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Environmental and Economic Research and Development Program

Executive Summary

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Assessment of High Penetration of Photovoltaics on Peak Demand and Annual Energy Use

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The power is within you.

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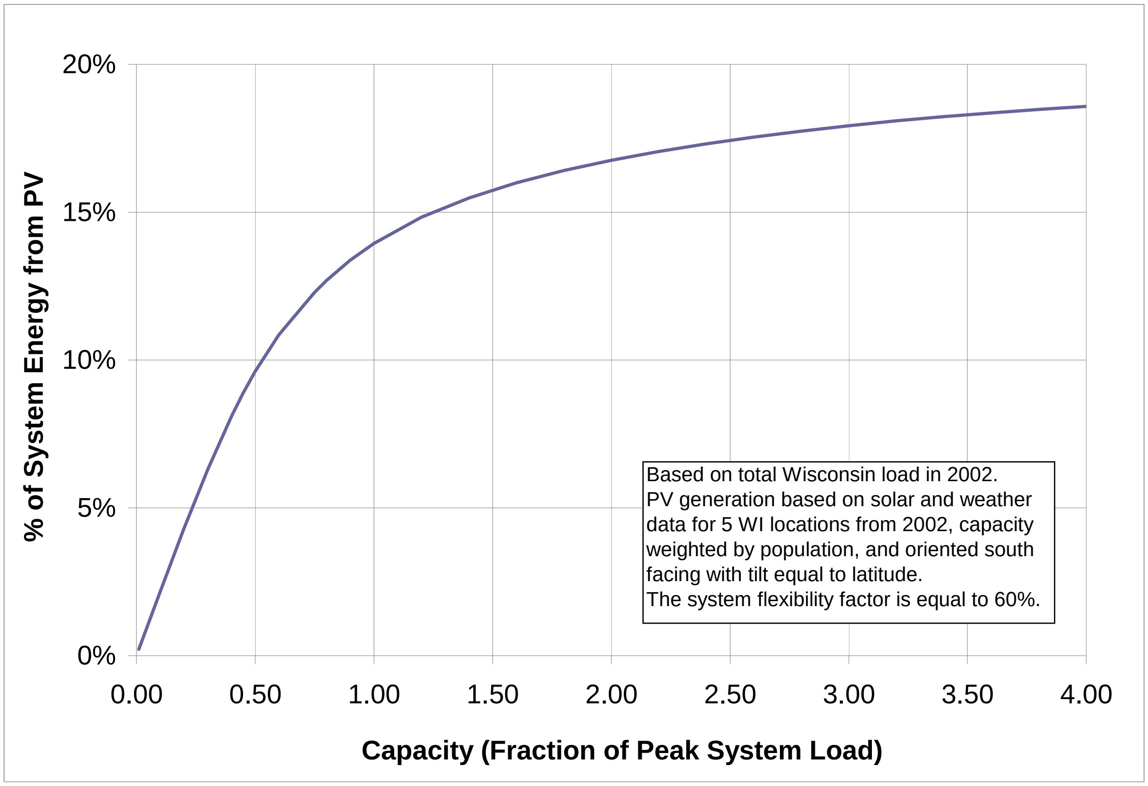
Executive Summary

The goals of the research were to provide an assessment of distributed solar photovoltaics in Wisconsin with regards to interaction with the utility grid, economics of varying levels of penetration, and quantify displaced emissions.

The first goal aimed to determine the impacts on the electric utility load with varying but high penetration rates of distributed solar photovoltaics. Analysis of distributed PV systems was carried out using TRNSYS. Within TRNSYS, the 5-parameter model for an individual solar PV system formed the basis for scale-up to simulate the performance of large numbers of distributed solar PV installations in Wisconsin. The simulations utilized measured hourly solar radiation and weather data from the National Solar Radiation Database. Hourly utility load data for each electric utility in Wisconsin for a complete year were used in combination with the simulated PV output to quantify the impacts of high penetration of distributed PV on the aggregate Wisconsin electric utility load.

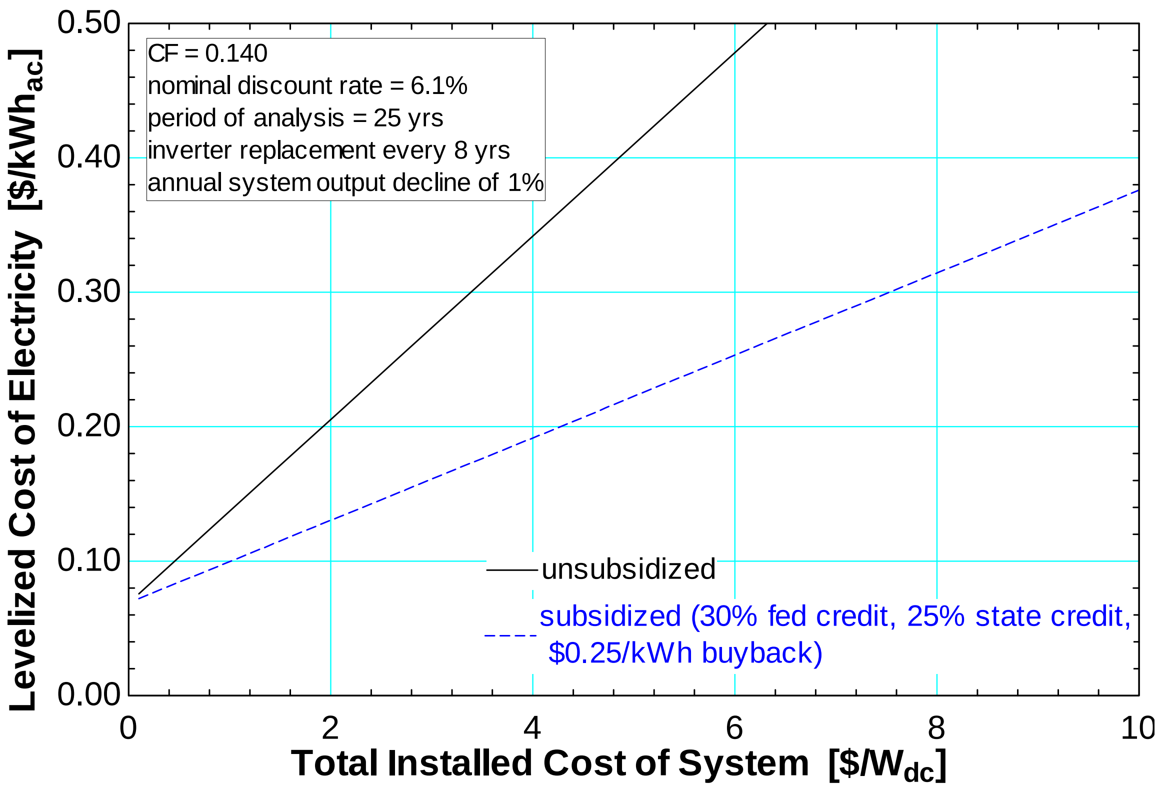
As the penetration rate of PV systems is increased, there are diminishing returns to further increasing the installed capacity of PV systems. At very high penetration rates, less of the energy generated from the PV system is useful and the contribution from PV and demand reduction both approach a limit. This limit is not affected by costs, but rather by the time-distribution of available solar radiation and the coincidence of aggregate utility electrical loads.



In Wisconsin, solar photovoltaics can contribute no more than 20% of the total electrical energy demand in the state based on a 60% flexibility factor, no short-term electrical storage, and a demand profile similar to the one experienced in calendar year 2002. A 20% contribution level would require a tremendous nominal capacity to be installed in the state; as such, it would not be cost-effective. The issues associated with minimum loading are not a concern at the current low penetration rates (installed capacity of 3.1 MW_{dc} – less than 0.025% of peak load). Minimum loading, and rejected power, become significant at penetration rates approaching 15% of peak load. Clearly, there is considerable room for growth in the installed base of solar PV capacity in the state of Wisconsin before minimum loading becomes a significant issue.

Distributed solar photovoltaics in Wisconsin will contribute only a small percentage of total electrical energy use in the near future, independent of economics. At an installed penetration rate of 15% of peak load (1980 MW_{dc}), solar PV will generate only 3% of the total electrical energy used in the state on an annual basis.

The second goal was to evaluate the economics of solar PV in Wisconsin. The economic analysis was accomplished by comparing the cost of electricity and a theoretical value of electricity generated from TRNSYS simulations of PV systems in Wisconsin. The cost of electricity was calculated based on the simulated performance of the PV system and current cost data for the PV panels, balance of system, installation, and inverter replacements. The value of electricity was calculated in two different ways, one approach assigned the utility's coincident marginal cost of generation to each unit of electricity generated by PV systems and the second assigned the coincident time-of-use rate to each unit of electricity generated by the PV systems.



The comparison, in Chapter 5, between the unit cost of solar PV electricity in Wisconsin and a theoretical value, based on generous time-of-use rates, indicates that the cost of electricity from PV is much greater than its value. The unsubsidized levelized cost of electricity for a typical residential solar PV installation in Wisconsin, under the conditions listed in Chapter 5, was calculated as \$0.614/kWh (\$614/MWh). The peak value of electricity from PV using the time-of-use rates was calculated as \$138/MWh (\$0.138/kWh). If subsidies were to close the difference of \$476/MWh, production incentives totaling \$0.476/kWh or initial investment subsidies totaling \$7/W_{dc}, 87.5% of total installed cost, would be required based on the calculations in Chapter 5.

The third goal to evaluate the emissions impacts of the distributed solar PV systems was accomplished using the PV simulation data and a simplified dispatch. The emissions simulation estimated the reduction in six emission types based on average emissions rates derived from the EPA's eGRID2007 database. The procedure and results are presented in detail in Chapter 6.

The estimated emissions reductions from using solar PV to displace traditional electricity generation depended upon the capacity of solar PV. At low levels of installed capacity, solar PV primarily displaces electricity generation from lower emission natural gas plants that are on the margin. At high levels of installed capacity, solar PV begins to displace generation from coal (higher emissions) or biomass plants during times when the system load is low and PV generation is still high. At an installed capacity of 100% of annual peak load, the emissions were reduced by approximately 22% when compared with the base scenario. A potential tax on CO_2 emissions would need to be on the order of $460 per ton to justify solar PV based solely on the emissions reductions. At such a high cost, nearly every other option for reducing CO_2 could be exhausted.

Wisconsin has a sufficient solar resource for solar photovoltaics to be a future source of electricity production. A very large level of capacity is required before this resource becomes a significant contribution to the total generation mix. On an economic basis, the investment in distributed solar photovoltaics in Wisconsin is not profitable at this time. With proper incentives, solar PV can be cost effective in Wisconsin.