CURRICULUM VITAE

Vasilis M. Fthenakis, Ph.D., AIChE Fellow; IEF Fellow

Energy Sciences & Technology Dep't
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Seminal Contribution:
His rigorous and proactive research and dissemination by leading publications and presentations, provided the underpinning of PV technologies in terms of their lifecycle impacts. Fthenakis' work is a crucial part of the scholarly landscape for comparing photovoltaics (PV) with other energy options. He asserted his life-cycle analysis (LCA) leadership by bringing the same scrutiny to non-solar technologies like nuclear energy. Helping to put several energy technologies on a comparable basis with solar has been a crucial contribution to today's key debates about energy and climate change.

EDUCATION

New York University, New York Ph.D. in Fluid Dynamics and Atmospheric Science, 1991.
Thesis topic: Modeling of water spraying of toxic gas releases; with Dr. Victor Zakkay
Columbia University, New York M.S. in Chemical Engineering, 1978.
Thesis topic: Modeling on the methanation of carbon monoxide; with Dr. John Happel.
University of Athens, Greece Diploma in Chemistry, 1975.

PROFESSIONAL EXPERIENCE

Senior Scientist (2007-) Scientist (2003-2007); Senior Research Engineer (1995-2003); Research Engineer I (1987-1995); Research Engineer II (1980-1987)
Departments of Energy Sciences and Environmental Sciences, **Brookhaven National Laboratory**
Current research focuses on energy-environmental impact analysis, air pollution prevention and control, and modeling of accidental chemical releases. He is the Head of the National Photovoltaic Environmental Research Center, since 2002. Leads the DOE-EERE Solar Vision Study, Siting and Environmental Impacts Tasks (to be produced in the Spring of 2010). Collaborates with NREL on a LCA harmonization study comparing several renewable energy technologies. He serves as BNL contact point with DOE-EERE for the solar technologies and wind energy technologies programs. Leads international collaborations on life cycle assessment (LCA) under the auspices of the International Energy Agency.

Senior Research Scientist (May 2006-present)**, Founder and Director** of the Center for Life Cycle Analysis, Professor Earth and Environmental Engineering, **Columbia University.** The Center is supported with research grants from the PV industry, EPA, NYSERDA and NREL. He advises and supports several MS/PhD students and an associate research scientist. Created (Fall 2009) and teaches a new course on PV Systems Engineering and Sustainabilty.

Major Contributions/Recognitions:
Fthenakis specializes in the area of photovoltaics (PV) and the environment. He has led the U.S. and to a certain degree the European PV industries onto a pathway of sustainable development. He identified potential barriers in PV commercialization and proactively conducted research that resolved concerns associated with rapid growth of the PV market. He built collaborations on silane safety and lead-free solder technologies among PV industry members, and he conceptualized and conducted original research on the life cycle of thin-film photovoltaics that opened the door to Europe and Asia for the U.S. thin film PV industry. Fthenakis foresaw the European trends towards banning products containing lead and cadmium and guided the crystalline silicon and the cadmium telluride industries in overcoming these barriers. In 1999, he organized and chaired a workshop in Vail, CO, to promote the use of lead-free solder technology in the PV industry. Eight years later, a large fraction of the crystalline-Si PV industry has

converted to lead-free solder alloys. Currently, PV products are exempted from the Waste Electronic and Electrical Equipment (WEEE) and RoHS regulations, largely because of Fthenakis' pioneering research on the life-cycle of photovoltaics.

He entered the area of life cycle analysis (LCA) in 2004, intrigued by what he considered an unbalanced presentation of the environmental impacts of photovoltaics. Given the broad scope of this research that covered several major PV technologies, he concentrated on 2nd generation thin-film photovoltaics for which there were not previous studies, while engaging European researchers in updating LCA studies of crystalline silicon PV technologies. Thus, he formed an ad-hoc committee and held scoping meetings with researchers from the University of Utrecht, the Energy research Center of the Netherlands, Chalmers University, University of Stuttgart, Siena University and Ambient Italia, assessing the LCA needs of the PV industry. Subsequently, he co-authored several papers with his collaborators compiling a well-balanced picture of PV in comparison with other energy technologies.

To safeguard the environmental friendliness of photovoltaics, he has been defining and promoting a proactive, long-term environmental strategy including recycling of photovoltaics at the end of their useful life. In 2002 he established a laboratory for studies on recycling of spent photovoltaic modules and manufacturing scrap, using hydrometallurgical separation technologies, and he hired post-doc researchers to run the lab and work on LCA. He also designed experiments for simulating the effect of fire on photovoltaics using a variety of techniques, included NSLS-x ray diffraction analysis of molten glass and lead a multi-disciplinary team from BNL and the U. of Chicago in conducting the studies. In 2005, he led a workshop organized by the European Union's Joint-Research Center and the German Ministry of the Environment that enabled a U.S. company to open a manufacturing facility in Germany. This workshop was largely based on research conducted by the Fthenakis group at BNL. In 2007, he conceptualized and organized a 5-yr International Energy Agency (IEA) PV-EH&S Task (Task 12). Currently he is leading the task as the U.S. Operating Agent.
His research on LCA since 2004 has produced 50 journal and conference papers (in a total of about 240 publications on energy and environmental topics). Three of his papers were ranked #11, 12 and 18 in the list of the top 40 cited articles in 2005-2008 of Progress in Photovoltaics: Research and Applications. He has been active at the IEEE PVSC and the EU PVSEC every year and has given many invited presentations in universities on LCA and environmental health and safety. In 2008, he published leading articles in Scientific American (ScAm) and Environmental Science and Technology (ES&T). The first showed how solar energy can satisfy all the energy needs of the US; it was featured in the cover of ScAm and translated in 19 languages. The later titled "Emissions from Photovoltaic Life Cycles, ES&T, 42(6), 2168-2174, 2008, featured in the cover of ES&T, was "A most accessed article in the ACS web-site" being accessed 2,973 times in February and March 2008. His research was highlighted in the New York Times, Science News, ES&T, IEEE Spectrum, Scientific American, Spiegel, NRC Handelsblad, and was broadcasted with interviews in several radio and TV programs.
Recently (2007-2009), he was invited and served in Energy Expert Panels by the California Energy Commission, the European Photovoltaic Industry Association, and the New York Academy of Sciences and gave several keynote presentations on photovoltaics and sustainability.

Fthenakis has received multiple Commendations and Certificates of Appreciation from the Department of Energy and also a Commendation from the Director of the National Renewable Energy Laboratory (NREL) for exemplary performance on PV safety analysis reviews.

Safety/Environmental Consulting
Expert investigator of major chemical industry accidents; Exxon/Mobil, Fairfax, VA (5/1/2001-12/2002) ; Dow Chemical, Pitsburg, CA (12/1999- 12/2000); 3M Corp., St. Paul, MN (7/1997- 8/1988); CITGO, Corpus Christi, TX (7/1995-7/1996); Webb, Murray & Associates, Inc., Houston, TX (8/1995-4/1996**);** Radian/SEMATECH, Austin, TX, 6/1994-12/9/1995); UNO-VEN, Lemont, IL (5/1992-12/1992); Allied Signal, Morristown, NJ (10/1992-12/1993); Tecsa, Bergamo, Italy (11/1992 – 11/1993); Amoco Chemical Co., Texas City, TX (1992); Industry Cooperative HF Mitigation Program (5/1990 - 12/1990); Ultramar Corp., Wilmington, CA (5/1991); Mobil Corp., Princeton, NJ (5/1990 - 1994); Amoco Corp., Chicago, IL (8/ 1990 - 1992); Eastman Kodak Co., Rochester, NY (6/1990); Standard Microsystems Corporation, Hauppauge, NY (5/1987)

Project Engineer **Fossil Energy Laboratory, Columbia University, NY (1979-1980)**
Performance evaluation studies on a moving bed coal-biomass gasifier.

Research Assistant **Catalysis Laboratory, Columbia University, NY (1977-1979)**
Catalysis Research Co., Palisades Park, NJ (6/1977-9/1977)
Development of mathematical models for various catalytic chemical reactions.

Chemist **ChemiResearch, Chania, Greece (1974-1976)**
Laboratory work on Water Quality Analysis.

TEACHING EXPERIENCE

Adjunct Professor (1997-present) Adjunct Associate Professor (1993-1996)	Earth & Environ Engineering Dept., Columbia University
Adjunct Professor of Env. Eng.(1996-present) Adjunct Associate Professor (1992-1995)	Civil Eng. Dept., City College, CUNY

STUDENT ADVISOR/MENTOR
2008-2009 Rob vanHaren (PhD); Marc Perez (MS/PhD); Jonathan Krones (MS/PhD); Thomas Nikolakakis (MS/PhD), Athanasios Bourtsalas (MS/PhD) Jordi Dunjo (visiting PhD); Sara Riazi (MS), Sandra Gualtero (MS); Michael Frempong (MS), Rob vanDer Meulen (visiting MS); Kevin Ho (graduate project); Tim Sheribam (lab); Jesse McManus and Dan Albert (summer interns)
2007 Chris Graves (lab), Anuta Belova (lab); Yvonne Liao, Half-Hollow Hills High School,
2005 Birger Lofgren and Gustaf Zettergren Chalrmers U., Sweden, (MS Thesis),
2004 Daniel Churn, Columbia U, Summer Intership Program, 2004
1990-1991 Summer Intership Program, Chem Eng Practice, MIT

HONORS
2006 US DOE Certificate of Appreciation "*for superior technical, management and communications skills exhibited in photovoltaic environmental research and in effective dissemination of research results",* 2/2006
2004 Fellow of the International Energy Foundation, 2/2004
2002 Fellow of the American Institute of Chemical Engineers, 2/2002 *"in recognition and appreciation of superior attainments, valuable contributions, and service to Chemical Engineering"*
1996 Certificate of *Appreciation for EH&S services*, Brookhaven National Laboratory, 11/27/96.
1992 Commendation from the Assistant Secretary for Conservation and Renewable Energy, DOE *"for exemplary performance on safety analysis"*, 3/6/92.
1992 Commendation from the Director of NREL, for S*afety Review Analysis*, 9/1/92.
1977-79 Graduate Research Scholarships (3), Columbia University

EDITOR
- Editorial Board of the "Journal of Loss Prevention", 1998-present
- Editorial Board of the Journal "Progress in Photovoltaics Research and Applications", 1996-present.
- Editor of the newsletter "Fossil Energy and the Environment", 1991-1993.

EXPERT PANELS & COMMITTEES
2010 NSF Workshop "Catalyzing Innovation in PV Manufacturing", May 6-7, 2010, Golden CO.
2009 NSF Workshop "Catalyzing Innovation in PV Manufacturing", May 6-7, 2010, Golden CO.
IEA Task 12 Expert Meeting, Sept 24, 2009, Hamburg , GER
2008 New York Academy of Sciences, Expert Panel on McKinsey report/Energy Issues
2007 California Energy Commission Expert Workshop on *Nuclear Power in California*
2007 European PV Industry Forum, Expert Panel on Sustainability Challenges
2004-present BNL Research Library Advisory Committee
2004-06 BNL Equal Employment Opportunity Committee
2004 Solar Cells 2004, International Scientific Advisory Committee, Badajoz, Spain.
2001 Petroleum Energy Research Forum (PERF) Modeling Subcommittee.

1996 Probabilistic Safety Assessment & Management (PSAM-III) Technical Programme Committee.
1992-93 Advisory Committee for starting an Environmental Engineering Department at the Technical University of Crete, Greece.
1992-96 AIChE, Health & Safety Division, Chair of Membership Committee & Member of Executive Committee.
1992 Expert Reviewer of the EPA Report to Congress on HF Mitigation, 1992.
1991 Panel of Experts - Center of Chemical Process Safety of the AIChE, Mitigation Workshop, 1991
1990 Coordinating Group on Computational Fluid Dynamics, ASME, Fluid Engineering Div.
1988-92 AIChE, Health & Safety Planning Committee.

SYMPOSIUM ORGANIZER & CHAIR

- 1st International Recycling Workshop, January 26, 2010, Berlin, Germany
- IEA Task 12 Workshop, January 25, 2010, Berlin, Germany
- NSF EPA workshop on Nano and the Environment, November 5-6, 2009, Chicago, IL NSF project no: CBET-0933674.
- Recycling Scoping Workshop, IEEE PV Specialists Conference, Philadelphia, 2009.
- Compressed Air Energy Storage (CAES), Columbia University, New York, October 2008.
- MRS Fall Meeting, Symposium "Life Cycle Analysis Tools for New Energy Conversion and Storage Systems, November 2007, Boston, MS.
- Organizer & Leader of International Energy Agency Task on PV EH&S, 5-yr task starting in 2007
- MRS Fall Meeting, Symposium "Life Cycle Analysis Tools for "Green" Materials and Processes Selection", November 2005, Boston, MS.
- International Energy Agency (IEA) Environmental Aspects of PV Power Systems, PV Expert Workshop, Utrecht, Holland, June 25-27, 1997: "Health, Safety and Environmental Aspects of Cell Technologies".
- ESREL'96-PSAM III Conference, European Safety & Reliability Association, International Association for Probabilistic Safety Assessment and Management, "Environmental Impacts."
- AICHE 1994 Summer National Meeting, Denver, CO, August 14-17, 1994: "Chemical Risk Assessment of Fossil Fuel Power Plants and Refineries"
- AICHE 1993 National Meeting, Seattle, WA, Aug. 15-19, 1993: "Mitigation of Hazardous Releases Through Design" and "Mitigation of Hazardous Releases: Modeling and Evaluation".
- AICHE 1992 National Meeting, Minneapolis, MN, Aug. 9-12, 1992: "Prevention and Control of Accidental Releases of Hazardous Gases "
- AICHE 1990 National Meeting, Orlando, March 18-22, 1990: "Safe Procedures for Accident Prevention in Chemical Industries"
- AICHE 1989 National Meeting, Philadelphia, Aug. 20-23, 1989: "Controls of Hazardous Gases I & II"

OTHER: Fellow of the American Institute of Chemical Engineers (AIChE), Fellow of the International Energy Foundation. He has been a member of the American Chemical Society (ACS), American Meteorological Society (AMS), Semiconductor Safety Association (SSA), Association of Environmental Engineering and Science Professors. Listed in "Who is Who in America" (1997-present) and "Who is Who in Science & Engineering" (1992-present).

PERSONAL: U.S. Citizen; married, two children.

PATENT

BSA 10-16 –Nonprovisional S.N. 12/756,507 awarded 4/8/1010 –"System and Method for Separating Tellurium from Cadmium Waste"

PUBLICATIONS

BOOK

1. Fthenakis, V.M., Prevention and Control of Accidental Releases of Hazardous Gases, Van Nostrand Reinhold, New York, 1993.

EDITOR-CONFERENCE PROCEEDINGS

2. Papasavva S. and Fthenakis V. Symposium G: Life Cycle Analysis Tools for "Green" Materials and Processes Selection, Materials Research Society, Symposium Proceedings Volume 895, Materials Research Society, Warrendale, PA, 2006.

3. Fthenakis V., Dilon A. and Savage N., Symposium R: Life Cycle Analysis for New Energy Conversion and Storage Systems, Materials Research Society, Symposium Proceedings Volume 1041, Materials Research Society, Warrendale, PA, 2008.

PEER- REVIEW JOURNAL ARTICLES

4. Happel, J., Suzuki, I., Kokayeff, P., and Fthenakis V. Multiple Isotope Tracing of Methanation Over Ni Catalyst, Journal of Catalysis 65:57-77 (1980).

5. Happel, J. et al. and Fthenakis, V. Multiple Isotope Tracing of Methanation, II, Journal of Catalysis 75:314-328 (1982).

6. Fthenakis, V.M. and Leigh, R.W. An Analysis of Selected Surface Characteristics and Latent Heat Storage for Passive Solar Space Heating, Alternative Energy Sources, 4(1):367-380, (1982).

7. Fthenakis, V.M. On the Effect of Melting Point in the Performance of Phase Change Thermal Storage, Alternative Energy Sources, 5(1):263-270, (1983).

8. Fthenakis, V.M. and Leigh, R.W. The Value of Improvements in Absorbing and Glazing Surfaces of Solar Devices, Solar Energy, 32(3):367-376 (1984).

9. Fthenakis, V.M., Moskowitz, P.D., and Lee, J.C. Manufacture of Amorphous Silicon and Gallium Arsenide Thin-Film Solar Cells: An Identification of Potential Health and Safety Hazards, Solar Cells, 13:43-58 (1984).

10. Wilenitz, I., Fthenakis, V.M., and Moskowitz, P.D. Costs of Controlling Emissions from the Manufacture of Silicon Dendritic Web Photovoltaic Cells, Solar Cells, 15:247-266 (1985).

11. Fthenakis, V.M. Electrical and Electromagnetic Hazards in Thin-Film Solar Cells Manufacturing, Solar Cells, 19(1):45-58 (1986).

12. Moskowitz, P.D., Fthenakis, V.M., Hamilton, L.D. and Lee J.C. Public health Issues in Photovoltaic Energy Systems: An Overview of Concerns, Solar Cells, 19:287-299 (1986).

13. Fthenakis, V.M., and Moskowitz, P.D., Characterization and Controls of Phosphine Hazards in Photovoltaic Cell Manufacture, Solar Cells, 22:303-317 (1987).

14. Morris S.C., Moskowitz, P.D., Fthenakis, V.M., and Hamilton, L.D., Chemical Emergencies: Evaluation of Guidelines for Risk Identification, Assessment, and Management, Environment International, 13:305-310 (1987).

15. Fthenakis, V.M., Moskowitz, P.D., and Hamilton, L.D. Personal Safety in Thin-Film Photovoltaic Cell Industries, Solar Cells, 19:269-281 (1986-1987).

16. Fthenakis, V.M., Moskowitz, P.D., and Sproull, R.D., Control of Accidental Releases of Hydrogen Selenide and Hydrogen Sulfide in the Manufacture of Photovoltaic Cells: A Feasibility Study, Journal of Loss Prevention, 1:206-212 (1988).

17. Fthenakis, V.M. and Moskowitz, P.D., Health and Safety Aspects of Thin-Film Photovoltaic Cell Manufacturing Technologies, Plant/Operations Progress, 7(4):236-241 (1988)

18. Fthenakis, V.M., The Feasibility of Unconfined Releases of Toxic Gases by Liquid Spraying, Chemical Engineering Communications, 83, 173-189, 1989.

19. Moskowitz, P.D., Fthenakis, V.M. and Lee J.C., Protecting Worker Health and Safety in Photovoltaic Research and Development Laboratories, Solar Cells, 27, 149-158, 1989.

20. Moskowitz, P.D. and Fthenakis, V.M., Toxic Materials Released from Photovoltaic Modules During Fires: Health Risks, Solar Cells, 29, 63-71, 1990.

21. Fthenakis, V.M. and Moskowitz, P.D., An Assessment of the Hazards of Silane Explosions, Solid State Technology, 33(1), 81-85, 1990.

22. Fthenakis, V.M., K.W. Schatz and V. Zakkay, A Theoretical Study of Absorption of Toxic Gases by Spraying, Journal of Loss Prevention, 3(2), 197-205, 1990.

23. Moskowitz, P.D. and Fthenakis, V.M., Environmental, Health and Safety Issues Associated with the Manufacture and Use of II-VI Photovoltaic Devices, Solar Cells, 30, 89-99, 1991.

24. Fthenakis, V.F. and P.D. Moskowitz, A Checklist of Suggested Safe Practices for the Storage, Distribution, Use and Disposal of Toxic and Hazardous Gases in Photovoltaic Cell Production, Solar Cells, 31, 513-525, 1991.

25. Fthenakis, V.M. and K.W. Schatz, Numerical Simulations of Turbulent Flow Fields Caused by Spraying of Water on Large Releases of Hydrogen Fluoride, FED-Vol. 131, Fluid Dynamics of Sprays, Book No. H00715, 37-44, 1991.

26. Fthenakis, V.M., R.W. Youngblood and P.D. Moskowitz, The Role of Fault Tree Analysis in Assessing Hazards from Hazardous Materials Used in Semiconductor Industries, SSA Journal, 6 (1), 51-56, 1992.

27. Fthenakis, V.M. and D. N. Blewitt, Performance Assessment of Water Spraying Systems for HF Mitigation, Journal of Loss Prevention, 6(4), 209-218, 1993.

28. Fthenakis, V.M., HGSPRAY: A complete model of spraying unconfined gaseous releases, Journal of Loss Prevention, 6(5), 327-331, 1993.

29. Fthenakis, V.M., K.W. Schatz, U.S. Rohatgi and V. Zakkay, Computation of flow fields induced by water spraying of an unconfined gaseous plume, Transactions of the ASME, Journal of Fluid Engineering, 115, 743:750, 1993.

30. Moskowitz P.D., Fthenakis, V.F., Crandal R.S., and Nelson B.P., Analysis of Risks Associated with the Use of Hazardous Production Materials in Research Laboratories, Solid State Technology, 37(7), 121-129, 1994.

31. Schatz K.W. and Fthenakis V.M., Mitigation of Hydrogen Fluoride Aerosols by Dry Powders, Journal of Loss Prevention, 7(6), 451-456, 1994.

32. Fthenakis V.M. and Blewitt D.N., Recent Developments on Modelling Mitigation of Accidental Releases of Hazardous Gases, Journal of Loss Prevention,. 8(2), 71-77, 1995.

33. Fthenakis V.M. and Moskowitz P.D., Control of Particulate and Gas in Photovoltaic Module Manufacture, Progress in Photovoltaics: Research and Applications, 2, 317-326, 1994.

34. Fthenakis V.M., Hazardous fluid releases, Journal of Loss Prevention, 7(3), 261-262, 1994.

35. Lipfert F.W, Moskowitz P.D., Fthenakis V.M., DePhillips, Viren J. and Sarrof, L., An assessment of adult risks of paresthesia due to mercury from coal combustion, Water, Air & Soil Pollution, 80: 1139-1148, 1995.

36. Fthenakis V.M. and Moskowitz P.D., Plasma Etching: Safety, Health and Environmental Considerations, Progress in Photovoltaics: Research and Applications, 3, 129-134, 1995.

37. Fthenakis V.M., Lipfert F. and Moskowitz P.D., An assessment of mercury emissions and health risks from a Coal-Fired Power Plant, Journal of Hazardous Materials, 44(2), 267-283, 1995.

38. Fthenakis V.M. and Moskowitz P.D., Thin-Film Photovoltaic Cells: Health and environmental Issues in their Manufacture, Use and Disposal, Progress in Photovoltaics Research and Applications, 3(5), 295-306, 1995.

39. Moskowitz P.D., R. Pardi, Fthenakis V.M., Hotzman S., Sun l.C., and Irla B., An Evaluation of Three Representative Multimedia Models Used to Support Cleanup Decision-Making at Hazardous, Mixed, and Radioactive Waste Sites, Risk Analysis Journal, 16(2), 1996.

40. Lipfert F.W, Moskowitz P.D., Fthenakis V.M., and Sarrof, L., Probabilistic Assessment of Health risks of Methylmercury from Burning Coal, NeuroToxicology, 17(1):197-212, 1996.

41. Fthenakis V.M, Eberspacher C., and Moskowitz P.D., Recycling Strategies to Enhance the Viability of CIS Photovoltaics, Progress in Photovoltaics: Research and Applications; 4, 447-456 (1996).

42. Lee J.C., Fthenakis V.M., Morris S.C., Goldstein G. and Moskowitz P.D, Projected Photovoltaic Energy Impacts on U.S. CO_2 Emissions: An Integrated Energy-Environmental Economic Analysis, Progress in Photovoltaics: Research and Applications, 5, 277-285, 1997.

43. Fthenakis V.M. and Lee J.C., The Impact of Photovoltaics on CO2 Emissions' Reduction in the US. The World Resource Review, 10(3), 434-445, 1998.

44. Fthenakis V.M., Prevention and Control of Accidental Releases of Hazardous Materials in PV Facilities, Progress in Photovoltaics: Research and Applications, 6, 91-98, 1998.

45. Ciccarelli G. Fthenakis V.M. and Boccio J., A Simple Method of Analysis for Gas Explosions, Journal of Loss Prevention, 12, 157-165, 1999.

46. Fthenakis V.M. and Rohatgi U.S., A model of Liquid Releases from a Submerged Vessel, Journal of Loss Prevention, 12, 437-449, 1999.

47. Fthenakis V. Morris S.C., Moskowitz P.D. and Morgan D., Toxicity of CdTe, CIS and CGS, Progress in Photovoltaics: Research and Applications, 7, 489-497, 1999.

48. Fthenakis V.M., HGSYSTEM: A Review, Critique, and Comparisons with Other Models, Journal of Loss Prevention, 12, 525-531, 1999.

49. Fthenakis V.M. and Moskowitz P.D., Photovoltaics: Environmental, Safety and Health Issues and Perspectives, Progress in Photovoltaics: Research and Applications 8, 27-38, 2000.

50. Fthenakis V., End-of Life Management and Recycling of PV Modules, Energy Policy, 28, 1051-1058, 2000.

51. Andrijievskij A, Fthenakis V.M., Loukashevich A, and Trifonov A., LOCADIS, A model and numerical code for simulating local aerosol dispersion, Journal of Loss Prevention, 14(1), 61-67, 2001.

52. Fthenakis V.M., Water Spray Systems for Mitigating Accidental Indoor Releases of Water-Soluble Gases, Journal of Loss Prevention, 14(3), 205-211, 2001.

53. Fthenakis V., A Release of Nitrogen Oxides in Bogalusa, Louisiana and Similarities of Causation to the Bhopal MIC Release, Journal of Loss Prevention, 14(4), 245-250, 2001.

54. Fthenakis V., Multilayer Protection Analysis for Photovoltaic Manufacturing Facilities, AIChE Process Safety Progress, 20(2), 1-8, 2001.

55. Morris S.C., Goldstein G.A. and Fthenakis V.M., NEMS and MARKAL-MACRO models for energy-environmental-economic analysis: A comparison of the electricity and carbon reduction projections, Environmental Modeling and Assessment, 7, 207-216, 2002.

56. Fthenakis V.M., Rohatgi U.S. and Chung B.D., A Simple Model for Predicting the release of Liquid-Vapor Mixture from a Large Break in a Pressurized Container, Journal of Loss Prevention, 16, 61-72, 2003

57. Lemley J., Fthenakis V. and Moskowitz P., Security Risk Analysis for Chemical Facilities, AIChE Process Safety Progress, 22(3), 153-162, 2003.

58. Fthenakis V., Life Cycle Impact Analysis of Cadmium in CdTe Photovoltaic Production, Renewable and Sustainable Energy Reviews, 8, 303-334, 2004.

59. Fthenakis V.M. and Bulawka A.O., Photovoltaics, Environmental Impact of, Encyclopedia of Energy, Vol. 5, 61-69, Elsevier, 2004.

60. Wang W. and Fthenakis V.M. Kinetics Study on Separation of Cadmium from Tellurium in Acidic Solution Media Using Cation Exchange Resin, Journal of Hazardous Materials, B125, 80-88, 2005.

61. Fthenakis V.M., Fuhrmann M., Heiser J. Lanzirotti A., Fitts, J. and Wang W., Emissions and Encapsulation of Cadmium in CdTe PV Modules during Fires, Progress in Photovoltaics: Research and Applications, 13: 713-723, 2005.

62. Mason J., Fthenakis V.M., Hansen T. and Kim C. Energy Pay-Back and Life Cycle CO2 Emissions of the BOS in an Optimized 3.5 MW PV Installation, Progress in Photovoltaics: Research and Applications, 14, 179-190, 2006.

63. Fthenakis V.M and Wang W., Extraction and Separation of Cd and Te from Cadmium Telluride Photovoltaic Manufacturing Scrap, Progress in Photovoltaics: Research and Applications, 14:363-371, 2006.

64. Fthenakis V.M. and Alsema E., Photovoltaics Energy Payback Times, Greenhouse Gas Emissions and External Costs: 2004-early 2005 Status, Progress in Photovoltaics Research and Applications, 14:275-280, 2006.

65. Fthenakis V.M. and Kim H.C., Greenhouse gas Emissions from Solar Electric and Nuclear Power: A Life Cycle Study, Energy Policy, 35, 2549-2557, 2007.

66. Fthenakis V.M. and Kim H.C., CdTe Photovoltaics: Life-cycle environmental profile and comparisons, Thin Solid Films, 515, 5961-5963, 2007.

67. Fthenakis V.M. and Kim H.C. Photovoltaics Life Cycle Analysis, Advances of Solar Energy, in press.

68. Fthenakis V.M., Kim H.C. and Alsema E., Emissions from photovoltaic life cycles, Environ. Sci. Technol., *42* (6), 2168–2174, 2008

69. Fthenakis V.M., Wang W. and Kim H.C, Life Cycle Inventory Analysis in the Production of Metals used in Photovoltaics, Renewable and Sustainable Energy Reviews, 13, 493-517, 2009.

70. Zweibel K., Mason J. and Fthenakis V., A Solar Grand Plan, Scientific American, 298(1), 64-73, 2008.

71. Mason J., Hansen T., Fthenakis V.. and Zweibel K., Coupling PV and CAES Power Plants to Transform Intermittent PV Electricity into a Dispachable Electricity Source, Progress in Photovoltaics Research and Applications, 16, 649-668, 2008.

72. Zweibel K., Mason J. and Fthenakis V. Solar Grand Plan: Solar as a Solution, Sun&Wind Energy, 4 (2008) 112-117.

73. Fthenakis V. Mason J. and Zweibel K., The Technical, Geographical and Economic Feasibility for Solar Energy to Supply the Energy Needs of the United States, Energy Policy, 37, 387-399, 2009.

74. Fthenakis V.M., and Kim H.C, Land Use and Electricity Generation: A Life Cycle Analysis, Renewable and Sustainable Energy Reviews, 13, 1465-1474, 2009.

75. Fthenakis V.M., Sustainability of photovoltaics: The case for thin-film solar cells, Renewable and Sustainable Energy Reviews, 13, 2746-2750, 2009.

76. Dunjo J. Fthenakis V.M, Vilchez J.A. and Arnaldos J., HAZard and Operability (HAZOP) Analysis: A Review, Journal of Hazardous Materials, in press.

77. Kim H.C. and Fthenakis V.M., Comparative Life Cycle Energy Payback Analysis of multi-junction a-SiGe and nanocrystalline /a-Si modules, Progress in Photovoltaics Research and Applications, 18, 1-13, 2010. (DOI:10.1002/pip.990)

78. Choi J.K. and Fthenakis V.M., Economic Feasibility of Photovoltaic Module Recycling: Survey and Model, Journal of Industrial Ecology, in press.

79. Fthenakis V.M. and Kim H.C., Life-cycle of water in U.S. electricity generation, Renewable and Sustainable Energy Reviews, in press. http://dx.doi.org/10.1016/j.rser.2010.03.008

80. Raugei M. and Fthenakis V.M., The expected future role of CdTe PV in global cadmium flows and emissions, Energy Policy, in press.

81. Fthenakis V.M., Clark D., Moalem M., Chandler P., Ridgeway R., Hulbert F., Cooper D. and Maroulis P., Nirogen Trifluoride Emissions from Photovoltaics: A Life-Cycle Assessment, Environ. Sci. Technol, in review.

82. Fthenakis V.M. and Kim H.C., Life Cycle Assessment of High-Concentration PV systems, Progress in Photovoltaics Research and Applications, in review.

83. Burrows K. and Fthenakis V.M. M., Glass Needs for a Growing Photovoltaics Industry, Progress in Photovoltaics Research and Applications, in review.

84. Choi J.K. and Fthenakis V.M., Design and Optimization of Photovoltaics Recycling Infrastructure, Environ. Sci. Technol, in review.

PEER-REVIEWED CONFERENCE PAPERS

85. Happel, J., Fthenakis, V., Suzuki, I., Yoshida, T., and Ozawa, S. Transient Isotope Tracing of Methanation Over Ni Catalyst, VII International Congress on Catalysis, 542-553, Tokyo, Elsevier (1981).

86. Moskowitz, P.D., Fthenakis, V.M., Hamilton, Lee, J.C., and Bulawka, A. Gas Health and Safety Hazards and Controls Associated with the Production of Thin-Film Photovoltaic Cells. Eighteenth IEEE Photovoltaic Specialists Conference, 1261-1266, 1985.

87. Moskowitz, P.D., V.M. Fthenakis, and P.D. Kalb, Preventing and Controlling Accidental Gas Releases, Photovoltaic Safety, (AIP 166), 161-174, American Institute of Physics, New York (1988).

88. Fthenakis, V.M. and Moskowitz, P.D., Control of Accidental Releases of Hydrogen Selenide in Vented Storage, Photovoltaic Safety, (AIP 166), 79-88, American Institute of Physics, New York (1988).

89. Moskowitz, P.D., Zweibel, K., and Fthenakis, V.M., Health, Safety and Environmental Issues Related to the Production, Use and Disposal of Cadmium-Based Photovoltaic Modules, Twenty-first IEEE Photovoltaic Specialists Conference, 1040-1042, 1990.

90. Fthenakis V.M., Lipfert F. and Moskowitz P.D., An Assessment of Mercury Emissions and Health Risks from Coal Combustion, Proceedings AIChE National Meeting, Denver, August 15, 1994.

91. Fthenakis V.M. Blewitt D.N. and Hague W.J., Modelling Absorption and Dilution of Unconfined Releases of Hazardous Gases by Water Curtains or Monitors, Proceedings of the International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety (CCPS), New Orleans, LA, September 26-29, 1995.

92. Fthenakis V.M., Mitigation Options for Accidental Releases of Hazardous Gases, Proceedings of the International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety (CCPS), New Orleans, LA, September 26-29, 1995.

93. Lipfert F., Fthenakis V.M., Moskowitz P.D., and Saroff L., Limiting the Propagation of Error in Probabilistic Risk Assessment Modeling: Methylmercury as an Example, Probabilistic Safety Assessment and Management'96, June 24-28, 1996, ESREL'96/PSAM-III, Vol. 3, pp. 2215-2220, Springer, London, 1996.

94. Fthenakis V.M., Mitigation of Unconfined Releases of Hazardous Gases via Liquid Spraying, Invited Paper, Proceedings American Nuclear Society Meeting on Emergency Preparedness and Response, Vol. II, pp. 677-680, San Francisco, April 22-25, 1997.

95. Fthenakis V.M., Approaches for Preventing and Mitigating Accidental Gaseous Chemical Releases, Proceedings American Nuclear Society Sixth Meeting on Emergency Preparedness and Response, Vol. II, pp. 673-676, San Francisco, Invited Paper, April 22-25, 1997.

96. Fthenakis V.M. and Moskowitz P.D., Emerging Photovoltaic Technologies: Environmental and Health Issues Update, 14th NREL Photovoltaics Program Review, American Institute of Physics, Conference Proceedings 394, 903-914, 1997.

97. Fthenakis V.M., Mitigation of Ammonia Aerosol Release via Water Spraying, Proceedings AIChE Symposium Ammonia Plant Safety, vol. 38, pp. 155-163, San Francisco, CA, Sept. 22-24, 1997.

98. Eberspacher C. and Fthenakis V.M., Disposal and Recycling of End-of-Life PV Modules, 26th Proceedings IEEE Photovoltaics Specialists Conference, Anaheim, October 1997, pp. 1067-1072, Institute of Electrical and Electronics Engineers, Picataway, NJ.

99. Fthenakis V.M., Mitigation of Ammonia Release via Water Spraying, Ammonia Plant Safety, vol. 38, pp. 155-163, American Institute of Chemical Engineers, New York, 1998.

100. Fthenakis V.M. The Value and Feasibility of Proactive Recycling. NCPV Program Review Meeting, Sept. 8-11, 1998, Denver CO; American Institute of Physics Conference Proceedings 462, pp. 332-337, American Institute of Physics, Woodbury, NY, 1999.

101. Fthenakis V.M. and Themelis N., Assessing and Managing Risks in Engineering, EARTHmatters, Columbia Earth Institute, winter 1998-99, 20-21, 1999. (invited *)

102. Fthenakis V., Ammonia Mitigation Study, Proceedings AIChe 48th Annual Safety in Ammonia Plants and Related Facilities Symposium, Vol. 44, pp. 89-93, Sept. 15, 2003, Orlando, FL.

103. Fthenakis V.M., Modeling of Accidental Releases of Anhydrous Ammonia and their Atmospheric Dispersion, Proceedings AIChE 49th Annual Symposium Safety in Ammonia Plants, Vol. 45, pp. 284-293, September 20-23, 2004, Denver CO.

104. Fthenakis V.M., Life Cycle Impact Analysis of Cadmium in CdTe PV Modules, 19th European Photovoltaic Solar Energy Conference, June 7-11 2004, Paris, France

105. Fthenakis V.M., Heiser J. and Fuhrmann M. and Wang W., Experimental Investigation of Emissions and Redistribution of Elements in CdTe PV Modules During Fires, 19th European Photovoltaic Solar Energy Conference, June 7-11 2004, Paris, France.

106. Fthenakis V.M., Alsema E., and M.J. de Wild-Scholten, Life Cycle Assessment of Photovoltaics: Perceptions, Needs, and Challenges, Proceedings 31st IEEE Photovoltaic Specialists Conference, ISBN: 0-7803-8708-2, pp 1655-1658, 2005.

107. Fthenakis V.M. and H.C. Kim, Life Cycle Energy Use and Greenhouse Gas Emissions in the Life Cycle of CdTe Photovoltaics. Materials Research Society Symposium Proceeding, Vol. 895, *83*-88, 2006.

108. Kim H.C. and Fthenakis V.M, Amonix High-Concentrator Photovoltaic system: Life cycle energy demand and greenhouse gas emissions, Proceedings IEEE 4th World Conference on Photovoltaic Energy Conversion, Hawaii, May 8-12, 2006, pp. 628-631.

109. Fthenakis V.M., Quantifying the life-cycle environmental profile of photovoltaics and comparisons with other electricity-generation technologies, Proceedings IEEE 4th World Conference on Photovoltaic Energy Conversion, Hawaii, May 8-12, 2006, pp. 2477-2480.

110. de Wild-Scholten M.J., Alsema E., ter Horst E.W., Bachler M. and Fthenakis V.M., A Cost and Environmental Impact Comparison of Grid-Connected Rooftop and Ground-Based PV Systems, Proceedings 21st European Photovoltaic Solar Energy Conference, Dresden, Germany, 4-8 September 2006, pp. 3167-3172.

111. Alsema E., de Wild-Scholten M.J. and Fthenakis V.M., Environmental Impacts of PV Electricity Generation - A Critical Comparison of Energy Supply Options, Proceedings 21st European Photovoltaic Solar Energy Conference, Dresden, Germany, 4-8 September 2006, pp. 3201-3207.

112. Fthenakis V.M., Colli A., Arellano A., Kirchsteiger C., and Ale B., Evaluation of Photovoltaics in a Comparative Context, Proceedings 21st European Photovoltaic Solar Energy Conference, Dresden, Germany, 4-8 September 2006, pp. 3194-3201.

113. Fthenakis V.M., Carlisle C. and Chan W., Silane Safety in amorphous silicon and silicon nitride operations, Proceedings 21st European Photovoltaic Solar Energy Conference, Dresden, Germany, 4-8 September 2006, 1761-1783.

114. Fthenakis V.M., Wang W., Meader A., and Squires K., Recycling of CdTe Photovoltaic Modules: Recovery of Glass, Cadmium and Tellurium, Proceedings 21st European Photovoltaic Solar Energy Conference, Dresden, Germany, 4-8 September 2006, pp. 2539-2541.

115. deWild-Scholten M., Alsema E., Fthenakis V., Agostinelli G., Dekkers H., Roth K., Kinzig V., Fluorinated Greenhouse Gases in Photovoltaic Module Manufacturing: Potential Emissions and Abatement Strategies, 22nd European Photovoltaic Solar Energy Conference, Milan, Italy, 3-7 September 2007.

116. Fthenakis V. and Kim H. C., Cu(InGa)Se2 Thin-Film Solar Cells: Comparative Life-Cycle Analysis of Buffer Layers, Proceedings 22nd European Photovoltaic Solar Energy Conference, Milan, Italy, 3-7 September 2007.

117. Raugei M., Frankl P., Alsema E., de Wild-Scholten M., Fthenakis V., Kim H.C., Life Cycle Assessment of present and Future Photovoltaic Systems, AIST Symposium Renewable Energy 2007, Chiba, Japan, October 11, 2007.

118. Fthenakis V.M., S. Gualtero, van der Meulen R., and Kim H. C., Comparative Life-cycle Analysis of Photovoltaics Based on Nano-materials: A Proposed Framework. Materials Research Society Symposium Proceeding Vol. 1041, R01-03, 2008.

119. Kim H. C. and Fthenakis V. M. The Fuel Cycles of Electricity Generation: A Comparison of Land Use. Materials Research Society Symposium Proceeding Vol. 1041, R05-03, 2008.

120. Fthenakis V.M., Mason J. and Zweibel K., A Grand Plan for Solar Energy: Starting form the United States, Proceedings 23rd European Photovoltaic Solar Energy Conference, Valencia, Spain, 1-4 Sept. 2008.

121. Fthenakis V. and Kim H.C., Life Cycle Analysis of two new Concentrator PV Systems, 23rd European Photovoltaic Solar Energy Conference, Valencia, Spain, 1-4 Sept. 2008.

122. Fthenakis V., Kim H., Gualtero S. and Bourtsalas A., Nanomaterials in PV Manufacture: Some Life Cycle Environmental and Health Considerations, Proceedings 34th IEEE PV Specialists Conference, Philadelphia, June 2009.

123. Fthenakis V., Raugei M., Held M., Kim H. C., Krones J. An update of Energy Payback Times and Greenhouse Gas emissions in the Life Cycle of Photovoltaics, Proceedings 24th European Photovoltaic Solar Energy Conference, Hamburg, Germany, 21-25 September 2009.

124. Fthenakis V. and Kim H. C., Life Cycle Assessment of Amonix 7700 HCPV Systems, Proceeding 6th Concentrating Photovoltaics Conference, CPV-6, April 2009, Freiberg, GER.

BOOK CHAPTERS (INVITED)

125. Fthenakis, V.M. and Moskowitz, P.D., Photovoltaic Energy Systems, Energy Technologies & the Environment, 19, 367-381, U.S. Department of Energy, Wash. DC, 1988.

126. Moskowitz, P.D., Fthenakis, V.M., Morris S.C. and Hamilton L.D., Approaches for Identifying, Characterizing and Managing Risks from Accidentally Released Toxic gases, Hazard Assessment and Control Technology in Semiconductor Manufacturing, 22, 271-283, Lewis Publishers, Michigan, 1989.

127. Moskowitz, P.D., Fthenakis, V.M., Youngblood and Mendez S.R., Evaluating Risks Associated with the Use of Silane, Hazard Assessment and Control Technology in Semiconductor Manufacturing, 10, 97-113, Lewis Publishers, Michigan, 1989.

128. Moskowitz, P. D. and Fthenakis, V. M., Identification, Characterization and Management of Risks from Accidentally Released Toxic Gases, Hazard Assessment of Chemicals, (Saxena, ed.), 83-109, Hemisphere Publishing, (1990).

129. Moskowitz, P.D., V.F. Fthenakis, L.D. Hamilton, P. Kalb, and J. Lee, Risks in New Technologies - Controlling Toxic and Hazardous Gas Releases During Photovoltaic Cell Manufacture, New Risks: Issues & Management (L.A. Cox and P.F. Ricci, ed.), 129-135, Plenum Press, New York, 1990.

130. Morris, S.C., P.D. Moskowitz, and V.F. Fthenakis, Comparison of EPA, ILO, and World Bank Guidelines for Risk Identification, Assessment, and Management of Chemical Emergencies, New Risks: Issues & Management (L.A. Cox and P.F. Ricci, ed.), 23-32, Plenum Press, New York, 1990.

131. Fthenakis, V.M., K.W. Schatz and V. Zakkay, Modeling of Water Spraying of Field Releases of Hydrogen Fluoride, International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, 403-429, American Institute of Chemical Engineers, New York, 1991.

132. Moskowitz, P.D., Fthenakis, V.M., and A. Hemenway, The Clean Air Act Amendments of 1990: Hazardous Air Pollutant Requirements and the DOE Clean Coal Technology Program, EPRI TR-101890, Managing Hazardous Air Pollutants: State of the Art,. 439-453, 1991.

133. Moskowitz, P. D.; Fthenakis, V. M.; Crandall, R. S.; Nelson, B. P. (1993). Safety Analysis for the Use of Hazardous Production Materials in Photovoltaic Applications. Prince, M., ed. Advances in Solar Energy: An Annual Review of Research and Development; Volume 8. Boulder, CO: American Solar Energy Society Chapter 17, pp. 345-396.

134. Moskowitz P.D., Bernholc N., Fthenakis V.M., Pardi R.M., Steinberger H. and Thumm W. Environmental, Health and Safety Issues Related to the Production and Use of Cadmium Telluride Photovoltaic Modules, Vol. 10, Advances in Solar Energy: An Annual Review of Research and Development (ed. K.W. Boer), 4,. 211-245, American Solar Energy Society, Inc., Boulder, CO, 1995.

135. Fthenakis V., Overview of Potential Hazards, Chapter V-1, pp.857-868, in Practical Handbook of Photovoltaics: Fundamentals and Applications, (Editors: T. Markvart and L. Gastaner), Elsevier, 2003.

136. Fthenakis V., Environmental, Health, and Safety Risks from Photovoltaics: An Overview, Wiley, in press

CONFERENCE & SYMPOSIUM PRESENTATIONS, REVIEWS & EDITORIALS

137. Happel, J. et al. and Fthenakis, V., Transient Tracing of Methanation, presented at the Joint Spring meeting of the New York-New England Catalysis Society, March 15, 1980, Yale University.

138. Fthenakis, V.M., Moskowitz, P.D., and Hamilton, L.D. Potential Health and Safety Hazards Associated with the Manufacture of Amorphous Silicon and Copper Indium Diselenide Photovoltaic Cells. Presented at the Intersol 85, Biennial Congress of the International Solar Energy Society (ISES), Montreal, Canada, June 1985.

139. Fthenakis, V.M. and Moskowitz, P.D. Production of Thin-Film Photovoltaic Cells: Health and Environmental Effects, BNL 37306. Presented at the 1985 Annual Symposium in Energy and Economic Development: Global Views and Issues in Greece, Massachusetts Institute of Technology, Cambridge, Massachusetts, Oct. 11-13, 1985.

140. Moskowitz, P.D., Fthenakis, V.M., Hamilton, L.D., Kalb, P., and Lee, J.C., Risk in New Technologies - Controlling Toxic Gas Releases During Photovoltaic Cell Manufacture, presented at Society for Risk Analysis, 1986 Annual Meeting, Boston, MA, November 9-12, 1986.

141. Morris, S.C., Moskowitz, P.D., Fthenakis, V.M., and Hamilton, L.D., Comparison of EPA, ILO, and World Bank Guidelines for Risk Identification, Assessment, or Management of Chemical Emergencies, presented at Society for Risk Analysis, 1986 Annual Meeting, Boston, MA, November 9-12, 1986.

142. Fthenakis, V.M. and Moskowitz, P.D. Don't Forget Electrical Shock Hazards, Environment, Safety and Health Bulletin, June 1986.

143. Moskowitz, P.D., Fthenakis, V.M., and Youngblood, R., Fault Tree and Consequence Analysis of Potential Hazards in the Photovoltaics Industry, presented at the ASCE Energy Division Specialty Conference, Atlantic City, NJ, April 27-30, 1987.

144. Fthenakis, V.M. and Moskowitz P.D., Design and Reliability of Two Systems for Controlling Accidental Hydrogen Selenide Releases, Presented at the 2nd SERI/DOE PV Safety Conference, Denver, Colorado, January 1988.

145. Stasko S. and Fthenakis V.M., MMSOILS Review, Risk Analysis Journal, 13(5) 1993, pp. 575-579.

146. Fthenakis, V.M., Review of "Sunlight to Electricity, Photovoltaic Technology and Business Prospects," Environment International 10(3):270 (1984).

147. Fthenakis, V.M., Review of "Guidelines for Hazard Evaluation Procedures", Environment International 14:65-66 (1988).

148. Fthenakis, V.M. and P.D. Moskowitz, Source Term and Consequence Modeling, Risk Analysis Journal, 7(3):405 (1987).

149. Fthenakis V., Controls of Accidental Releases of Hazardous Gases, Editorial, Journal of Loss Prevention, 3(2), 186, 1990.

150. Fthenakis V.M., Safety and Environmental Issues in High-tech Technologies, Presented at the National Technology Initiative, Research Triangle Park, Raleigh, NC, May 12, 1992.

151. Fthenakis, V.M., Mathematical Models for Mitigation, Workshop on Mitigation, International Conference & Workshop on Modeling & Mitigating the Consequences of Accidental Releases of Hazardous Materials, New Orleans, May 20, 1991.

152. Fthenakis V.M., Workshop on Long Island's Environmental Needs and Concerns, State University of New York, Stonybrook , 1992

153. Moskowitz P.D., Viren, J. and Fthenakis V.M., An update on environmental, health and safety issues of interest to the photovoltaic industry, presented at the 11th Annual PV R&D Conference, Golden, CO, May 13-15, 1992: BNL 47666, Upton, NY, 1992.

154. Nelson, B.P., Crandall R.S. Moskowitz P.D. and Fthenakis, V.M. Overview of safety assessment, regulation, and control of hazardous material at NREL, American Institute of Physics (AIP) Proceedings 11th Annual PV R&D Conference, 268, 549-555, Golden, CO, May 13-15, 1992; BNL 47653, Upton, NY, 1992.

155. Von Roerdern, B.; Nelson, B. P.; Moskowitz, P. D.; Fthenakis, V. M.; Crandall, R. S.; Iwaniczko, E.; McConnell, R. J.; Van Geet, O. D.; Xu, Y. (1992). Safety Analysis Report for the Amorphous Silicon Deposition Laboratory at the Joyce Street Facility. 115 pp.

156. Fthenakis V.M. and Blewitt D.N., Modeling Mitigation via Water Sprays of Accidental Releases of Hazardous Gases, presented at Air & Waste Management Association 87th Annual Meeting, Cincinnati, Ohio, June 20-24, 1994.

157. Fthenakis V.M., The current and future trends in chemical engineering education and research in the U.S. and Europe and the needs in Greece, Invited lecture, Technical University of Crete, Greece, Dec. 1993.

158. Fthenakis V.M., Computer Tools for Design of Scrubbers, SEMATECH S66a Scrubber Workshop, Austin, TX, Oct. 26, 1994.

159. Fthenakis V.M., Pilot Tests Analysis" and A Computer Model of Cross-Flow in Packed Bed Scrubbers in MS Excel Visual Basic", SEMATECH S66a Scrubber Optimization Workshop, Austin, TX, Dec. 4-5, 1995.

160. Fthenakis V.M., Cross-Flow versus Countercurrent Flow Packed-Bed Scrubbers: A Mathematical Analysis, Proceedings AIChE Spring National Meeting, New Orleans, Louisiana, February 28, 1996.

161. Steiberger H., Hochwimmer R., Schmid H., Thumm W., Kettrup A., Moskowitz P.D., and Fthenakis V.M., Environmental Impacts of Mining and Manufacturing Cycles of Cadmium-Telluride Photovoltaic Cells, presented at Probabilistic Safety Assessment and Management'96, ESREL'96/PSAM-III June 24-28, 1996.

162. Fthenakis V.M., Health and Environmental Issues Related to Manufacture, Use and Disposal of Photovoltaic Cells, Earth Engineering Seminar, Department of Chemical Engineering, Columbia University, September 27, 1996.

163. Fthenakis V.M., DEGATEC-A Windows Version of DEGADIS, Software Review, Journal of Loss Prevention, 10(2), 135-137, 1997.

164. Fthenakis V.M., Projected Photovoltaic Energy Impacts on US CO_2 Emissions, 8th Global Warming International Conference, Columbia University, New York, NY, May 26-29, 1997.

165. Fthenakis V.M. Prevention and Control of Accidental Releases of Hazardous Gases, International Energy Agency (IEA) PV Expert Workshop, Utrecht, Holland, June 25-27, 1997:

166. Fthenakis V.M., MARKAL-MACRO: A Computer Tool for Integrated Energy-Environmental-Economic Analysis, presented at the Workshop PV and the Environment 1998, Keystone, CO, July 23-24, 1998, Paper 2-4, BNL-52557.

167. Fthenakis V.M., MARKAL-MACRO: A Computer Tool for Integrated Energy-Environmental-Economic Analysis, Proceedings of the Workshop "PV and the Environment 1998", Keystone, CO, July 23-24, 1998, Paper 2-4, BNL-52557.

168. Andrijievskij A, Fthenakis V.M., Loukashevich A, and Trifonov A., LOCMIGR, A Computer package for Simulation of Aerosol Releases in The Environment, Proceedings of ANS 7th Topical Meeting on Emergency Preparedness and Response, Santa Fe, New Mexico, USA, 14-17 September 1999.

169. Fthenakis V.M. Impact of RCRA and TCLP, presented at the Sandia Solder-Joint Durability Symposium, Feb. 18-19, 1999, Albuquerque, NM

170. Fthenakis V., Guidelines for Post-Release Mitigation Technology in the Chemical Process Industry, Process Safety and Environmental Protection, Trans IChemE, 77(B3), 1999.

171. Fthenakis V., (editor) Proceedings of the Pb-free Solder Technology Transfer Workshop, October 19, 1999, Vail, CO, Brookhaven National Laboratory Report, 1999.

172. Fthenakis V.M., A Review of Recent Silane Explosion Tests, NCPV 2000 Program Review Meeting, Denver, CO, April 17-19, 2000.

173. Fthenakis V.M., Multi-layer Hazard Management for Manufacturing Facilities, Semiconductor Safety Association (SSA) Annual Symposium, New Orleans, LA, April 13, 2001.

174. Fthenakis V.M., Multi-layer Protection Analysis for Photovoltaic Manufacturing Facilities, Paper 2e, Proceedings of the American Institute of Chemical Engineers (AIChE) 35th Annual Loss Prevention Symposium, Houston, TX, April 23, 2001.

175. Fthenakis V.M., Accident Prevention and Hazard Management for Photovoltaic Manufacturing Facilities, NCPV Program Review Meeting, Golden, CO, October 14-17, 2001

176. Fthenakis V.M., Predictions of Future PV Capacity and CO_2 Emissions' Reduction in the United States, NCPV Program Review Meeting, Golden, CO, October 14-17, 2001.

177. Fthenakis V., Process Hazard Analysis, Environmental Health and Safety Tutorial, 29th IEEE-PVSC, May 20, 2002.

178. Fthenakis V.M. and Zweibel K., CdTe PV: Real and Perceived Risks, Presented at the NCPV and Solar Program Review Meeting, March 24-26, 2003, Denver, CO, NREL Report No. CP-520-33561.

179. Morris S. and Fthenakis V., MARKAL Analysis of PV Capacity and CO2 Emissions/ Reduction in the US, 3rd World Conference on Photovoltaic Energy Conversion, WCPEC-3, May 12-16, 2003, Osaka, Japan.

180. Fthenakis V., EHS Issues in III-V solar Cell Manufacturing, 3rd World Conference on Photovoltaic Energy Conversion, WCPEC-3, May 12-16, 2003, Osaka, Japan.

181. Fthenakis V., The Role of Hazard Analysis in PV Manufacture, 3rd World Conference on Photovoltaic Energy Conversion, WCPEC-3, May 12-16, 2003, Osaka, Japan.

182. Fthenakis V.M., Life Cycle Analysis of Cadmium in Photovoltaic Modules, Columbia University Colloquium Series, March 2, 2004.

183. Fthenakis V.M., Life Cycle Analysis of Cadmium in CdTe Photovoltaic Modules, EEC Workshop on Life Cycle Analysis of Solar Modules, March 18, 2004.

184. Fthenakis V.M., BNL Research on Recycling, EEC Workshop on Life Cycle Analysis of Solar Modules, March 18, 2004, March 19, 2004.

185. Fthenakis V. and Wang W. Progress in cadmium telluride photovoltaic module recycling, presented at the DOE Solar Program Review Meeting, Denver, CO, October 25-28, 2004.

186. Fthenakis V. and W. Wang W., Environmental Impact Assessment for Elements used in Cu(InGa)Se_2 Photovoltaics, presented at the DOE Solar Program Review Meeting, Denver, CO, October 25-28, 2004.

187. Wang W. and Fthenakis V.M., Feasibility of Recycling of Cadmium-Telluride Photovoltaics, The Minerals, Metals & Materials Society (TMS 2005) Extraction & Processing Division (EPD) Congress 2005, pp. 1053-1064.

188. Fthenakis V., Promising Advances in Photovoltaics, Critical Issues Editorial, *Chemical Engineering Progress*, 101(4), 5, 2005.

189. Fthenakis V.M. and Wang W., Emission Factors in the Production of Materials Used in Photovoltaics, 20th EURPVSEC, Barcelona, Spain, June 6-10, 2005

190. Fthenakis V.M. and Wang W., Advances on Recycling of CdTe and CIGS Photovoltaic Modules, 20th EURPVSEC, Barcelona, Spain, June 6-10, 2005.

191. Fthenakis V.M. and H.C. Kim, Life Cycle Greenhouse Gas emissions from the Nuclear and Photovoltaic Fuel Cycle, Material Research Society, Symposium G, Life Cycle Analysis Tools for "Green" Materials and Process Selection, Nov. 2005, Boston, MS.

192. Fthenakis V.M. Life Cycle Analysis: Some Science and Energy Policy Issues. Department of Earth & Environmental Engineering, Fall 2005 Seminar Series, September 30, 2005. .(viewgraphs*).*

193. Wang W. and Fthenakis V.M., Recovery of Tellurium from Cadmium Telluride Photovoltaic Module Manufacturing Scrap &other Sources, The Minerals, Metals & Materials Society (TMS 2006), 135th Annual Meeting & Exhibition, San Antonio, Texas, March 12-16, 2006.

194. Fthenakis V. Solar Energy and the Environment, Alternate Energy Workshop, Brookhaven National Laboratory, March 2006

195. Fthenakis V.M., CdTe Photovoltaics Life Cycle Analysis, European Material Research Society Meeting (EU-MRS), Symposium O, Invited Paper, Nice, France, May 29-June 2006.

196. Fthenakis V.M. Photovoltaics Life Cycle Analysis, Invited plenary presentation, Renewable Energy 2006, Chiba, Japan, October 11, 2006.

197. Fthenakis V.M., Mason J., Hansen T., Zweibel K., The potential for large-scale integration of PV with compressed air energy storage, 33rd IEEE Photovoltaic Specialists Conference, May 11-16, 2008, San Diego, CA.

198. Ngai E. and Fthenakis V.M., Lessons Learned from accidents involving metal hydride gases in PV manufacturing, 33rd IEEE Photovoltaic Specialists Conference, May 11-16, 2008, San Diego, CA.

199. Fthenakis V.M., Sustainability of thin-film CIGS and CdTe photovoltaics, 33rd IEEE Photovoltaic Specialists Conference, May 11-16, 2008, San Diego, CA.

200. Ngai E. and Fthenakis V.M., Silane Safety Seminar, 33rd IEEE Photovoltaic Specialists Conference, May 11-16, 2008, San Diego, CA.

201. Fthenakis V.M., The technical, geographical and economic feasibility for the solar energy to supply the energy needs of the United States, Columbia University Energy Seminars, March 28, 2008.

202. Fthenakis V.M., The potential of Solar Energy In the United States, State University of NY at Stony Brook, Sponsored by Materials Science Dpt., Physics Dpt and the Advanced Energy Research and Technology Center, Nov. 10, 2008.

203. Fthenakis V.M., Photovoltaics Recycling and Sustainability, IEEEPVSC Recycling Scoping Workshop, June 2009.

204. Choi J-K. and Fthenakis V.M., A Model for Optimization of Cost and Revenue in Photovoltaics Recycling, Photovoltaics Recycling and Sustainability, IEEEPVSC Recycling Scoping Workshop, June 2009.

TECHNICAL REPORTS

205. Leigh, R.W. and Fthenakis, V.M. The Value of Technical Improvements in Passive Solar Collection-Storage Devices, BNL 51486, Nov. 1981.

206. Fthenakis, V.M. and Leigh, R.W. The Fuel Conservation Potential of Solar Storage Walls, BNL Report, 1982.

207. D'Acierno, J., Beller, M., and Lamontagne, J. (Fthenakis, V.M. et al. Contributor). Resource, Capital, and Labor Requirements of the National Energy Plan: 1980-2000, BNL 51497, Aug. 1982.

208. Fthenakis, V.M., Lee, J.C., and Moskowitz, P.D. Amorphous Silicon and Gallium Arsenide Thin-Film Technologies for Photovoltaic Cell Production: An Identification of Potential Health and Safety Hazards, BNL 51768, Oct. 1983.

209. Fthenakis, V.M. and Moskowitz, P.D. Characterization of Gas Hazards in the Manufacture of a-Si Photovoltaic Cells, BNL 51854, April 1985.

210. Fthenakis, V.M. Hazards from Radio-Frequency and Laser Equipment in the Manufacture of a-Si Photovoltaic Cells, BNL 51853, April 1985.

211. Moskowitz, P.D., Fthenakis, V.M., and Lee, J.C. Potential Health and Safety Hazards Associated with the Production of Cadmium Telluride, Copper Indium Diselenide, and Zinc Phosphide Photovoltaic Cells, BNL 51832, April 1985.

212. Fthenakis, V.M., Moskowitz, P.D., and Sproull, R.D. Specifying Environmental Control Systems for Toxic Gases: A Case Study for Hydrogen Selenide and Hydrogen Sulfide, BNL 39203, 1986.

213. Moskowitz, P.D., Zweibel, K., and Fthenakis, V.M., Health, Safety and Environmental Issues Related to Cadmium Usage in Photovoltaic Energy Systems, BNL 44946, NREL TR-211-3621. Dec. 1989.

214. P.D. Moskowitz and V.M. Fthenakis, Environmental, Health and Safety Issues Associated with the Manufacture and Use of II-VI Photovoltaic Devices, BNL45907, Oct. 1990.

215. Fthenakis, V.M., and Moskowitz, P.D. Manufacture of Thin Film Photovoltaic Cells: Identification of Potential Health and Safety Hazards in Miscellaneous Processes, BNL Draft, 1987.

216. Moskowitz, P.D., Fthenakis, V.M., Lee J.C., and L.D. Hamilton, Process Characteristics, Environmental Hazards, and Control Management Options for large-scale Crystalline Silicon and Amorphous Silicon Photovoltaic Cell Manufacturing Facilities. Prepared for Energia Nuclear e dell Energia Alternative, Rome, Italy, 1988.

217. Moskowitz, P.D., and Fthenakis V.M. Toxic Materials Released from Photovoltaic Modules During Fires: Health Risks. BNL Draft, 1989.

218. Fthenakis, V.M. and Moskowitz, P.D. Manufacture of Thin-Film Photovoltaic Cells: Characterization and Management of Phosphine Hazards, BNL 51989, Feb. 1986.

219. Fthenakis V.M., Preliminary Environmental Audit Report, prepared for Standard Microsystems Corporation, Hauppauge, NY, May 1987.

220. Moskowitz, P.D., and Fthenakis V.M. Compendium of Safe Practices in Photovoltaic Cell Manufacturing. BNL, 1989.

221. Fthenakis V.M., Safety Assessment of a Silane Distribution System, prepared for Eastman Kodak Co., Rochester, NY, Aug. 1990.

222. Fthenakis, V.M., Modeling of Water Spraying of HF Releases, Report prepared for the Industry Cooperative HF Mitigation / Assessment Program, Dec. 1990.

223. Fthenakis, V.M., Modeling of Large-scale Spraying of Unconfined HF Releases, prepared for Amoco Corp., Chicago, IL, Nov. 1990

224. Fthenakis, V.M., Review of a South Coast Air Quality Management Document, ENV-101, prepared for Ultramar Inc., Long Beach, CA, June 1990.

225. Fthenakis, V.M., Modeling the Atmospheric Dispersion of Accidentally Released Heavy Gases from Photovoltaic Cell Manufacturing Facilities, BNL 52058, June 1991.

226. Moskowitz P.D., DePhillips, M.P., Fthenakis V.M. and Hemenway A., The Clean Air Act Amendments of 1990: Hazardous Air Pollutant Requirements and the DOE Clean Cola Technology Program, BNL-47167, Nov. 1991

227. Fthenakis V.M., Simulations of water spray systems for Amoco Chemical's Texas City Plant, ENV-5-106, prepared for Amoco Chemical Company, Texas City, 1992.

228. DePhillips, M.P., Moskowitz P.D. and Fthenakis V.M., SUNRAYCE 93: Working safely with lead-acid batteries and photovoltaic power systems, BNL 48416, Upton, NY 1992.

229. Fthenakis V.M. and Moskowitz P.D., Control of particulate and gas emissions of Cd, Se, and As compounds in photovoltaic module manufacture, BNL Draft report, November 1993.

230. Fthenakis V.M., A review of accidents, prevention and mitigation options related to hazardous gases, BNL 49192, 1993.

231. Fthenakis V.M., Morris S.C. and Moskowitz P.D., Guidelines for accident prevention and emergency preparedness, BNL 49158, 1993.

232. Fthenakis V.M., Simulations of water monitor spraying, Final report, ENV-5-9405, prepared for Allied-Signal Inc., Morristown, NY, 1994.

233. Fthenakis V.M., Modeling of water spray systems in Amoco's Mandan refinery, ENV-5-9406, prepared for Amoco Corporation, Chicago, IL, 1994.

234. Lipfert F.W, Moskowitz P.D., Fthenakis V.M., Viren J. and Sarrof, L., An assessment of adult risks of paresthesia due to mercury from coal combustion. BNL49862, Upton NY, 1994.

235. DePhillips M.P., Fthenakis V.M. and Moskowitz P.D., Waste Reduction Options for Manufacturing of CIS Photovoltaic Cells, BNL-61769, March 1994.

236. Fthenakis V.M., Photovoltaic Modules and Electromagnetic Interference, BNL report, Jan. 1995.

237. Crandall R.S., Nelson, B.P., Moskowitz P.D. and Fthenakis, V.M. Safety analysis report (SAR) for the use of hazardous production materials in photovoltaic applications at the National Renewable Energy Laboratory, NREL/MP-451-4778A, National Renewable Energy Laboratory, Golden, CO., 1992.

238. Crandall R.S., Nelson, B.P., Moskowitz P.D. and Fthenakis, V.M. Safety analysis report (SAR) for the use of hazardous production materials in photovoltaic applications at the National Renewable Energy Laboratory, Volume II Appendices. 247 pp. NREL Report No. MP-451-4778-B, National Renewable Energy Laboratory, Golden, CO., 1992.

239. Fthenakis V.M., Comparison of Air Pollution Control Options for Toxic Gases in Photovoltaic and Semiconductor Manufacturing Facilities, AIChE 1996 Loss Prevention Symposium, LPS 1995, Paper 5d, Boston, MA, August 1995.

240. Moskowitz P.D., R. Pardi, Fthenakis V.M., Hotzman S., Sun l.C., Rambaugh J.O, and Potter S., Three Multimedia Models Used at Hazardous and Radioactive Waste Sites, BNL-62863, Feb. 1996, Brookhaven National Laboratory.

241. The OSHA and EPA Programs on Preventing Chemical Accidents and Potential Applications to the Photovoltaic Industry, BNL-63423, Aug. 1996.

242. Fthenakis V.M., Modeling of an Indoors HF Mitigation Water Deluge System, Final Report, ENV-5-9701, December 1997, prepared for 3M Corporation, St Paul, MN.

243. Fthenakis V.M., A HF Mitigation System for a RailCar Tank Unloading Station, Final Report, ENV-5-9803, April 1998, prepared for 3M Corporation, St Paul, MN.

244. Zweibel K., Moskowitz P. and Fthenakis V., Thin-Film Cadmium Telluride Photovoltaics: ES&H Issues, Solutions, and Perspectives, NREL/TP-520-24057, Feb. 1998.

245. Fthenakis V., Zweibel K., and Moskowitz P. Proceedings of the Photovoltaics and the Environment 1998, Workshop, July 23-24, 1998, Keystone, CO, BNL-52557, published Feb. 1999.

246. Fthenakis V., Optimization of the Tilt and Setting of Water Sprays for HF Mitigation, prepared for Dow Chemical, September 2000.

247. Fthenakis V., Regulations on Photovoltaic Module Disposal and Recycling, BNL Informal Report, January 29, 2001.

248. Fthenakis V. and Blewitt D., Performance Assessment of a Water Deluge System for Mitigating Accidental Releases of HF in a Chemical Plant, prepared for Dow Chemical, March 2001.

249. Fthenakis V. and Blewitt D., Modeling of HF Release and Atmospheric Dispersion, prepared for Dow Chemical, June 2001.

250. Bowerman B. and Fthenakis V., EH&S Analysis of Dye-Sensitized Photovoltaic Solar Cell Production, BNL Draft Report, September 2001.

251. Fthenakis V.M., Options for Greenhouse Gas Abatement from Exhaust Streams, BNL Draft Report, September 2001.

252. Fthenakis V. and Bowerman B., III-V Photovoltaics -An Update of EH&S Issues, BNL Draft Report, July 2002.

253. Fthenakis V.M., Nomination of CdTe to the National Toxicology Program, BNL Report, May 2003.

254. Chern D. and Fthenakis V. Material Inventory Analysis in Manufacturing Cu(InGa)Se2 Photovoltaics, BNL draft report, Aug. 2003.

255. Fthenakis V. and Alkons F. EHS Considerations for Large Chemical Systems in Hundred-Megawatt Photovoltaic Cell Manufacturing, BNL Draft Report, November 2003, Brookhaven National Laboratory, Upton, NY.

256. Fthenakis V.M. and Trammell S.R., Reference Guide For Hazard Analysis in PV Facilities, BNL Report, September 2003.

257. Wang W. and Fthenakis V.M., Leaching of Cadmium, Tellurium and Copper from Cadmium Telluride Photovoltaic Modules, Recycling Task -Progress Report I, BNL-72178-2004, February 3, 2004.

258. Wang W. and Fthenakis V.M., Separation of Cadmium from Cadmium-Tellurium-Containing Waste Streams, Recycling Task -Progress Phase II, April 19th, 2004.

259. Wang W. and Fthenakis V.M., Recycling of CIGS PV Module Scrap, Progress Report-Phase I, September I, 2005.

260. Wang W. and Fthenakis V.M., Recycling of Cadmium Telluride Photovoltaic Modules; Phase III: Separations on Industrial Waste, August 29, 2005

261. Fthenakis V. and Wang W., Material and Energy Inventory Analyses in the Production of Metals used in Photovoltaics, Brookhaven National Laboratory Report, October 2006.

262. Fthenakis V.M. (IEA Task 12 operating agent), Methodology Guidelines on Life Cycle Assessment of Photovoltaics Electricity, PVPS Task 12, International Energy Agency.

RECENT <u>KEYNOTE</u> PRESENTATIONS

263. Fthenakis V., Semiconductors and Photovoltaics, Parallel routes to Sustainability, Semiconductor Environmental Safety and Health Association (SESHA) Annual Conference, Scottsdale, AZ, May 21, 2009.

264. Fthenakis V., Enabling Large Growth of Photovoltaics, National Research Center "Demokritos", Summer School, Athens, July 10, 2009.

265. Sustainability of Thin-Film Photovoltaics, InterSolar Conference, San Francisco, July 16, 2009.

266. Fthenakis V. Sustainability of Photovoltaics, Technical University of Crete, International Conference on renewable Energy under the auspices of the Patriarch, Sept 1-2, 2009, Chania, Greece.