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

by

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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

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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 CO_2 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 CO_2 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 CO_2 abatement. Regional grid CO_2 indicators measure the combined effect of solar radiation and carbon intensity of the grid, on CO_2 abatement through PV electricity generation. PV electricity generated in the MRO and SPP grids provided the highest CO_2 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 CO_2 reduction outlined in the Waxman – Markey bill (H.R. 2454) until 2050 was used to establish CO_2 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.