

**INTEGRATED ASSESSMENT OF USING PHOTOVOLTAIC
TECHNOLOGY IN THE UNITED STATES ELECTRICITY SECTOR**

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Natural Resources and Environment)
in The University of Michigan
2009

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To the Power of Creativity, Imagination and Rationalism
Bestowed Upon the Human Race

To Mum, Dad and Warney

To James, Cliff, Lars, Jason, Robert and Kirk

ACKNOWLEDGEMENTS

First and foremost I would like to thank my advisor, Professor Gregory A. Keoleian. His support, patience, guidance and encouragement throughout these five years have been instrumental for the completion of this work. I am deeply indebted to him and grateful for his guidance. His ability to recognize my skill-set and capacity, and guide me towards accomplishing things I haven't done before is quite simply one of his greatest assets as an advisor and a mentor.

I would like to thank Professor Michael Moore for teaching the class Natural Resource Micro-economics that provided me a platform to get interested in economics, and further earn a Master' degree in Applied Economics. I also completely appreciate his support and guidance during these five years. I would like to thank Professor Jonathan Bulkley for adding an important component of time varying fuel mix to my research work. I do completely appreciate his time and feedback that helped enrich the contents of my dissertation research. I would also like to sincerely thank Professor Brian Talbot for a unique business perspective on photovoltaic technology and deployment that he provided me with throughout this process. I consummately appreciate his time as well.

Outside of University of Michigan, I must acknowledge and thank Dr. Donald Hanson for his support in helping me with my dissertation research. His time, feedback and providing me with an opportunity to intern with Argonne laboratory in summer 2008 was extremely useful to my progress. In addition I also want to acknowledge Todd Munson for providing me with the much needed help in AMPL coding. I completely appreciate his help too. Last but not the least Steve Kryukov's help in getting me started with AMPL was extremely helpful to my research progress.

I must acknowledge the Peter M. Wege foundation, University of Michigan Rackham Graduate School, Argonne National Laboratory and Sally and Glick's Foundation, all the four organizations that supported my research. I would like to thank my colleagues in the Center for Sustainable Systems and many other friends for their unconditional support and friendship. I would also like to express my gratitude to Alissa Kendall for helping me out during each stage of this challenging PhD process. Her practical know-how was instrumental in me completing my doctoral degree. I would

express a special thanks to Sergio Pacca for being both my friend and mentor when I started, and for teaching me every time I needed help to this day.

I will also be thankful to my former advisor Prof. Angela Linder and Prof. Bonzongo, both from University of Florida. Their guidance at the very beginning of my graduate research career was invaluable. Without their sincere advice and encouragement, I would not have had the chance and courage to pursue with a doctoral degree. I would like to express my gratitude to Prof. Joseph Delfino as well. Most importantly, I could never have attempted any of this without the love and support of my parents. I deeply appreciate their faith in me, no matter what I have chosen to do. My mum did believe in me when no one else did, and when I gave them all no reason to either. Her role in how she helped me with each step along the way without her knowing the least bit about energy economics can absolutely not be under-stated. Dad's moral and financial support is rubber hits the road, but absolutely crucial for me even getting anywhere near to this stage, thank you does not justify it but it is a good start. I am very positive that I could not have completed this process without friends. I am extremely fortunate to have a set of great mates who think different than how I think, which is an incredible help because they provide me solutions to address real world problems. I cannot overstate the value of an incredible set of friends who have supported me through this process: Warney, Kim, Abira, Sharon and Alex. If the P and h belongs to me, the D definitely belongs to them, and we all know that one needs all the three alphabets to complete this degree. As am editing this section there is one thing that I do remember: *Courage* doesn't always roar. Sometimes *courage* is the quiet *voice* at the end of the day saying, "I *will try again tomorrow.*" I had to dig deep and draw on every last ounce of courage from both within and from my mates to cross the finish line.

I want to say a very sincere thanks to Rackham as well. Every time when I encountered a problem everyone in Rackham was incredibly cooperative in helping me solve the problem. A special thanks to Denise. Rackham is one of the most helpful institutions to PhD students from my experience. Inside CSS, I would like to thank Jarod with whom I enjoyed working on the final paper. This section will not be complete without me thanking Helaine, Mindy, Sondra, Diana, Kim, Judy and Lisa in SNRE, I cannot envision myself completing my dissertation without each one of your incredible support. Thank You. For all probabilities I would have been kicked out for miserably failing with the bureaucratic paperwork at some point of time if it wasn't for each of their incredible help. The very sanctuary of 'Center for Sustainable Systems' played a significant role as well. I have spent more time in here than my home, and it is indeed logical that I feel most comfortable in CSS. I will miss CSS that day I leave. It's been my home for five years. It is the best place on Earth to write a dissertation.

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ABSTRACT

Increased renewable deployment is necessary to reduce environmental impacts, and improve the sustainability of the U.S. electricity sector. This dissertation explores implications of increased photovoltaic (PV) utilization using an integrated energy economic framework with four methods: life cycle modeling of manufacturing and end of life management for PV technologies; grid dispatching modeling for a comparative assessment of CO₂ abatement potential at different fuel mix scales; cost benefit analysis of PV under a cap and trade market for greenhouse gases and regional pollutants; constrained optimization to evaluate the deployment and cost reduction of photovoltaics under technological and policy scenarios in the future.

The dispatching model demonstrated that the actual CO₂ abatement of PV electricity is dependent on both displaced peak load resources and PV installation capacities. Using average fuel mixes either over- or under-estimates the abatement. Due to the predominant displacement of the low carbon intensive natural gas at the margin in ERCOT, the marginal abatement was lower by 15% when compared to the average cases (for PV capacity of 1 to 1,000 kWp). In CAL-ISO using an average fuel mix approach underestimated the CO₂ abatement. Regional grid CO₂ indicators measure the combined effect of solar radiation and carbon intensity of the grid, on CO₂ abatement through PV electricity generation. PV electricity generated in the MRO and SPP grids provided the highest CO₂ abatement.

Inclusion of allowance prices in PV performance evaluation is a unique feature of the economic model. PV economic performance increased by 23% from the base case (BC ratio 0.29 at $r = 2\%$) with the inclusion of permit prices. A collective improvement in manufacturing cost, efficiency and resource availability raises the benefit-cost ratio to 2.73. Cumulative CO₂ reduction outlined in the Waxman – Markey bill (H.R. 2454) until 2050 was used to establish CO₂ reduction targets for the constrained optimization model. PV was tested against natural gas and wind using seven different modeling scenarios, but was only deployed after 2040. This modeling framework was also used to study the influence of technological breakthroughs, gas energy costs, subsidies and renewable portfolio standards on PV deployment in the future.