise were measured with electrodes located in the basal turn (sensitive to high frequency sounds) and in the third cochlear turn (sensitive to low-frequency sounds). All recordings were made with electrodes located in the endolymphatic compartment of the guinea pig inner ear. The sound stimuli used are shown in Figure 3. White noise stimuli were generated and digitally low-pass filtered with a cutoff slope of approximately 55 dB/octave. The noise was digitally generated "frozen noise" so that it had the characteristics of white noise but was exactly repeatable for each of the low-pass filtered conditions, allowing multiple responses to be time-domain averaged. The spectra here were obtained from 20 responses averaged with the noise at a level of 90 dB SPL for the 4 kHz filtered condition. The low-pass cutoff frequency of the filter was varied in half-octave steps from 125 Hz to 4 kHz. Filtered electrical signals sent to the headphone for sound stimulation are shown in the upper panel of Figure 3. These stimuli were delivered by a Sennheiser HD 580 driver and the spectra measured in the canal are shown in the middle panel of Figure 3. For each cutoff frequency the noise levels were measured either with or without filtering the microphone response with a 22 Hz high-pass filter that reduced ambient room noise. The signals were also measured with A-weighting as shown in the lower panel of Figure 3. The noise level for the 125 Hz low-pass filtered condition had an A-weighted level of 56 dB A.

Spectra shown on an expanded frequency scale (0 to 300 Hz) for three simultaneously recorded conditions are shown in Figure 4. Responses measured from the animal are expressed as dB re. 1V where -72 dB represents ~ 250 μV response amplitude. The microphone ear canal measurements of Figure 4, which are the same data as in Figure 3, show that the low-frequency components are indeed frozen, as all measures overlie each other in the 20 – 100 Hz range. The right column of Figure 4 shows the average spectral level over the 12-125 Hz range for each low-pass filter condition. When measured in the basal region of the cochlea, noise with lower frequency cutoff produced larger responses in the low-frequency range. The spectral average over the 12-125 Hz range was approximately 3 dB greater for the 125 Hz cutoff noise than it was with the cutoff set to 2000 Hz, a characteristic that was not present in the simultaneously measured sound levels in the ear canal demonstrating that our inner-ear measures are not an analysis artifact. This same tendency was more pronounced when responses were measured from the third cochlear turn in that the noise with the lowest cutoff frequency generated a substantially larger response. When the response amplitude from the third turn was averaged across the 12-125 Hz range, an approximately 6 dB decline was seen between the 125 Hz and 2000 Hz low-pass filter settings. The results of similar measurements made in 5 animals are summarized in Figure 5. The responses in the low-frequency spectral region (12-125 Hz) were 8.8 dB greater

from the 125 Hz low-pass cutoff noise as compared to that from the 2 kHz or higher cutoff frequencies. In other words, *responses from low-frequency stimulus components were 2-3x greater in amplitude when high-frequency sounds were not present.*

3.3 The Effect of A-Weighting

Although the low-pass filtered noise with a cutoff frequency of 2 kHz or greater was set to 90 dB SPL, the measured sound levels decreased, as expected, for stimuli with lower cutoff frequencies as higher frequency components were filtered out. The decline with cutoff frequency, measured in dB SPL, is shown in the lower panel of Figure 3. The changes as cutoff frequency was varied become even more pronounced when the sound was A-weighted. The A-weighted level of the noise with the cutoff filter set at 125 Hz was 56 dB A.

The low frequency responses of the ear, measured as the average spectral components from 12 – 125 Hz, as a function of noise levels is summarized in the left panel of Figure 6. As level was increased, the response from the 125 Hz low-pass filtered noise was always larger than the 4 kHz low-pass filtered noise. In this plot, the sound level represents how the data were collected, based on the noise level for the 4 kHz low-pass (i.e., wide-band) condition. In the right panel, we provide a comparison of the two noise–band responses corrected by A-weighted levels. There are two major observations that result from the comparison in Figure 6 (right panel):

1) **Low-pass filtered noise with a cutoff frequency of 125 Hz presented at a level of ~43 dB A stimulated the apical regions of the cochlea to the same degree as noise with a low-pass cutoff frequency of 4 kHz (i.e. wide band) at a level of 90 dB A.**
2) **At stimulus levels above 45 dB A, 125 Hz low-pass filtered noise generated larger responses at the apical regions of the cochlea than were generated by ANY level of 4 kHz low-frequency cutoff (i.e. wide band) noise.**

4 DISCUSSION AND CONCLUSIONS

The sensitivity of the apical regions of the cochlea to low-frequency sounds, and the suppressive influence of higher frequency sounds on this response, is confirmed by this study. We have demonstrated that A-weighted noise levels of as low as 45 dB A can stimulate apical regions to the same degree as wide band noise of much higher levels, as high as 90 dB A. This study shows that it cannot be assumed that noise levels as low as 40 dB A are benign and do not cause strong stimulation of the ear. Low-frequency noise around 40 dB A undoubtedly affects the ear. If the noise consists of predominantly low frequencies, then it will induce greater stimulation of the ear than has hitherto been appreciated. The observation that responses to primarily low-frequency noise stimulation are larger and do not saturate to the degree seen when higher-frequency components are present (Figure 6) is in complete agreement to the behavior previously seen with tonal stimuli[7]. The input/output functions of cochlear responses saturated at progressively higher levels for 500 Hz, 50 Hz and 5 Hz tonal stimuli presented in quiet. This means that the largest electrical responses in the apical regions of the cochlea will occur specifically when very low-frequency sound dominates the stimulus and mid-frequency components (200 – 2000 Hz) are absent.

The responses from inside the inner ear reported here may provide a physiologic basis for Krahé's psychoacoustical studies that showed how low-frequency noises with sharp cutoff slopes

are judged to be more annoying than when presented with higher-frequency sounds, as is the case when lower-cutoff slopes are present[4,5]. Although our studies offer support for Krahé's findings, we do not necessarily agree with his interpretation that the annoyance is mediated by primary type I afferent auditory nerve fibers. We have shown empirically that infrasound rarely leads to direct excitation of single-auditory-nerve afferent fibers [7] and there are many other mechanisms that should not be ruled out, including:

1) Stimulation mediated by type II afferent fibers. Type II fibers innervate multiple OHC and connect to multiple cell types of the cochlear nucleus[8] in the brainstem. These pathways may be inhibitory to conscious hearing[9], and may also be linked to alerting and attention pathways.

2) Cochlear Fluids Disturbances. Low-frequency stimulation at non-damaging levels has been shown to result in a localized endolymphatic hydrops – a swelling of the endolymphatic inner-ear compartment – with associated basally-directed endolymph flow[10]. Wit et al. showed that during endolymph volume increases, pressure changes were consistent with a flow through a narrow duct (the ductus reuniens) into a more compliant chamber (the sacculus)[11]. Histologic studies showed that the sacculus is highly compliant and is one of the first structures affected by endolymphatic hydrops[12]. Low-frequency sound exposure could therefore produce saccular disturbance, with symptoms including unsteadiness and disequilibrium. Furthermore, endolymphatic hydrops has been shown to contribute to an occlusion of the cochlear helicotrema which then makes the ear approximately 20 dB more sensitive to very low-frequency sounds[13]. This leads to the possibility of a positive feedback process, with low-frequency stimulation generating hydrops that in turn makes the ear more sensitive to the low-frequency stimulation. In addition to the mechanical disturbance of the saccule caused by endolymphatic hydrops, saccular enlargement also brings the saccular membranes closer and possibly in contact with the stapes footplate which would result in more efficient, direct stimulation of the saccule.

3) Amplitude modulation of sounds in the acoustic range. We have shown that low-frequency sounds that do not directly stimulate the IHCs and primary afferents, can influence the responses of the auditory nerve (i.e., sounds that will be heard) by inducing a biological form of amplitude modulation[7]. This type of modulation occurs within the cochlea and cannot be measured with a sound level meter. Rather, because the low-frequency displacements of the basilar membrane affect the amplification properties of the OHCs, responses to high-frequency sounds are perceived as being modulated in amplitude.

It is well documented that people find noise with prominent low frequency content annoying[4,5,14]. In the context of wind turbine noise it is known that the larger wind turbines can generate high levels of low frequency noise and infrasound[15,16,17,18,19]. The concern arising from the work we report here is that the cochlear apex of people exposed to such low-frequency sounds will be stimulated to a far greater degree than is suggested by their measured A-weighted sound level. The demonstration that sounds in the range of 40 – 45 dB A may be causing intense stimulation of the cochlear apex has not previously been appreciated. This may account for why the influence of low frequency noise on humans is greater than that estimated from spectral measurements and why consideration of noise crest factors is appropriate[20]. The fact that apical stimulation is maximal when mid- and high-frequency components are absent from the sound may also be important to wind turbine noise effects. It is known that people's houses attenuate sound frequencies in the audible range but have little influence, or may even increase infrasound and low-frequency sound levels[21]. Thus, prolonged periods of exposure to wind turbine noise in an otherwise quiet environment (such as a quiet bedroom) seems to represent a condition in which apical stimulation would be maximized. Intense stimulation of the cochlear apex will certainly have some influence on human physiology. On this basis we think that the concept of

"what you can't hear can't hurt you" is false. Similarly, there are potential mechanisms by which low-frequency sounds could influence vestibular physiology which are being ignored by some[22]. Our measurements showing that the ear generates large electrical responses to low-frequency stimulation suggest that the effects of low-frequency sound on people living near wind turbines should not be dismissed by those with little understanding of how low frequency sounds indeed affect the ear[19,21,22]. More research on this topic is necessary to enlighten the scientific, medical, and legal communities, and the public, some of whom are being chronically exposed to these sounds.

5 ACKNOWLEDGEMENTS

This work was supported by grant R01 DC001368 from the NIDCD, National Institutes of Health. We thank Jared Hartsock and Ruth Gill for their assistance with the experiments.

6 REFERENCES

1. Cheatham MA, Dallos P. Inner hair cell response patterns: implications for low-frequency hearing. J Acoust Soc Am 110(4), 2034-2044 (2001).
2. Békésy, Georg von. Experiments in hearing. New York, McGraw-Hill, (1960)
3. Schermuly L, Klinke R. Origin of infrasound sensitive neurones in the papilla basilaris of the pigeon: an HRP study. Hear Res. 48, 69-77, (1990).
4. Krahé D Why is sharp-limited low-frequency noise extremely annoying? Acoustics (2008).
5. Krahé D Low Frequency Noise – Strain on the Brain Proceedings of the 14th International Meeting on Low Frequency Noise and Vibration and its Control, Aalborg, Denmark (2010
6. Brown DJ, Hartsock JJ, Gill RM, Henson H, Salt AN. Estimating the operating point of the cochlear transducer using low-frequency biased distortion products. J Acoust Soc Am. 125:2129-2145 (2009).
7. Salt AN, Lichtenhan JT. Responses of the Inner Ear to Infrasound. Proceedings of the Fourth International Meeting on Wind Turbine Noise, Rome Italy (2011).
8. Benson TE, Brown MC. Postsynaptic targets of type II auditory nerve fibers in the cochlear nucleus. J Assoc Res Otolaryngol 5:111-125 (2004).
9. Kaltenbach, J. A., & Godfrey, D. A. Dorsal cochlear nucleus hyperactivity and tinnitus: Are they related? American Journal of Audiology, 17, S148-S161 (2008).
10. Salt, A.N. Acute endolymphatic hydrops generated by exposure of the ear to non-traumatic low frequency tone. JARO 5, 203-214 (2004).
11. Wit HP, Warmerdam TJ, Albers FW. Measurement of the mechanical compliance of the endolymphatic compartments in the guinea pig. Hear Res 145:82-90 (2000).
12. Kimura R, Schuknecht H. Membranous hydrops in the inner ear of the guinea pig after obliteration of the endolymphatic sac. Pract Otolaryngol. 27: 343-354 (1965).
13. Salt AN, Brown DJ, Hartsock JJ, Plontke SK. Displacements of the organ of Corti by gel injections into the cochlear apex. Hear Res. 250:63-75 (2009).
14. Bradley JS. Annoyance caused by constant-amplitude and amplitude-modulated sounds containing rumble. Noise Control Engineering Journal 42:203-208 (1994).
15. Van den Berg, G.P. The sound of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise. PhD Dissertation, University of Groningen,

Netherlands. http://dissertations.ub.rug.nl/faculties/science/2006/g.p.van.den.berg/. (2006).
16. Bray W, James R. Dynamic measurements of wind turbine acoustic signals, employing sound quality engineering methods considering the time and frequency sensitivities of human perception. Proceedings of Noise-Con 2011, Portland, Oregon, (2011).
17. Møller and CS Pedersen. Low-frequency noise from large wind turbines. J. Acoust. Soc. Am. 129: 3727-3744 (2011).
18. O'Neal RD, Hellweg RD, Lempeter RM. Low frequency noise and infrasound from wind turbines. Noise Control Eng. J. 59: 135-157 (2011).
19. Bolin K, Bluhm G, Eriksson G, Nilsson ME. Infrasound and low frequency noise from wind turbines: exposure and health effects Environ. Res. Lett. 6 (2011).
20. Swinbanks MA. The Audibility of Low Frequency Wind Turbine Noise. Proceedings of the Fourth International Meeting on Wind Turbine Noise, Rome Italy (2011).
21. Møller H, Pedersen S, Staunstrup JK, Pedersen CS. Assessment of low-frequency noise from wind turbines in Maastricht. City Council of Maastricht, ISBN 978-87-92328-82-3, Aalborg University, (2012).
22. Wind Turbine Health Impact Study: Report of Independent Expert Panel. Massachusetts Department of Environmental Protection and Massachusetts Department of Public Health. www.**mass**.gov/dep/**energy/wind/turbine_impact_study**.pdf (2012).

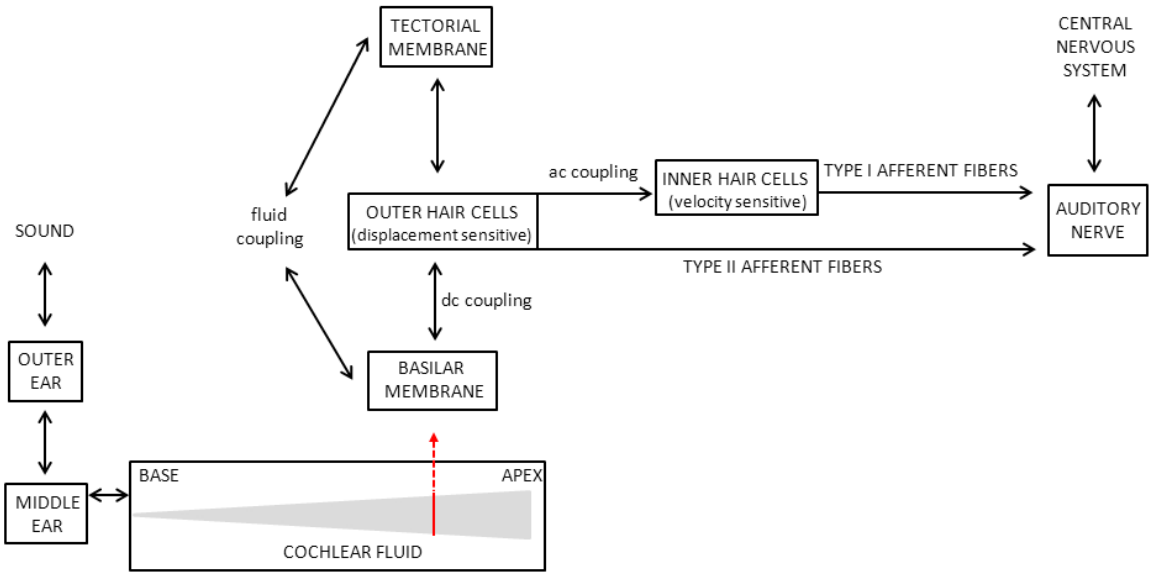


Fig. 1 – Schematic of the auditory periphery. The guinea pig cochlea has 1 row of inner hair cells (IHC) and three rows of outer hair cells (OHC) along its length. The red line and subsequent compartments describe some anatomical and physiological properties of a given segment. After sound propagates through the outer and middle ear, the basilar membrane is set into motion. OHCs in the cochlear apex region respond to low frequencies and are sensitive to the displacement of the basilar membrane motion and are dc-coupled to the sound stimulus. In contrast, the IHC are free within the cochlear fluid causing them to be excited by the velocity of basilar membrane motion, are ac-coupled to the sound stimulus, and are insensitive to low frequency stimulation.

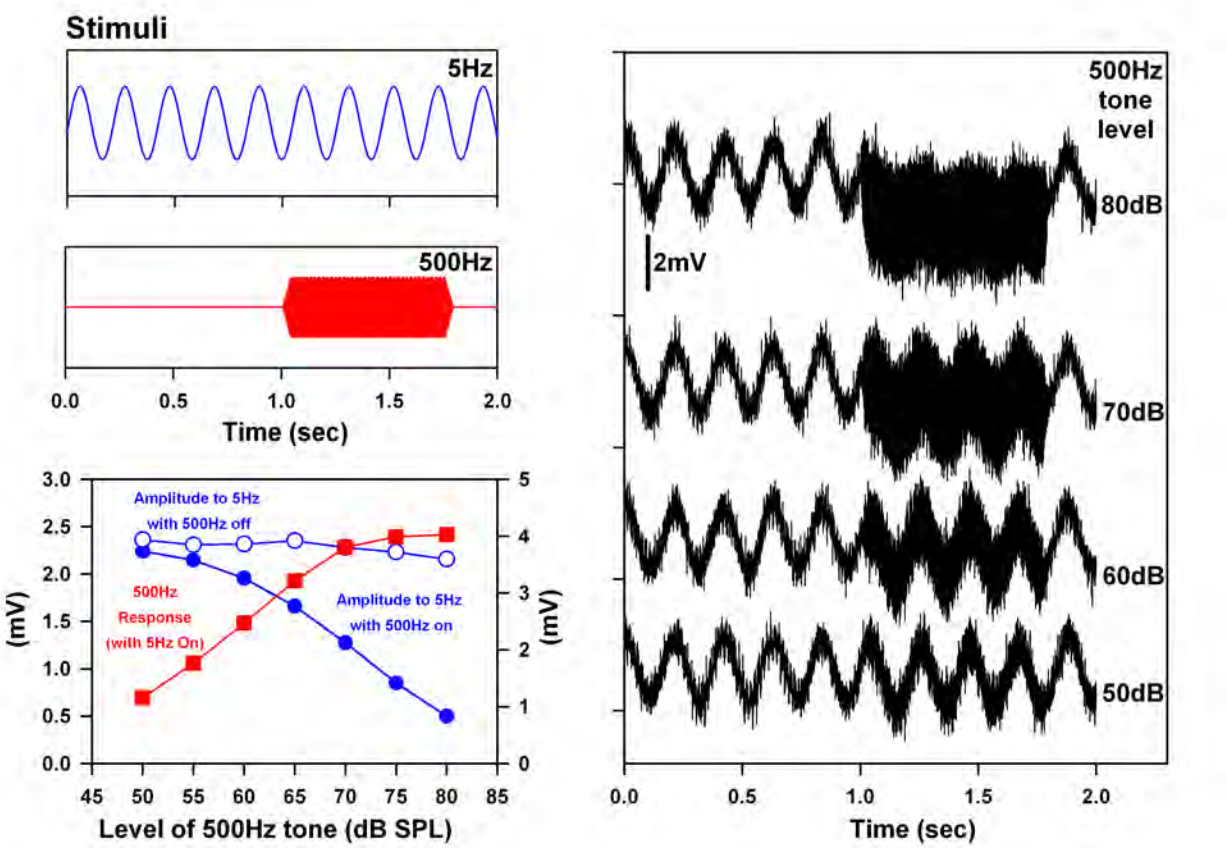


Fig. 2 – Higher-frequency stimuli (500 Hz) suppress the response to a very low-frequency (5 Hz) stimulus. A 500 Hz tone of varied level was superimposed on a 5 Hz, 90 dB stimulus. As the level of the 5 Hz tone was increased, the amplitude of the 5 Hz response declined (right panel).Amplitude measurements (lower left panel) show that 5 Hz stimulation well below saturation (red curve) caused a reduction in response amplitude to the 5 Hz.

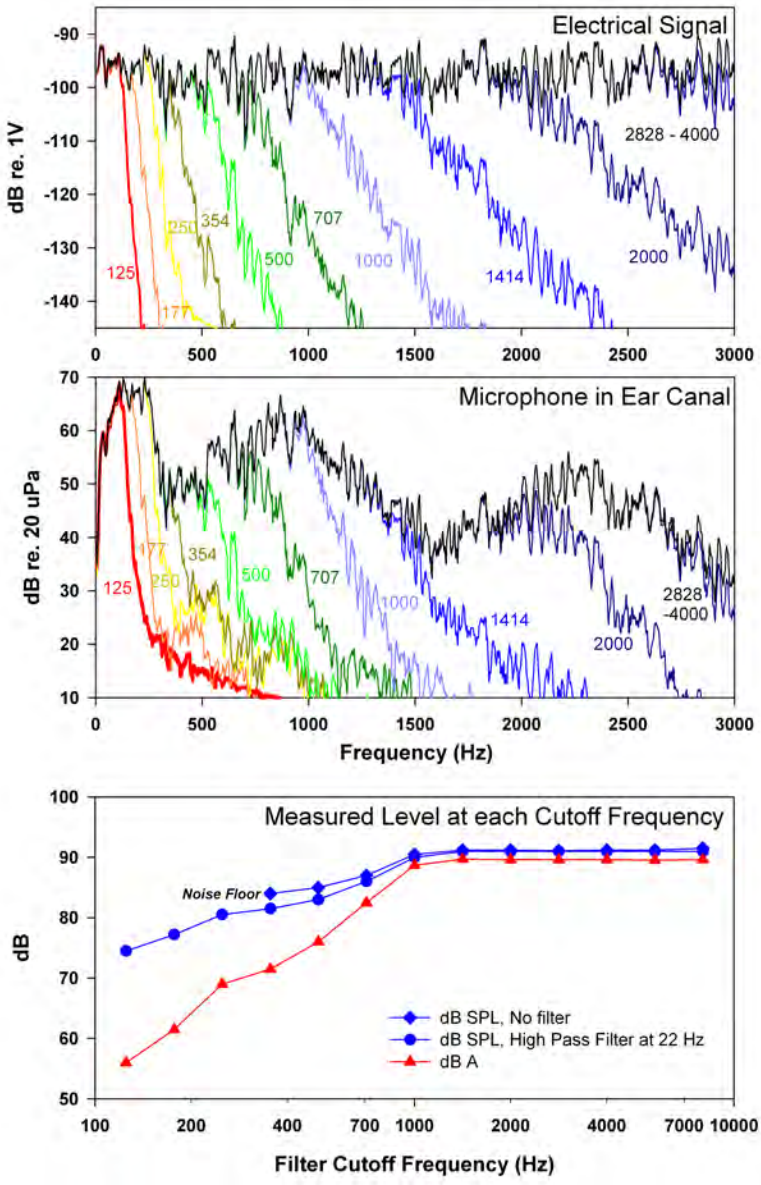


Fig. 3 – Low-pass noise used in this study. The upper panel shows the spectra of low-pass noises with cutoff frequency varied from 125 Hz to 4 kHz. Note that the filter altered the high-frequency component of the noise but had no influence on the low-frequency content (below 100 Hz). The cutoff slope was approximately 55 dB/octave. The middle panel shows the stimuli measured in vivo in the external canal after being delivered by the Sennheiser headphone. The lower panel shows the stimuli with different cutoff frequencies measured in dB SPL and in dB A.

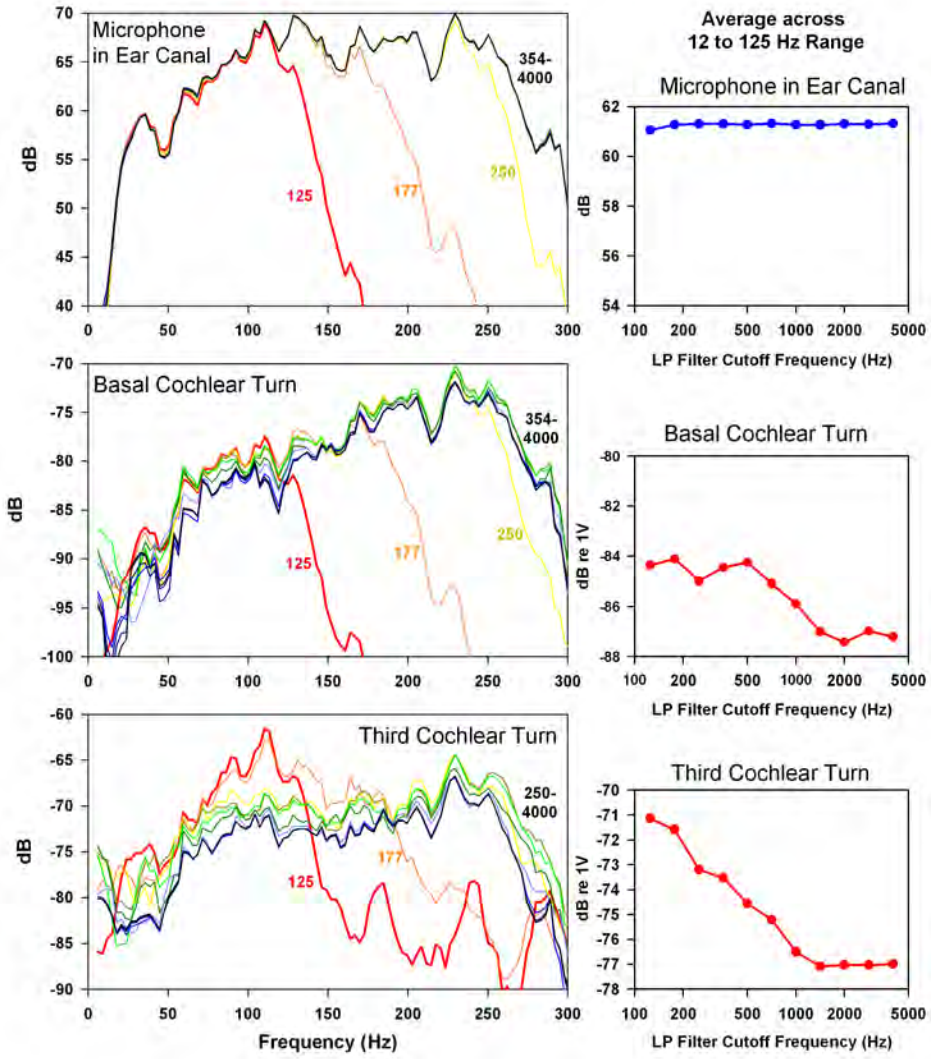


Fig. 4 – Spectra expanded to show the lowest 300 Hz of the frequency range. At each noise filter cutoff frequency, all responses (all 3 panels) were recorded simultaneously to the same stimuli. Top row: The low-frequency region of the sound field showed little variation as cutoff frequency was changed. Middle Row: Responses from the basal cochlear turn were larger when high frequency components were absent. Bottom Row: Apical (Third turn) responses were substantially greater when high frequency components were absent. In this case, the lowest band of noise (125 Hz cutoff) generated ~ 6 dB larger responses than the widest band of noise (4 kHz cutoff). For each condition, the average spectral level in to 12 Hz to 125 Hz range was graphed relative to the noise filter cutoff frequency in the right column.

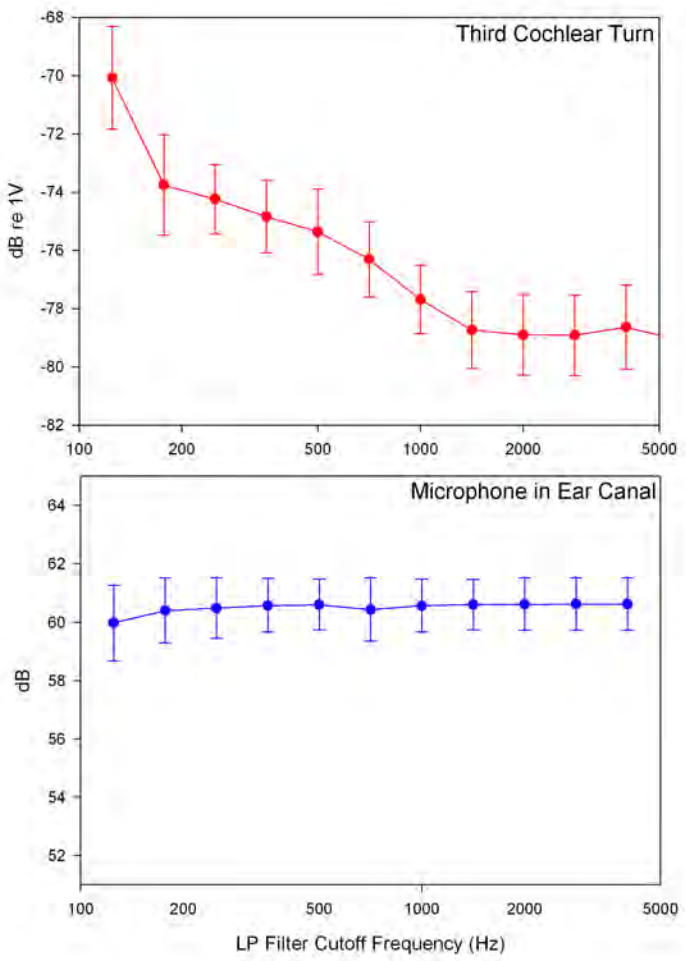


Fig. 5 – Average response amplitudes (+/- SD) in 5 experiments. At each noise cutoff frequency, response amplitude was measured as the average spectral level in the 12 – 125 Hz range. Responses from the apical region of the cochlea showed a systematic decline as noise cutoff frequency is varied, while responses from the microphone, analyzed in an identical manner, did not.

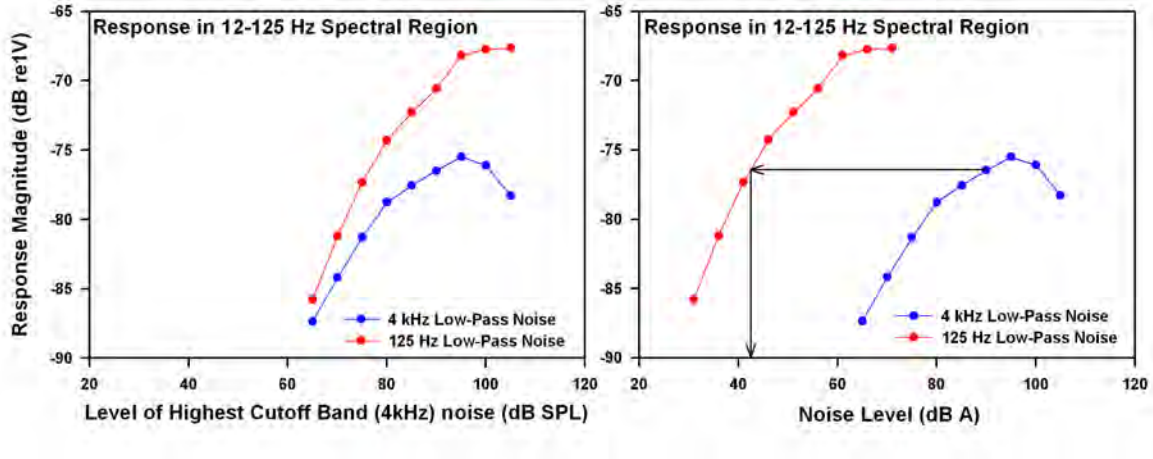


Fig. 6 – ***Left panel:*** *Response amplitudes as the noise level was varied in 5 dB steps. Shown here is only the response amplitudes to the lowest (125 Hz) and highest (4 kHz) noise filter cutoff frequencies used. Amplitudes were the average from the spectrum across the 12 – 125 Hz range (as in Figure 4). Noise with higher frequencies present always generated lower response amplitudes than when higher frequencies were absent. For the 4 kHz band, the responses saturate and decline as level was increased, while the responses to the low-band (125 Hz cutoff) noise keep increasing.* ***Right panel:*** *The same data plotted based on the A-weighted level of the stimuli measured at each cutoff frequency. This shows that low-frequency noise (125 Hz cutoff) of ~43 dB A generated as large of a response at low frequencies as did a 90 dB A wide band (4 kHz cutoff) noise. Indeed, for 125Hz low-pass noise of 45 dB A or greater, an ear's response will be larger than for wide band noise presented at ANY level.*