BEFORE THE STATE OF WASHINGTON

ENERGY FACILITY SITE EVAUATION COUNCIL

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| In the Matter of Application No. 2003-01:<br>SAGEBRUSH POWER PARTNERS, LLC;<br>KITTITAS VALLEY WIND POWER PROJECT | EXHIBIT 39 (DK-T) |

**APPLICANT'S PREFILED DIRECT TESTIMONY**
**WITNESS # 20: DANIEL KAMMEN**

Q Please state your name and business address.

A My name is Daniel Kammen and my business address is 310 Barrows Hall Berkeley, CA 94720-3050.

Q What is your present occupation, profession; and what are your responsibilities and areas of expertise?

A I am a professor and director of the Renewable and Appropriate Energy Laboratory of the University of California at Berkeley. I hold joint appointments as Professor of Energy and Society with the Energy and Resources Group, Professor of Nuclear Engineering in the



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Department of Nuclear Engineering, and Professor of Public Policy at the Goldman School of Public Policy, all at the University of California at Berkeley. I teach courses and conduct research on a variety of topics primarily related to energy and its impacts, with an emphasis on renewable energy sources, as well as risk analysis and communication.

Q Would you please identify what has been marked for identification as Exhibit 39 (DK-1)?

A Exhibit 39 (DK-1) is a résumé of my educational background, expertise and employment experience.

Q. Would you please briefly describe your expertise and qualifications?

A I received my undergraduate degree in physics from Cornell University (1984), and my masters and doctorate in physics from Harvard (1986 & 1988) for work on theoretical solid state physics and computational biophysics. I was then the Wezmann & Bantrell Postdoctoral Fellow at the California Institute of Technology in the Divisions of Engineering, Biology, and the Humanities (1988 - 1991). First at Caltech and then as a Lecturer in Physics and in the Kennedy School of Government at Harvard University, I developed a number of projects focused on renewable energy technologies and environmental resource management. At Harvard I also worked on risk analysis as applied to global warming and methodological studies of forecasting and hazard assessment. I received the 1993 21st Century Earth Award, recognizing contributions to



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rural development and environmental conservation from the Global Industrial and Policy Research Institute and *Nihon Keizai Shimbun* in Japan.

From 1993 – 1998, I was an Assistant Professor of Public and International Affairs in the Woodrow Wilson School of Public and International Affairs at Princeton University. I played a key role in developing the interdisciplinary Science, Technology, and Environmental Policy (STEP) Program at Princeton, that awards undergraduate and masters certificates and a doctoral degree. I was STEP Chair from 1997 - 1999 and co-chair before that. In July of 1998, I joined the interdisciplinary Energy and Resources Group (ERG) at the University of California, Berkeley as an Associate Professor of Energy and Society. I am a Fellow of the American Physical Society and a Permanent Fellow of the African Academy of Sciences.

My research interests include: the science, engineering, management, and dissemination of renewable energy systems; health and environmental impacts of energy generation and use, and energy forecasting and risk analysis. I am the author of over 90 journal publications, a book on environmental, technological, and health risks *(Should We Risk It?* Princeton University Press, 1999) and numerous reports on renewable energy and development. I have been featured on radio, network and public broadcasting television and in print as an analyst of energy, environmental, and risk policy issues and current events. My recent work on energy R&D policy appeared in *Science*, and *Environment*, and has been featured on PBS, KQED, CNN, and in many newspapers via the Reuters news service.



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I advise the U. S. and Swedish Agencies for International Development, the World Bank, and the US President's Committee on Science and Technology (PCAST), and am a member of the Intergovernmental Panel on Climate Change (Working Group III and the Special Report on Technology Transfer). I serve on the technical review board for the Global Environmental Facility (the STAP), am a lead author for the Special Report on Technology Transfer of the Intergovernmental Panel on Climate Change, and advise the World Bank and the American Academy of Arts and Sciences and well as the African Academy of Sciences.

Q Are you regarded as an expert with regard to risk analysis?

A Yes. I have published a book, *Should We Risk It* (Princeton University Press, 1999) on the methodologies and practicalities of performing risk assessments as well as peer reviewed journal articles on the subject of risk analysis and have taught the subject at both the undergraduate and graduate levels. I have also testified before U. S. House of Representatives' Science Committee panels on these issues.

Q Would you please explain to the Council the principles, techniques methods used to conduct risk analyses?

A Risk analysis generally begins with identifying the potential sources of risk posed by the activity or facility to be evaluated. This involves identifying the conditions that could create a hazard and evaluating both the probability of those conditions occurring and the



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likely consequences if they were to occur. These risks are then quantified using accepted risk calculation methodologies, including an analysis of sensitivities. The resulting quantified risk calculations are then evaluated and compared to the risks of other common or related activities to determine whether they are significant or not.

Q Are there local, national or international regulatory standards for public safety risks related to wind turbines?

A No. Currently there are no local or national regulatory standards for public safety risks relating to wind turbines in the United States. Guidance documents have been developed for this subject in some European countries, but there are no uniform international regulatory standards. However, third party certification programs for wind turbines (such as RISO, DNV and GL) do incorporate safety features and performance in their review of turbines for certification.

Q Are there local, national or international standards regarding public safety risks for other types of energy facilities?

A Generally speaking, no. There are no uniform standards that, for instance, state that the individual risk posed by any prospective energy facility should be less than or equal to 1 in a million or some other specific risk level. Certain types of facilities that are regulated by the federal government, such as nuclear plants and interstate petroleum pipelines, are subject to national safety-related standards, but these are not based on uniform risk criteria.



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Q Would you generally describe the differing risk standards presently used in the U.S. for different types of risks?

A Currently, federal and state government agencies do not utilize a consistent, uniform approach to establishing "acceptable" risk limits for various activities. In many instances, no explicit risk level is stated for regulatory purposes (for example operating a motor vehicle). In other cases, regulatory agencies have adopted specific risk thresholds for various types of activities such as the remediation of contaminated sites and the allowable levels of certain potentially carcinogenic or otherwise hazardous substances in drinking water or food. While there is no uniform risk standard for regulatory purposes in the US, the most common risk standard, where such standards exist, is 1 in a million risk of death.

Q Where you requested to conduct a risk analysis study for the Kittitas Valley Wind Power Project?

A Yes

Q Will you please describe the study you were requested to conduct for the Kittitas Valley Wind Power Project?

A I was requested to analyze and evaluate the potential public safety risks posed by the proposed wind power project, specifically the risk of a turbine blade becoming detached,



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the risk of a turbine tower collapsing and the risk of ice being thrown from turbine blades. I was also asked to compare the risks of these wind turbine related scenarios to other types of risks that have already been quantified in order to put them in perspective.

Q Is this type of study within your area of authority and /or expertise?

A Yes.

Q Please describe the methodology of the study.

A First, we researched available information on the frequency and probability of the wind turbine related risks we were asked to evaluate. We sought information on the documented frequency of occurrence of these potential hazards as well as published sources regarding appropriate mitigations or setbacks to minimize these risks. Then we utilized the information from the ASC and the Applicant regarding the proposed types and sizes of turbines proposed for the Kittitas Valley Wind Power Project as well as the proposed locations of the turbines relative to roads and other areas with humans present to calculate the potential public safety risk of tower collapse, blade throw or ice throw. We then compared the calculated risk levels for the proposed project to other, already quantified risks to evaluate their significance.

Q Would you please identify what has been marked for identification as Exhibit 39-2 (DK-2)?



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A Exhibit 39-2 (DK-2) is a copy of the risk analysis referred to above that I conducted for the Kittitas Valley Wind Power project.

Q Are the contents of this study either based upon your own knowledge, or upon evidence, such as studies and reports as reasonably prudent persons in your field and expertise are accustomed to rely in the conduct of their affairs?

Deleted: a

A Yes.

Q To the best of your knowledge, are the contents of this study true?

A Yes.

Q Do you incorporate the facts and content of this report as part of your testimony?

A Yes.

Q Are you able to answer questions under cross-examination regarding this report?

A Yes

Q Do you sponsor the admission into evidence of these this study?

A Yes



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Q Would you please summarize and briefly describe the study.

A We compiled available research regarding the risks of tower collapse, blade throw and ice throw, based on published studies and guidance documents from the US and Europe. We then calculated probabilities of the various hazards based on the available research and the specific type and sizes of turbines being proposed for this project (60 meter RD to 90 meter RD) and the specifics of the particular project site location (such as proximity to homes, roads, etc.) We then compared the calculated risk levels to other, known risk levels for common activities to evaluate their significance.

Q Based on your research, has any member of the ever public been killed by a wind turbine?

A The only reported case of a member of the public being killed by a wind turbine that we were able to find was a parachutist in Germany who jumped into a wind turbine.

Q Based on your analysis, what is the probability of a member of the public being injured or killed by a turbine at the Kittitas Valley Wind Power Project?

A Our results indicate that based on the proposed layout, turbine size and other factors, the probability of a wind turbine at the proposed project killing or seriously injuring a member of the public as a result of blade throw, tower collapse or ice throw is less than 1



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in 1 billion. This is based on a 1 in one million chance of a blade or other object being thrown (per the European wind power handbooks we referenced) and the actual frequency of cars passing along Highway 97 in the project area, which we believe is the area within the project site with the highest probability of a blade or piece of ice thrown from a wind turbine striking a member of the public.

The resulting risk level is low and insignificant compared to either other energy generating technologies or many common activities such as riding a bike, driving a car, eating peanut butter, or living in a city such as New York or Boston.

Q What does your analysis assume regarding the likelihood of someone at the spot and instant where a flying object (e.g. as a result of blade throw, ice throw, tower collapse) lands?

A We used data from the Application for Site Certification (Section 3.10) regarding the actual average daily traffic volumes (ADT) for the public roads within the project area as well as the project layout map showing the location of all project facilities relative to roads and other areas where human presence is most likely to evaluate the probability of a person or vehicle actually being at the precise location where a falling blade, tower or piece of ice might land. We also took into consideration the Applicant's proposed setback distances for all turbines from roads, property lines and houses as well as the fact that the Applicant has stated that the project facilities will be located behind fences with locked gates. The results of our analysis indicate that Highway 97, with 2,800 vehicles passing per day in 2001 according to data from WA DOT, presented in Section 3.10 of



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the ASC, is the location within the project area with the highest probability of a blade or piece of ice thrown from a wind turbine striking a member of the public. Using the average daily traffic of 2,800 vehicles, and the probability of a blade or large piece of ice being thrown far enough to reach Highway 97 (based on the site layout provided in the ASC), we estimated that the probability of a car being struck by ice or a blade from a turbine to be less than one in one billion.

Q How does the risk level of someone being killed by a wind turbine at the Kittitas Valley wind project compare with regulatory standards, or with those or other common activities?

A The risks of many common activities have already been quantified and reported in published sources. These are often used in communicating the results of risk analyses so that decision makers and members of the public can evaluate the significance of the risk level of a given activity or proposal relative to the risks of other activities that are more familiar. As described in Exhibit DK 3, our analysis concludes that the risk of a person being killed or seriously injured from a blade being thrown, a tower collapsing, or ice being thrown from a turbine is less than the following risks (risk source in parentheses):

- Traveling in automobile for 300 miles (accident)
- Riding a bicycle 10 miles (accident)
- Having one chest x-ray at a modern hospital (cancer caused by radiation)
- Living for 2 days in New York or Boston (air pollution)
- Drinking half a liter of wine (cirrhosis of the liver)
- Eating 40 tablespoons of peanut butter (liver cancer caused by aflatoxin B)



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- Drinking 30 12 oz. cans of diet soda (cancer caused by saccharin)
- Eating 100 charcoal-broiled steaks (cancer from benzopyrene)

Q In your opinion, does the Kittitas Valley Wind Power Project, as currently proposed, present a significant risk to public health or safety?

A No, the potential public health and safety risks posed by this project are insignificant and less than the risks posed by other common energy generating technologies and countless other common activities.



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EXHIBIT 39-1 (DK-1)

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U. S. Citizen, Married, daughter (Folasadé)


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## RESEARCH INTERESTS

Science and technology policy focused on energy, development and environmental management. Technology and policy questions in developing nations, particularly involving: the linkages between energy, health, and the environment; technology transfer and diffusion; household energy management; renewable energy; women; minority groups. Global environmental change including deep cuts in greenhouse gas emissions and resource consumption. Environmental and technological risk. Management of innovation and energy R&D policy. Geographic expertise: Africa; Latin America.

## EDUCATION

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|---|---|---|---|
| Ph.D. | Harvard University | Physics | June 1988 |
| M.A. | Harvard University | Physics | June 1986 |
| A.B. | Cornell University | Physics | May 1984 |

## POSITIONS HELD

| | |
|---|---|
| 2001 - | Professor of Public Policy in the Goldman School of Public Policy, University of California, Berkeley |
| 2001 - | Professor of Energy and Society, University of California, Berkeley |
| 2001 - | Professor of Nuclear Engineering, University of California, Berkeley |
| 1999 - | Director, (**R**enewable and **A**ppropriate **E**nergy **L**aboratory; **RAEL**) University of California, Berkeley |
| 1999 - 2001 | Associate Professor of Nuclear Engineering, University of California, Berkeley |

1998 - 2001 Associate Professor of Energy and Society, Energy and Resources Group (ERG), University of California, Berkeley
1997 - 1999 Chair, Science, Technology & Environmental Policy Program (STEP), Woodrow Wilson School of Public and International Affairs, Princeton University
1997 - 1999 Class of 1934 Preceptor, Woodrow Wilson School of Public and International Affairs
1993 - 1999 Assistant Professor of Public and International Affairs, Woodrow Wilson School of Public and International Affairs, Princeton University
1993 - 1999 Research Faculty, Center for Energy and Environmental Studies, School of Engineering and Applied Science, Princeton University
1993 - Permanent Fellow, African Academy of Sciences
1991 - 1993 Research Associate, Northeast Regional Center for Global Environmental Change, and the Department of Physics, Harvard University
1991 - 1993 Affiliate Fellow, Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University
1988 - 1991 Weizmann & Bantrell Postdoctoral Research Fellow in the Division of Engineering and Applied Science, and the Division of Biology, California Institute of Technology

**TEACHING**

*University of California, Berkeley*

- Environmental Classics (ER290) (with Dr. Isha Ray)
- Methods in Interdisciplinary Studies ('Tricks of the Trade') (ER292B)
- Freshman Seminar: The Century of Fossil Fuels, the Century of Global Warming (ER24)
- Energy and Society (ER100/200)
- Renewable Energy (ER120)
- The Politics of Climate Change Policy (ER290) [faculty advisor]
- Energy and Development (ER290)
- Group Studies in Energy Research (ER298)
- Individual Research in Energy (ER299)
- Issues in Nuclear Science and Technology (NE39) (team taught)
- Honors Research – Environmental Science, Policy and Management (ESPM, College of Natural Resources, H196)

*Princeton University*

- Environment and Development (WWS 571b)
- Technology Transfer and Development (WWS 571c)
- Methods in Science, Technology and Public Policy (WWS 589)
- Process and Methods in Science and Technology Policy (WWS 308)
- Topics in Renewable Energy Conversion (MAE 319) (team taught)
- Science, Technology and Public Policy (WWS 304)
- Environmental Science and Policy (ENV 201) (team taught)

*Harvard University*

- Senior Engineering Thesis Research (Engineering Sciences 96r)

• Biomass, Land Management, and Environmental Change (Chair, Working Group) John F. Kennedy School of Government

*California Institute of Technology*

• Tropical Development and Conservation (Biology 23)

## POSTDOCTORAL ADVISEES

2000 - Timothy Lipman (Ph.D. 1999) University of California, Davis, Environmental Policy Analysis/Graduate Group in Ecology; Institute of Transportation Studies - Davis)

2000 - 2002 Antonia Herzog (Ph.D. 1997, University of California, San Diego, Physics). UC Presidential Postdoctoral Fellow, 2000 – 2001
Current: Senior Policy Researcher, Natural Resources Defense Council, Washington, DC.

1998 - 2001 Lloyd Connelly (Ph.D. 1998, University of California, Berkeley, Mechanical Engineering).
Current: Enrolled in Medical School, University of California, Davis.

1997 - 1999 Daniel Klooster (Ph.D. 1997, University of California, Los Angeles, Geography)
Current: Assistant Professor of Geography, Florida State University

1996 – 1997 Lisa Naughton (Ph.D. 1996, University of Florida, Wildlife Ecology)
Current: Assistant Professor of Geography, University of Wisconsin, Madison.

## DOCTORAL DISSERTATION ADVISEES (UCB students unless indicated)

2002 - Tracey Osborne, "Biomass and Development in the Caribbean"

2001 - Kamal Kapadia, 'Renewable Energy for Development'

2000 - Nate Hultman, "Carbon Markets, Climate Change Science and Policy", NASA Earth Sciences Doctoral Fellow, 2000 - 2003

1999 - 2001 Andrew MacAllister, "Renewable energy infrastructure", Link Energy Fellow, 1999-00

2000 - Joanna Lewis, "Wind Energy Infrastructure in China"

1999 - Donna Green, "Solar battery charging, development, and politics in Thailand".

1999 - Robert Bailis, "Renewable energy and development", FLAS Fellow, 1999-2000.

1998 - Arne Jacobson, "Renewable energy and development" Link Energy Fellow, 2000 – 2001.

1998 - Chris Greacen, "Renewable energy and development", US EPA STAR Fellow, 1998 - 2001).

1997 - 2001 Richard D. Duke (STEP, Princeton) "Economics of renewable energy technologies" (Link Energy Foundation Fellow, '98 - '99; US EPA STAR Fellow, 1998 - 2001). Thesis: *Clean Energy Technology Buydowns: Economic Theory, Analytic Tools, and the Photovoltaics Case*
Current: Senior Financial Analyst, MacKenzie Consulting, New York City, NY.

1996 - 1999 Katherine Purvis (Chemistry, Princeton) "Toxic Paint Solvents and Worker Exposure in Kenya" (PEI-RISE; with S. Bernasek, Chemistry)

Current: Assistant Professor of Chemistry and Environmental Studies, The Claremont Colleges, Claremont, California

1996 - 2001 Robert Margolis (STEP, Princeton) "US energy R&D and innovation"

1995 - 2000 David Hassenzahl (STEP, Princeton). Thesis: *Comparative Environmental Regulation and Risk Management*
Current: Assistant Professor of Science Policy, UNLV (Greenspun School of Public Policy)

1995 - 2000 Majid Ezzati, (STEP, Princeton). Thesis: *Energy Technology, Indoor Air Pollution, and Respiratory Infections in Developing Countries: A Field Study from Central Kenya* (SSRC International Pre-Dissertation Fellow, '97 - '98).
Current: Fellow, Resources for the Future, Environment and Risk Group (Washington, DC).

1994 - 1997 Amy F. Richardson (WWS, Princeton), *People, Preferences, Parties and PAC's: Constituent Representation in the Senate on Environmental Issues* (with L. M. Bartels).
Current: Senior Fellow, Environmental Policy Analysis, Mackenzie Consulting, Pittsburgh, PA.

**Dissertation Committees:**

1997 – 2001 Teresah Holloway, Atmospheric and Oceanic Studies, Princeton University
Current: Postdoctoral Fellow,

1993 – 1997 Georgios Kassinis, WWS, Princeton University
Current: Assistant Professor of Public Policy, University of Cyprus, Greece.

**UNDERGRADUATE THESIS ADVISEES**

1999 – 2000 Advised 4 undergraduate senior projects (UC Berkeley), departmental honors (3)

1998 – 99 Advised 7 senior thesis (Princeton University)

1996 - 97 Advised 6 senior theses (Princeton University)
Student honors include: Marshall Fellowship, a Fulbright Scholarship (to Kenya); the Westoff Prize in Demography; Woodrow Wilson School Senior Thesis Prize; Princeton Environmental Institute Senior Thesis Prize; Civil Engineering and Operations Research Senior Thesis Award (CEOR Prize).

1995 - 96 *On leave:* Advised 1 senior thesis (Princeton University)
Student honors include: the Lieutenant John A. Larkin, Jr. Memorial Prize (WWS); and the Environmental Studies Senior Thesis Award from the Princeton Environmental Institute.

1994 - 95 Advised 7 senior theses (Princeton University)
Student honors include: a Rhodes Fellowship; a Marshall Fellowship; Princeton University's Pyne Prize; and a Fulbright Scholarship (to Mexico)

1993 - 94 Advised 5 senior theses (Princeton University)
Student honors include: the Gaile F. Johnson Prize in Public Affairs (WWS); and a Fulbright Scholarship (to Kenya)

1992 - 93 Advised 2 senior theses (Harvard University)
Including one nominated for a Hoopes Prize

1991 - 92 Advised 2 senior theses (Harvard University)

**EXTERNAL RESEARCH FUNDING AWARDS** (Principal Investigator unless noted)

Pending:

"Climate Dynamics and Health in Sub-Saharan Africa", with D. Balk (Columbia University), submitted to the US National Institute of Health, $450,000.

"Integrative Methods and Models in Global Carbon Management", National Science Foundation – Biocomplexity. Co-PI with J. Harte, D. M. Kammen, R. Norgaard, $950,000.

"Local approaches to energy management and indoor air quality", US AID, $95,000.

Current & Past Support:

2003 - "A Review of Approaches to Advanced Power Technology Programs in the United States and Abroad Including Linked Mobile and Stationary Sector Developments", California Air Resources Board, $63,000.

1999 - "Research, education and outreach on energy and sustainable societies" The Energy Foundation, (San Francisco, CA), $250,000.

2000 Solo Energy Corporation. Unrestricted gift to support RAEL, $40,000.

2000 – 2001 Core Management Team (with E. Vine [LBL], J. Sharpless [former CEC Commissioner], J. Quinn [UC Davis], K. Birkinshaw [CEC]), California Energy Commission, Public Interest Environmental Research – Environmental Area (PIEREA), $10,500,000 annual program budget.

2001 – 2002 "UV Water Purification Technology for Development", Award Winning Entry, the World Development Marketplace Competition, $100,500. http://www.developmentmarketplace.org/html/results.html#DMAward

2000 – 2001 Faculty Research Grant (COR), "Sustainable Renewable Energy Markets", $5600.

2000 – 2001 "Resources Policy Internship Program", California Public Utilities Commission, $815,000.

2000-2002 "Biomass Energy For Sustainable Economic, Social, And Environmental Development In Zimbabwe", Shell Environmental Initiative (London, UK), $260,000.

1999 - 2000 "Photovoltaic System Field Evaluation and Training Program for East Africa", $54,000, The Lewis Anthony Dexter Charitable Trust (Chicago, Illinois, USA).

1999 - 2000 "Dissemination of Small-scale UV Water Disinfection Systems in Southern Mexico: Support and Evaluation", $12,000, The Lewis Anthony Dexter Charitable Trust (Chicago, Illinois, USA).

1998 - 2000 Co-PI (w/Lisa Naughton, University of Wisconsin) "Resource Access and Environmental Change: An Analysis of the Linkages Between Forest Property Rights, Biofuel Management, and Ecological Impacts in western Uganda", $50,000, National Science Foundation Grant SBR 98-10144; Division of Geography and Regional Science.

1996 - 1998 "Community Energy, Ecology and Health Management: Laikipia, Kenya". The Summit Foundation, Washington, DC, $198,000.

1996 - 1998 “Sustainable development in Molo, Kenya,” $95,211. The Dubois Fund, Houston, TX.

1996 - 1998 "Community Energy, Ecology and Health Management: Laikipia, Kenya". The Compton Foundation, Menlo Park, CA, $25,000.

1995 - 1996 MacArthur Foundation grant for student-faculty collaborative research, $7,600.

1993 - 1995 "Engineering and policy analysis of renewable energy technology transfer: solar and nuclear energy," Department of Energy, Northeast Regional Center for Global Environmental Change, $66,500.

1993 - 1994 Research Fellowship: Program on Environment, The East-West Center for Cultural and Technical Exchange, Honolulu, Hawaii, $9,000.

1993 *Award Recipient*: 21st Century Award from Nihon Keizai Shimbun, Inc. and the Global Industrial and Social Progress Research Institute: ¥5 m ($45,000).

1992 - 1996 Center for Field Research (*Earthwatch*): $94,000; "Solar and wind energy for Kenya." An additional local expertise research and training components were supported by: Green Cross International (1995), UNESCO (1994) to provide scholarships to African scholars and community activists working in the area of renewable energy and the environment.

**AWARDS**

Aldo Leopold Environmental Leadership Fellow (2001) (*Declined).*

Development Marketplace (2000) Award Winner, the World Bank. “Low Cost UV Water Disinfection System for Household Use in Lesser-Developed Nations (Dr. Lloyd Connelly and D. M. Kammen).
WWW: http://www.developmentmarketplace.org

Class of 1934 Preceptor, 1996 - 1999 (Woodrow Wilson School)

Bronze Medal (with Danielle A. Gordon) *Chicago Quantitative Alliance 1995 Academic Competition* for the paper, "Uncertainty and overconfidence in time series forecasts: application to the Standard & Poor's 500 stock index", *Applied Financial Economics*, **6 (3)**, 189 – 198 (1996).

Awarded the ANBAR Management Intelligence Citation of Excellence (1997): http://www.anbar.co.uk/anbar/excellence/authors.htm

Fellow, American Physical Society (1994). Citation:
*For his efforts to foster development with culturally appropriate renewable energy projects and to link local sustainable development with programs to mitigate global environmental degradation.*

*1993 21st Century Earth Award*: for research addressing the amelioration or solution of such global environmental problems as climate change, deforestation or biodiversity preservation. Citation:

*For research aimed at reducing greenhouse gas emissions and improving environmental health in developing nations: a proposal for energy management, cooking technology, and education*.

Teaching Award (Biology Undergraduate Student Curriculum Committee, California Institute of Technology, 1991).

Weizmann & Bantrell Postdoctoral Fellowship in the Division of Engineering and Applied Science (1988-89), Division of Biology (1989-91); California Institute of Technology.

Cornell University A. B., *Cum Laude* (1984).

Westinghouse Science Talent Search: Honors Group (1980).

## EDITORIAL BOARDS

*Annual Review of the Environment* (2001 – 2005)
*Global Change Science* (journal developed from *Chemosphere*), 1999 –
*Chemosphere*, Editor, Global Change Science and Policy Section, 1993 – 1999

## ADVISORY COMMITTEES

University of California Green Buildings/Clean Energy Steering Committee, 2003.
Elected At Large Member, Section on Societal Impacts of Science and Engineering (Section X), American Association for the Advancement of Science (AAAS), 1998 – 2002.
California Energy Commission, Core Management Team, Public Interest Environmental Research – Environmental Area (PIEREA), $10,500,000 annual budget, 2000 – 2002.
Roster of Experts, Scientific and Technical Advisory Panel (STAP); Global Environment Facility (GEF), 1996 -
The Annapolis Center for Risk Analysis, 1995.
Team Leader, Evaluation of Energy, Environment, and Development Programme, Africa Division, Swedish International Development Cooperation Agency (Sida), 1996 - 1997
U. S. Environmental Protection Agency (Climate Change Division)
Editorial Advisory Council, *African Technology Forum,* 1994 - 1996
U. S. Department of Energy: National Institute for Global Environmental Change, 1993 – 1995
Elected Member, The Council of Advisors: Energy Section (http://www.thecouncils.com/)

## REFEREE

*Journals*:

*Ambio, Appropriate Technology, Atmospheric Environment, Energy Policy, The Energy Journal, Energy - The International Journal, Environment, Environmental Health Perspectives, Environmental Science & Technology (EST), Global Biogeochemical Cycles, Global Change Science, Nature, Risk Analysis, Science, Scientific American,*

*Solar Energy, Strategic Environmental Management, World Bank Research Observer, Whole Earth, World Development*

*Publishers*:

Cambridge University Press, Island Press, McGraw Hill, MIT Press, Resources for the Future, UNDP, World Resources Institute, Yale University Press

*Funding Agencies*:

Compton Foundation, Earthwatch, GEF/UNDP, National Institute of Health, National Science Foundation, US AID, US EPA, US NIH, Winrock International Foundation

## LANGUAGES & TECHNICAL SKILLS

Spanish (conversant), Swahili (conversant)
Private Pilot (PPL: Single Engine, Land)
Concert electrical wiring (*Grateful Dead*, Summer 1988)
Computer Programming: BASIC, C++, FORTRAN, PASCAL, STATA

**REFERENCES**: Available Upon Request

## UNIVERSITY SERVICE, RESEARCH AND PROGRAM ADMINISTRATION

*At the University of California, Berkeley:*

2002 Executive Committee, Berkeley 'Future of the Planet' program.
2002 Harry S. Truman Fellowship Selection Committee, 2001 – 2003.
2003 Udall Fellowship Selection Committee, 2001 – 2003.
2004 Chair, Faculty Search Committee, "Science, Technology and Environmental Policy", ERG Search.
2005 Search Committee, Dean of the College of Natural Resources, 2001 – 2002.
2006 Committee on Status of Women and Ethnic Minorities (SWEM), 2001 – 2002.
2007 Chair, Faculty Search Committee, "Environmental and Development Sociology", Energy and Resources Group (2000 – 2001). Successful recruitment of Dr. Isha Ray
2008 Search Committee Member, "Science, Technology and Environmental Policy", joint search between ERG and the Goldman School of Public Policy (1999 – 2001)
2009 Campus Representative - Advisory Committee of the University of California Energy Institute (UCEI), 1999 – 2002.
2010 Co-Chair, Curriculum Committee, Energy & Resources Group, 1999-
2011 Faculty Affiliate, African Studies Program, 1998-
2012 Faculty Affiliate, Center for Risk Analysis, 1998-
2013 Faculty Affiliate, Health, Environment and Development (HED) Program, 1998-

*At Princeton University:*

- Faculty Fellow, Princeton Society of Fellows, 1998 - 1999
- Labouisse Development Studies Fellowship Selection Committee, 1996 - (Chair, 1998-1999)
- Chair, Science, Technology & Environmental Policy (STEP) Program, 1997 - 1999
- Co-Chair, Program on Science, Technology and Public Policy, 1993 - 1997
- Woodrow Wilson School Student-Faculty Diversity Committee, 1996 - 1997

- Associate Faculty, Princeton Environmental Institute, 1996 - 1999
- Faculty Fellow, Forbes College, Princeton University, 1994 - 1999
- Princeton Environmental Initiative, Planning committee, 1993 - 1994.
- Program Director, conference: "Polluted or Pristine? Scientific, cultural, and policy implications of pre-industrial anthropogenic impact on the global carbon cycle", hosted by the Program on Environment, East-West Center, Honolulu, Hawaii. September 17 - 19, 1993.
- Woodrow Wilson School: Undergraduate Prize Committee, 1993 - 1994
- Woodrow Wilson School: Ph.D. Admissions Committee, 1993 - 1995, 1996 - 1999
- Woodrow Wilson School Undergraduate Committee, 1993 - 1995, 1996 -1999
- Princeton University Committee on African Studies, 1993 - 1999

*At Harvard University:*

- Harvard University Committee on African Studies, 1991 - 1993.

## INTERNATIONAL ORGANIZATIONS

• Advisor, Energy Sector, Asian Development Bank, 2000 -
• Coordinating Lead-Author, Intergovernmental Panel on Climate Change (IPCC), Special Report on Technology Transfer (1998 - 2000)
• Global Environment Facility (GEF/UNDP), Scientific and Technical Review Panel, 1997 - 2002
• Co-Chair (with Stephen Karekezi) Princeton-AFREPREN (African Energy Policy Research Network) Visiting Fellows Program for emerging scholars from developing nations.
• AAAS Member-at-Large, Section Committee on Societal Impacts of Science and Engineering, 1998 - 2002 (elected member).
• American Physical Society, 1983 - 1987, 1993 -
Elected to the Executive Committee: *Forum on Physics and Society*, 1995 - 1998
Nominating Committee, 1997 - 1998
• American Association of Geographers, 1992 - 1997
• American Wind Energy Association, 1994 -
• National Council, Federation of American Scientists, 1995 - 2000
• African Academy of Sciences, Elected Permanent Fellow, 1995

## PUBLIC OUTREACH AND ACTIVISM

Chairman of the Advisory Panel, EcoEquity (http://www.ecoequity.org)

**BOOKS & EDITED VOLUMES**

*In preparation*:

*Energy Farmers*: An exploration of old and new modes of thinking about, and managing energy resources.

*Where There's Smoke: Uncovering the World's Number One Killer*
Book on energy, health, and development. This book, intended for a popular audience is represented by the literary agency of Sanford J. Greenburger Associates.

*The Road to Celebration: Adventures in Energy and Development in route to Sandinista Nicaragua* (Contract with Columbia University Press: New York). Manuscript complete.

*In print*:

2002 Climate Technology Initiative, Contributing Author (2002) *Technology Without Borders: Case Studies of Successful Technology Transfer* (International Energy Agency: Paris, France).
URL: http://www.iea.org/public/studies/cti.htm

2000 Intergovernmental Panel on Climate Change Working Groups II and III (2000) *Methodological and Technological Issues in Technology Transfer* (Cambridge University Press: New York, Cambridge UK and New York, NY). Coordinating Lead Author. ISBN 0-521-80494-9.

1999 Kammen, D. M. and Hassenzahl, D. M. *Should We Risk It? Exploring Environmental, Health and Technological Problem Solving*, in press, Princeton University Press. ISBN 0-169-00426-9, 406 pages, 77 tables, 82 illustrations.
WWW: http://socrates.berkeley.edu/~kammen/#book
• Book Club Selection: *Library of Science*. Reviewed in *Science*, *Risk Analysis*, *Scientific American, WholeEarth.*

1996 Nditu, M. and Kammen, D. M. *Solar Cookbook: Less Wood, Less Smoke, Better Health* (Academy Science Publishers: Nairobi, Kenya). ISBN 9966-831-32-0.

1996. Kiswahili version of *Solar Cookbook*. *Kitabu cha Upishi Ukitumia Kawi ya Jua*. ISBN 9966-831-33-9.

1994 Kammen, D. M., Smith, K. R., Rambo, A. T. and Khalil, M. A. K (editors) Preindustrial Human Environmental Impacts: Are there Lessons for Global Change Science and Policy? *Chemosphere* (Pergamon Press: Oxford UK), **Vol. 29 (5)**, 317 pages.

## JOURNAL PUBLICATIONS, BOOK CHAPTERS & ARTICLES

In preparation or review:

Kammen, D. M. and Karakezi, S. (2002) "The Power of Development: Energy Policies to Empower, Not Build Technological Imperialism", in preparation.

Chiu, W. A., Cox, L., Kammen, D. M. (2002) "A new model of one- and two-stage carcinogenesis and low-dose risk response", in preparation.

Hassenzahl, D. M., Goble, R. L., Kammen, D. M. and Hattis, D. B. (2002) "When can a risk assessment conclude that there is no risk?" *Risk Analysis*, in review.

Kammen, D. M. (2002) "Energy and Equity" in *The Encyclopedia of Energy*, C. Cleveland (ed.), (Academic Press, San Diego, CA).

Kammen, D. M. (2002) "A Taxonomy of Renewable Energy" in *The Encyclopedia of Energy*, C. Cleveland (ed.), (Academic Press, San Diego, CA).

Kammen, D. M. and Pacca, S., (2003) "The true costs of energy", *Annual Review of Energy and the Environment*, **28**.

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FOR THE FOLLOWING ARTICLES IN PRINT: • = REFEREED PUBLICATION (85 OF 133 TOTAL)

**2003**

133. • Bailis, R., Ezzati, M., and Kammen, D. M. (2003) "Greenhouse Gas Emissions from Cooking Technologies in Kenya", *Environmental Science & Technology*, in press.

**2002**

132. • Hultman, N. E. and Kammen, D. M. (2002) "Equitable Carbon Revenue Distribution under an International Emissions Trading Regime", Conference Paper No. 5; Available at: http://www.umass.edu/peri/pdfs/CDP5.PDF

131. • Lipman, T. E. and Kammen, D. M. "Renewable Energy: Now a Realistic Challenge to Oil", in *The Future of Oil as a Source of Energy*, 87 – 107.

130. • Duke, R. D. and Kammen, D. M. (2002) "Energy for Development: Solar Home Systems in Africa and Global Carbon Emissions "*Climate Change for Africa: Science, Technology, Policy and Capacity Building*, Pak Sum Low, editor (Kluwer Academic Publishers), 250-266.

129. • Ezzati, M., and Kammen, D. M. (2002) "Health effects of biomass use for rural cooking in developing nations", *Indoor Air*, June, 2002.

128. • Bailis, R., Ezzati, M., and Kammen, D. M. (2002) "An Estimate of Greenhouse Gas Emissions from Common Kenyan Cookstoves Under Conditions of Actual Use", *Indoor Air*, June, 2002.

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**2001**

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95. • Haines, A. and Kammen, D. M. (2000) "Renewable energy systems and public health", *Global Change and Human Health*, **1**, 78 – 87.

94. • Masera, O., Saatkamp, B. D., and Kammen, D. M. (2000) "From fuel switching to multiple cooking fuels: A critique of the energy ladder model in rural households", *World Development*, **28 (12)**, 2083 - 2103.

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**1999**

86. Ezzati, M., Kammen, D. M., and Mbinda, B. M. (1999) "Field research programme on energy technology, health, and the environment", *Boiling Point*, **43,** 33 – 34.

85. Kammen, D. M. (1999) "Wind and sun power for Kenya", *Regional Energy News*, **5 (1/2)**, 8 – 10.

84. Margolis, R. and Kammen, D. M. (1999) "Energy R&D and innovation: Challenges and opportunities", Proceedings of the *National Institute for Global Environmental Change* conference, "Energy Generation and Environmental Planning" 19 – 21 April, 1999, Sacramento, California.

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82. • Hibbert, R. Bai, Z., Navia, J., Kammen, D. M., Zhang, J. (1999) "High lead exposures resulting from pottery production in a village in Michoacan State, Mexico", *J. Exposure Analysis and Environmental Epidemiology*, **9**, 343 – 351.

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• Hearing Testimony, U. S. Senate Committee on Commerce, Science and Transportation (7/10/01)
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2000 • UNDP/World Bank Experts Meeting on Making a Difference in Emerging Photovoltaics • Markets, Marrakech, Morocco (9/25-28/00).
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• New Challenges in Tropical Medicine, Oxford, UK (9/20/00)
• Human Dimensions of Climate Change Meeting, Carnegie Mellon University (7/19/00)
• Health Impacts of Indoor Air Pollution and Household Energy Use in Developing Countries, Washington, DC (5/3-4/00)

1999 • International Energy Division, Lawrence Berkeley Laboratory
• Center for International Studies, Stanford University
• Stanford Linear Accelerator Center (SLAC)
• Department of Engineering and Public Policy, Carnegie Mellon University
• The World Bank, Washington, DC
• Columbia University: School of Engineering
• Tata Energy Research Institute, New Delhi, India
• Energy and Resources Group, University of California, Berkeley

Updated: 2-2-2003

**EXHIBIT 39-2**

## Analysis of Potential Safety Risks of the proposed Kittitas Valley Wind Power Project

The objective of this analysis is to provide an initial assessment of the sensitivity of potential public health and safety risks associated with the proposed Kittitas Valley Wind Power Project in Kittitas County, Washington. This analysis is to be submitted as expert testimony for EFSEC's consideration.

The purpose of the analysis is to evaluate the potential human health risks to the public of operating the proposed project. This analysis consists of two main components:

1) Perform actual risk calculations on the potential risks posed by wind turbines and comparing those risk levels with the risks of other common activities[1]
2) Quantify the risks and evaluate whether they are significant or not.

## General Risks Posed by Wind Turbines

There are no existing standards in the US for the acceptable risk level for wind power projects. Wind turbines do, however, have to comply with many safety rules, for example as a result of the certifying of wind turbine components (DNV, GL, RISO, etc.). Currently, there are no specific regulatory minimum distances for wind turbines to other infrastructure and building based on safety conditions. In general, there are no definitive national or state risk standards for most types of energy facilities. The specific concerns that have been raised regarding public safety risks in relation to the proposed Kittitas Valley project, and thus are the subject of this risk assessment are:

- Separation and throwing of whole or partial rotor blade
- Tower collapse
- Throwing of ice from the turbine blades

A structural failure of a wind turbine might lead to loss of blade (or parts of it) and thus cause a risk to nearby people and property. To deal with risks of wind turbine in a rational manner, the contents of several national handbooks (from Denmark, Germany and the Netherlands) with procedures for the risk assessment of wind turbines [2][3][4] have been used. A large data set representing 43,000 turbines in 3 countries and over 15,000MW of capacity was used to evaluate the actual risks of the aforementioned events.

The Kittitas Valley wind project is in the planning and permitting phase, thus the exact type of turbine to be used is not yet known. However, the developer, Zilkha Renewable Energy, has proposed using a range of turbine sizes from 60 to 90 meters in rotor diameter. For that reason, generic turbine data such as hub height, rotor diameter, rotor speed, potential throwing distances of blades, and risk contours as a function of the rated power have been collected. The data are based on turbine model for a range from 60 meter rotor diameter (RD) 1 MW turbines up to 90 meter RD 3 MW. The developer has indicated that the most likely wind turbine model for this project will be in the range of 1.5 MW turbines (with a rotor diameter of 70.5 meters).

**Calculation method for theoretical risk of blade throw**

Individual Risk (IR) = the probability that a member of the public will die from an accident at a plant (or any other hazardous activity) if he/she is permanently at a certain place without protection. The conservative maximum value for the IR based on *European Wind Turbine Standards (EWTS)*[5] is 1 in a million ($10^{-6}$) per year.

The IR is usually presented as contours with equal IR values around a plant or turbine. These contours indicate at what distance from the turbines vulnerable objects should be considered in the risk analysis. That distance equals the maximum throwing distance of a blade under overspeed conditions (equal to two times rated speed). The above mentioned criteria appear to be applicable for evaluating the probability of a blade or any other component directly hitting a person, or a group of persons.

The tip wind speed of a rotor blade is as high as 80m/s. Bearing in mind the weight of several tons of a single blade, the kinetic energy of a modern wind turbine is a possible hazard to the public, although the probability of blade failure is very low. The trajectories of blade fragments are calculated taking into account the site layout and wind turbine type specific data. Several tens of thousands of trajectories are calculated to quantify the probability of an impact on a certain location. These probabilities are the basis for the risk analysis.

The method used to determine the probability that a blade (or any other turbine component) may hit a person assumes that the centre of gravity of the blade follows a ballistic lift curve. The method further includes the size of the blade (or any other component), the size of the object or area, and if relevant, the velocity. The computer program "Probabilistic Design Tool for Wind Turbines" – PRODETO by Risø National Laboratory[6],[7] has been used in order to calculate the probability of failure of wind-turbine rotor blades.

Fig. 1 shows an example of the results of the risk modeling of the IR contours for a 2 MW turbine. Fig. 1A shows the IR contours resulting from the 3 individual scenarios: Loss of entire blade, collapse of entire turbine, and collapse of rotor and/or nacelle.

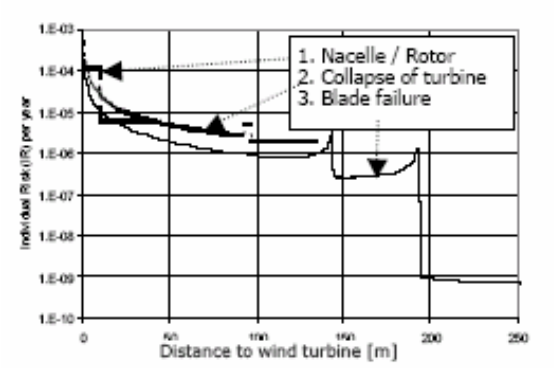

Fig. 1A: *Individual Risk (IR) per year versus distance to wind turbine resulting from the individual scenarios for a 2 MW wind turbine.*

Fig. 1B shows the sum of all IR values.

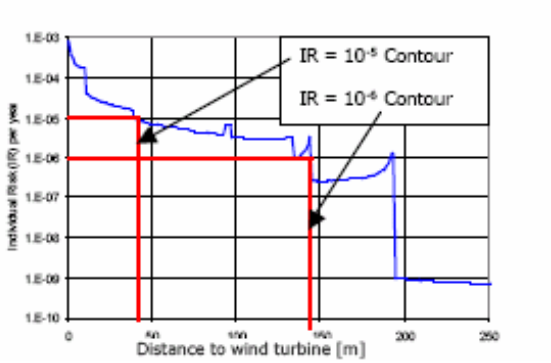


*Fig. 1B: Individual Risk (IR) per year versus distance to wind turbine for a 2 MW wind turbine, including all scenarios of Table 1.*

Using this modeling, different contours have been plotted for turbines in the range of 1000 kW up to 2 MW (60 m RD to 90 m RD).
Table 2 shows values for the IR = 1 in 100,000 ($10^{-5}$) and IR = 1 in a million ($10^{-6}$) contours (deaths per million people within a given distance of the wind turbine) as a function of the turbine size, these values have been acquired from the modeling plots.

Table 1. *IR contours (distance to wind turbine) as a function of turbine size*[8]

| **Type of turbine** | | | |
|---|---|---|---|
| Rated Power [MW] | 1.0 | 1.5 | 2.0 |
| Rotor Diameter [m] | 60 | 70 | 80 |
| IR = $10^{-6}$ contour [m] | 124 | 134 | 144 |
| IR = $10^{-5}$ contour [m] | 28 | 37 | 39 |

As is shown in Table 1 above, the IR = 1 in 100,000 ($10^{-5}$) contour equals half the rotor diameter and the IR = 1 in a million ($10^{-6}$) contour equals the maximum throwing distance of a blade at rated rotor speed.

It should be noted that the towers from the proposed Kittitas Valley Wind Power Project will be mostly on private land that is behind locked gates and in no case will be within tip height of any house or property line. The closest turbines are approximately 1000 feet (300 meters) from any house; in that case the house is owned by the same person on whose land the turbine will be located. From these calculations it can be said that for three bladed turbines in the range of 1MW to 2MW the IR = 1 in a million ($10^{-6}$) contours vary from 120m to 150m.

**Calculation method for Ice Throw**

Ice throw is a concern related to the fact that any object at the end of the rotating blades is traveling at a high rate of speed. In the case of a 60 meter RD turbine (about 200 feet), rotating at 20 RPM, the tip of the blade is traveling at just over 140 mph. If the turbine diameter increases to 80 meters, the tip speed increases to just over 187 mph. There are published reports (see footnote 9, Seifert *et al*) of ice having accumulated at the tip of the turbine and upon breaking loose, traveling up to 100 meters.

While there are theoretical claims that ice can travel great distances when sent flying from an operating turbine, most use the simplifying assumption that there is no air resistance. This assumption leads to very significant errors. Recent studies have been done using computer modeling which includes the influence of air resistance on ice throw[9],[10]. These studies included validation of the computer model by comparison with field observations. While their recommendation is to use the complex computer models to evaluate each site, there are some general conclusions. The research on wind turbine ice shedding in Europe has resulted in a recommendation of a setback distance that is 1 ½ times the height of the tower from areas where the public has access.

Using D = 1.5 (tip height), where D is the set back distance, tip height is the height of blade tip at its highest point. For the most likely turbine scenario proposed for this project, a 1.5 MW turbine with a 70.5 meter RD and tip height of 100 meters, this would require a safety setback of 150 meters or 495 feet from houses, roads or other areas with high incidence of human traffic.

**Actual Probability of Falling Object (blade, ice) Striking a Member of the Public**

The risk levels for a blade or ice thrown from a wind turbine presented above depends on the assumptions one makes about the probability of a person(s) being at the exact spot where a flying object might land at that exact moment in time. Given the rural, sparsely populated nature of the area, and the fact that the developer has stated the area will be fenced off, that probability appears to be very low.

At the proposed project site, the area with by far the highest frequency of human presence is Highway 97, which runs through the middle of the project area. It is logical then to calculate the probability that a vehicle would be present at the time a blade or ice fragment were thrown to determine more accurately the risk of a vehicle being struck. As noted in Section 3.10 of the Application of Site Certification, the Average Daily Traffic volume for 2001 for this section of Highway 97 is reported by WA DOT to be 2,800 vehicles. Making some simple assumptions about the average size of vehicles and their travel speed, and factoring in the distance from Highway 97 to the nearest proposed turbine, the probability of a blade or any other component hitting a car is less than one in one billion ($p = 6 \times 10^{-10}$). This assumes that any object thrown from a wind turbine and striking a vehicle leads to mortal accident (which is a very conservative assumption). In reality not all thrown objects that could hit a car will lead to a mortal accident so the added risk is actually smaller .

**Risk Comparisons**

In order to evaluate the calculated risk levels presented by the proposed project, it is useful to compare them to the risks of other activities that are perhaps more familiar to most people. The following table lists a variety of activities that all increase the chance of death per year by one in one million. Comparing the risk level of an object thrown from a wind turbine actually striking a person or vehicle at the proposed project site calculated above (one in one billion) to the following list of activities that all present a risk of one in one million it is clear that the proposed project is less likely to result in death than many very common activities. The likelihood of any of the following increasing the chance of death is 1,000 times greater than the calculated risk level presented by the proposed project. It appears reasonable, therefore, to determine that the proposed project does not present a significant risk to public health or safety.

*Table 2. Risks that increase chance of death per year by $10^{-6}$ (one chance in one million)*

| Activity | Cause of Death |
|---|---|
| Smoking 1.4 cigarettes | cancer, heart disease |
| Drinking .5 liter of wine | cirrhosis of the liver |
| Spending 1 hour in a coal mine | black lung disease |
| Spending 3 hours in a coal mine | accident |
| Living 2 days in New York or Boston | air pollution |
| Traveling 6 minutes by canoe | accident |
| Traveling 10 miles by bicycle | accident |
| Traveling 300 miles by car | accident |
| Flying 1000 miles by jet | accident |
| Flying 6000 miles by jet | cancer caused by cosmic radiation |
| Living 2 months in Denver | cancer caused by cosmic radiation |
| Living 2 months in average stone or brick building | cancer caused by natural radioactivity |
| One chest X ray taken in a good hospital | cancer caused by radiation |
| Living 2 months with a cigarette smoker | cancer, heart disease |
| Eating 40 tablespoons of peanut butter | liver cancer caused by aflatoxin B |
| Drinking Miami drinking water for 1 year | cancer caused by chloroform |
| Drinking 30 12 oz cans of diet soda | cancer caused by saccharin |
| Living 5 years at site boundary of a typical nuclear power plant | cancer caused by radiation |
| Drinking 1000 24-oz soft drinks from plastic bottles | cancer from acrylonitrile monomer |
| Living 20 years near a polyvinyl chloride plant | |
| Living 150 years within 20 miles of a nuclear power plant | cancer caused by radiation |
| Living 50 years within 5 miles of a nuclear power plant | cancer caused by radiation |
| Eating 100 charcoal-broiled steaks | cancer from benzopyrene |

Wilson, R., "Analyzing the Daily Risks of Life." *Technology Review*, 81, 1979

Note: These data are based on simple extrapolations from population averages. Some data are based on actuarial statistics (e.g., coal mine accidents) and others are based on theoretical models (e.g., cancers from chlorinated water).

**EXHIBIT 39-2**

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[1] D.M. Kammen and D.M. Hassenzahl. Should we risk it? Princeton Ed. 1999.

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[3] Committee for the Prevention of Disasters. Guidelines for Quantitative Risk Assessment. CPR 18E. Den Haag, Sdu: 1999. This report documents the methods to calculate the risks due to dangerous substances using the models and data available. Calculation of the risks relates, on the one hand, to stationary installations and, on the other hand, to transport and related activities. The report consists of two parts. Part 1 describes the methods to calculate the risks of stationary installations. Part 1 was written by the National Institute of Public Health and the Environment (RIVM) under a supervisory committee of representatives from the subcommission on Risk Evaluation of the Committee for the Prevention of Disasters (CPR-RE). Part 2 describes the calculation of the risks connected with the transport of dangerous goods, based on the approach developed in accordance with the Ministry of Housing, Spatial Planning and the Environment.

[4] The incidents reported are gathered in the German WMEP database from ISET a Danish database from Energie og Miljødata, and a Dutch database. Windenergie Report Deustschland 2002 by Institut für Solare Energieversorgungstechnik (ISET) in Kassel is the continuation of a series of practical reports on the operation and performance of wind turbines in Germany. The annual reports for the Scientific Measurement and Evaluation Program, or WMEP for its German acronym, will continue at least into 2004.

[5] European Wind Turbine Standards (EWTS). J.W.M. Dekker J.T.G. Pierik (Editors).
The determination of the target values for structural reliability can be done empirically. However, a probabilistic approach is preferred. This probabilistic method has been applied already in other branches of industry like offshore and civil engineering, but is not introduced in the wind energy branch yet. The code of realibility which is not local to a country, but shall be applied Europe-wide, is the Eurocode 1. Therefore, it is recommended to apply the safety level of the Eurocode to wind turbines, which would mean a yearly safety index of 4.7, corresponding to a failure probability of $10^{-6}$/year.

[6] A Probabilistic Design Tool for Wind Turbines. H. Braam, J. J. D. van Dam, ECN; C. J. Christensen, M. L. Thøgersen, G. C. Larsen, Risø; K. O. Ronold, DNV Risø National Laboratory, December 1998, ISBN 87-550-2466-3.

[7] Braam, H. et al: “Handboek Risicozonering Windturbines” Handbook Risk Assessment of Wind Turbine, May 2002.

Rotor Blade Failure - Risk Analysis for the Surrounding of a Wind Turbine T. Hahm, J. Kröning, TÜV-Nord e.V.

[8] The IR contours as a function of the turbine size data given in Table 3 are acquired from the Handbook Risk Assessment Handbook (edited by NOVEM).

[9] Risk Analysis of Ice Throw From Wind Turbines by Henry Seifert et al, DEWI (German Wind Energy Institute)

[10] Technical Requirements For Rotor Blades Operating In Cold Climate by Henry Seifert, DEWI (German Wind Energy Institute)