SATELLITE-BASED SOLAR RESOURCE ASSESSMENT:

SOCIAL, ECONOMIC AND CULTURAL CHALLENGES AND BARRIERS, TECHNOLOGICAL GAPS

Richard Perez
ASRC, The University at Albany

ABSTRACT

Access to comprehensive solar resource information opens door to a solid analysis capability which often opens door to new solutions, better planning, better targeted R&D, and faster, more intelligent, development of solar energy. This pointed is articulated through two examples identifying overlooked solar energy development potential with appropriate solar resource information.

DEFINING THE ISSUE

Solar resource information is a broad term that encompasses all the data and parameters which characterize the radiation that drives solar energy systems.

The information may be as simple as an annual average gauging a local climate, or as detailed as a next-day forecasts for direct normal irradiance to manage and market the output of a solar thermal power plant. Likewise, prospective users of this information have a wide range of needs depending on their interests and objectives. Let's look at specific examples:

1. <u>Estimating the economic feasibility of a grid-connected residential PV or domestic hot water (DHW) system</u>: In most cases the solar resource information already published under the form of Typical Meteorological Years (TMY) or even climatological monthly averages, even with the current level of accuracy and/or limited geographical coverage, should be more than adequate to make sensible decisions.
2. <u>Siting of a multi MW solar thermal facility:</u> These capital-intensive systems rely on direct normal irradiance (DNI) which is noticeably more variable than the global irradiance driving flat plate systems. Given the € millions at play, microclimatic optimization is a prime concern. This can only be achieved with access to high-resolution mapped solar resource information -- not yet universally available.
3. <u>Investigation of PV grid-support capability</u>: It has been shown that under certain circumstances, the deployment of dispersed PV installations can strengthened the reliability of the power grid by providing peak output during times of high demand and grid stress. The solar resource information needed to investigate this question

consists of site/time-specific irradiance time series (hourly or less) necessary to simulate the production of PV arrays coincident with actual electrical demand.

4. Management of a large dispersed PV resource: The deployment of dispersed PV installations throughout regional power grids will affect the management of power flows on these grids as soon as the penetration of PV installations reaches a few percent. The solar resource information required to properly manage that flow will consist of recent, real-time, and forecasted site-specific irradiances.
5. Engaging in sensible socio-economic planning concerning the development of solar energy: Intelligent decisions concerning the future of solar energy require a complete understanding of the technology's scope and of its capabilities. Too often, as will be illustrated below, an incomplete understanding of the solar resource will lead to missed opportunities and misguided planning. Therefore, it is important that socio-economic decision makers, including governments, regulators, businesses and financiers have access to as complete a solar resource characterization as possible, implying, high resolution, time/site-specificity, passed and future. The point is that solar resource does not only consist of maps or atlases but is a complex *multi-facetted* set of information required to address complex, *multi-facetted* issues.

IDENTIFYING OPPORTUNITIES WITH THE APPROPRIATE SOLAR RESOURCE INFORMATION

Two investigations recently completed in the USA have uncovered opportunities for PV deployment that were not entirely intuitive, and that could not have been identified by relying solely on "traditional" solar resource information, such as typical data time series or atlas maps. A brief synopsis of these investigations is presented:

Identification of high PV effective capacity in the northeastern USA: The north-central/eastern portion of the United States had not been considered as one of the leading prospective markets for PV. Indeed, a quick look at the US solar radiation atlas (Fig. 1, top right) indicates that the solar resource is more abundant in the south and the west of the country. However the value produced by a power plant does not depends only on its energy yield, but also on its ability to provide added capacity to a local grid, a transmission and distribution (T&D) system, or a utility customer. As a non-controllable, non-dispatchable resource, PV generation was, until recently, assigned a zero capacity credit by utility planners, particularly in region with moderate solar resource, such as the northeastern US.

A more detailed look at the resource – its ability to match demand – through the analysis of time/site specific solar resource data and coincident utility/regional loads revealed that, in some cases the capacity credit of PV installations greatly exceeds their capacity factor (ratio of average output to rating). The author and his colleagues analyzed 100+ utility load-years through the USA and derived a capacity credit map of the United States that is considerably different from the climatic map (Fig. 1, lower left) (see perez et al., 1995, 1996).

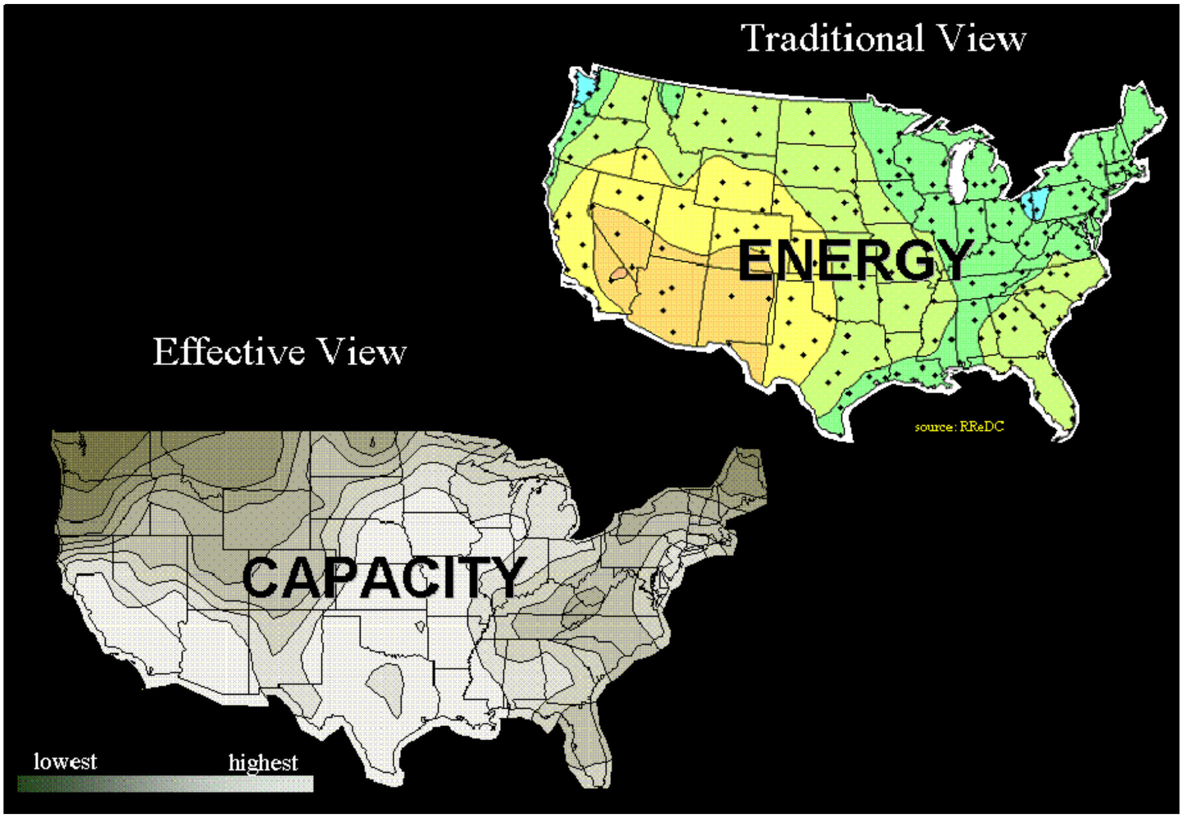
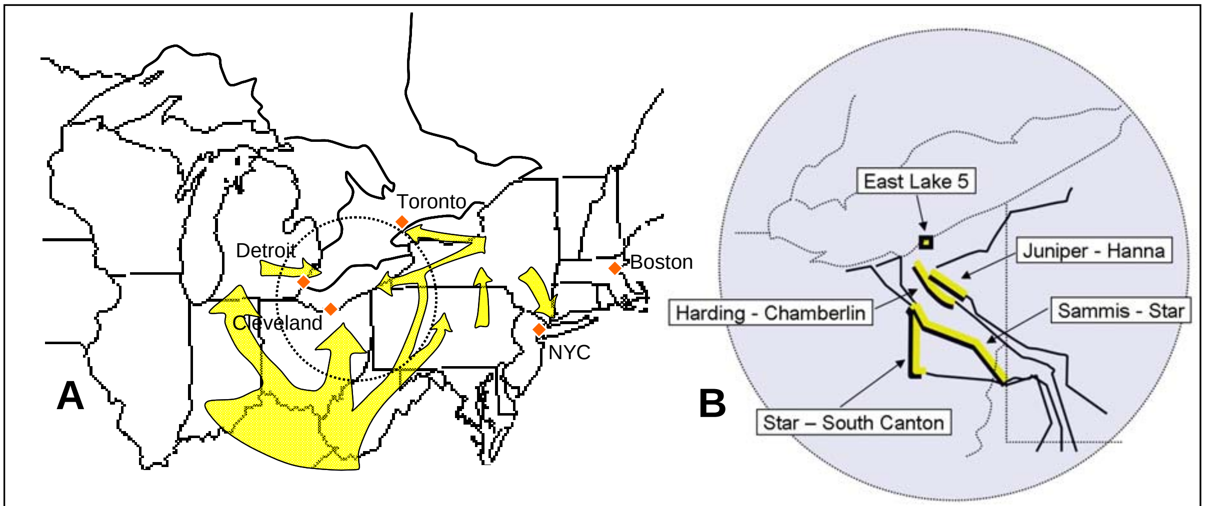


Fig. 1: Comparing climatic solar energy resource map (top right) and effective load carrying capability maps of the United Sates

In insight, the results are logical, because they show that, where peak loads are indirectly driven by solar gain, through heat waves and commercial air-conditioning demand, the effective capacity of PV is the most significant. This is the case for the large urban-suburban region extending from Washington to Boston where “9-to-5” commercial A/C loads are very large. By contrast “sunny” Florida, which sometimes experiences early morning winter demand peaks from electric heating is characterized by a much smaller PV effective capacity despite a larger climatic solar resource. Although they are logical, these attributes would have been overlooked without access to a proper characterization of solar resources: time/site-specific irradiances at arbitrary locations.

<u>Dispersed PV as an outage-preventive power generation base</u>: The largest blackout in the United States and Canada occurred over a matter of hours on August 14, 2003. The total regional cost of the outage has been estimated at upward of $8 billion.

On the afternoon of August 14, loads and power transfers through the northeastern US were high. The region was experiencing large power transfers (~5 GW) from the south-central US to the north. Much of that power transited through northern Ohio on its way to the major load centers of Detroit, Cleveland and Toronto, where local energy production was insufficient. A series of precursor events took place near Cleveland, where large (345 kV) power lines were carrying much of the south-to-north power flow (see Figure 2). At 1:31 PM a local power plant, attempting to meet voltages depressed by high demand, failed, leading to the loss of 600 MW. At 3:05 a 345 kV power line failed due to tree contact, losing another 500 MW. The lost power had to be carried by neighboring lines. At 3:32 another 345 kV power line, which had absorbed part of the above losses failed, also due to tree contact resulting in the rerouting of the1200 MW it carried to other neighboring paths, including the Star-South Canton 345 kV power line which failed at 3:41 PM due to overload. Two aggravating factors in this series of events were the inadequate situational awareness of the local utility, and the failure of the concerned reliability coordinator organizations to provide effective problem diagnostics. The precursor events were thus left to evolve without effective interventions from grid operators – utilizing such mitigating efforts as targeted rolling blackouts. When the Star-South Canton line failed, much of the power found its way on secondary power lines (138 kV) that overloaded one after the other, and on the only remaining local 345 kV line: Sammis-Star which, overloaded at 4:05 PM, marking the beginning of the massive outage.



	Before 1:31 PM	1:31 PM	3:05 PM	3:32 PM	3:41 PM	4:05 PM	Cause
East Lake 5 Plant	100% (600MW)	Failed	Failed	Failed	Failed	Failed	Exceeding MVAR limit
Harding-Chamberlain	35% (400MW)	45% (500MW)	Failed	Failed	Failed	Failed	Tree Contact
Juniper-Hanna	55% (800MW)	70% (1 GW)	80% (1.2 GW)	Failed	Failed	Failed	Tree Contact
Star-South Canton	65% (650MW)	80% (800MW)	90% (900MW)	120% (1.2 GW)	Failed	Failed	Overaload
Star-Sammis	55% (650MW)	60% (700MW)	65% (800MW)	85% (1 GW)	120% (1.4 GW)	Failed	Overaload

Fig. 2: Regional power transfers in the afternoon of 8/14 (A). Much of this power flowed through 345kV lines in eastern Ohio (B). The loss of the East Lake generating facility and of the power lines compounded by the lack of situational awareness from the grid operators forced the power flows into alternate paths and precipitated the outage (source US-Canada Task Force, 2003])

The north-south power flow in eastern Ohio got pushed on other paths to the east and west toward the load centers. These massive power flow reroutings resulted in line failure at an exponentially increasing rate, as the flow was redistributed into fewer and fewer paths. Within four minutes, all of the south-to-north paths had been severed. The northeastern corner of North America became and electrical island where demand exceeded generation (see figure 3). The resulting depressed voltages and frequencies caused the line trips and generation failure cascade to continue within the electrical island, creating several sub-islands. Sub-islands where local generation was sufficient to meet demand (New England, Quebec, Upstate New York) stabilized and remained online. The other sub-islands (including New York City, Toronto, Detroit and Cleveland), blacked out.

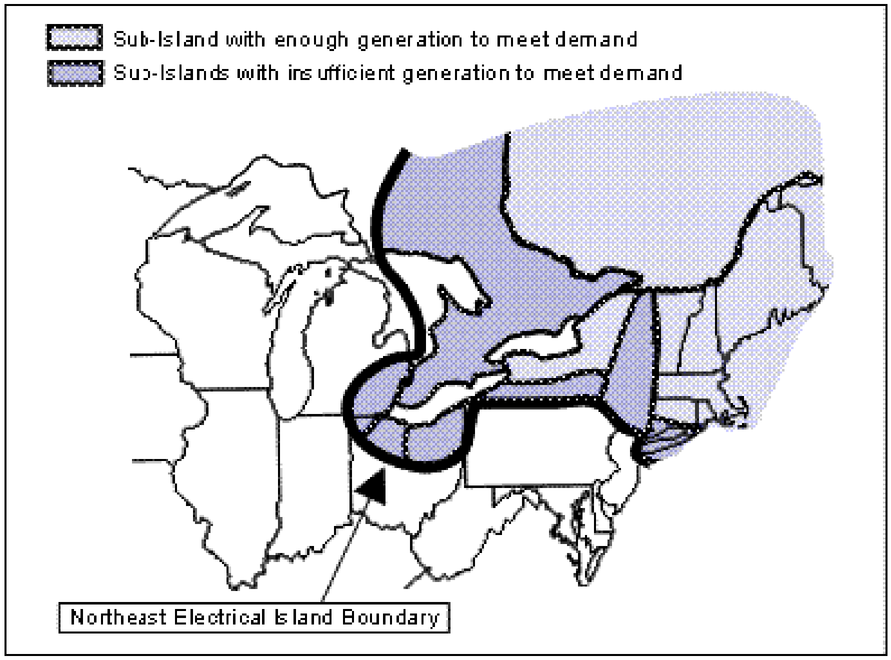


Fig. 3: Within 7 minutes of the Sammis-Star trip, all paths wheeling power from south to north were severed resulting in a large power deficient island (source US-Canada Task Force, 2003)

The US-Canada Task Force (2003) identified three main causes for the outage: (1) inadequate situational awareness from the local utility; (2) inadequate tree trimming; (3) inadequate diagnostic support from reliability coordinators. The task force thus concluded that the outage was preventable and that better, enforceable controls and regulations should take care of future similar contingencies. However, above and beyond these "official" causes, the analysis of events clearly suggests that, had regional power transfers to meet localized energy demands not been as high, the probability of each contingency – even unattended – leading to the next, and finally into cascade would have been much lower.

As was discussed above, one of the well documented attributes of PV generation is its high Effective Load Carrying Capability when loads are driven by air-conditioning (A/C) demand. Conditions on August 14th 2003, although not extreme, represented a "textbook example" of high regional A/C demand creating high power transfers and stress on the grid. Therefore it was no coincidence that the solar resource – indirectly driving demand – was plentiful – see Fig. 4 and 5.

Using two independent methods based on (1) avoiding each precursor contingencies and (2) reducing regional power transfers by 10%, a recent study by the author and his colleagues (Perez and Collins, 2004, Perez et al., 2004) showed that at most a few hundred PV MW located in and around each major concerned metropolitan area would have provided an insurance against the unfortunate contingencies of 8/14 compounded by the shortcomings of the concerned utilities and grid reliability coordinators.

This analysis and its conclusions showing that distributed PV could be one of the solutions to strengthen the reliability of the power grid could not have been undertaken without access to time/site specific maps of the solar resource.

DISCUSSION

The two case studies show that some very important attributes of PV generation affecting its value, market penetration, and design can only be captured with an appropriate form of solar resource information. Some of these results were counter-intuitive and had been overlooked.

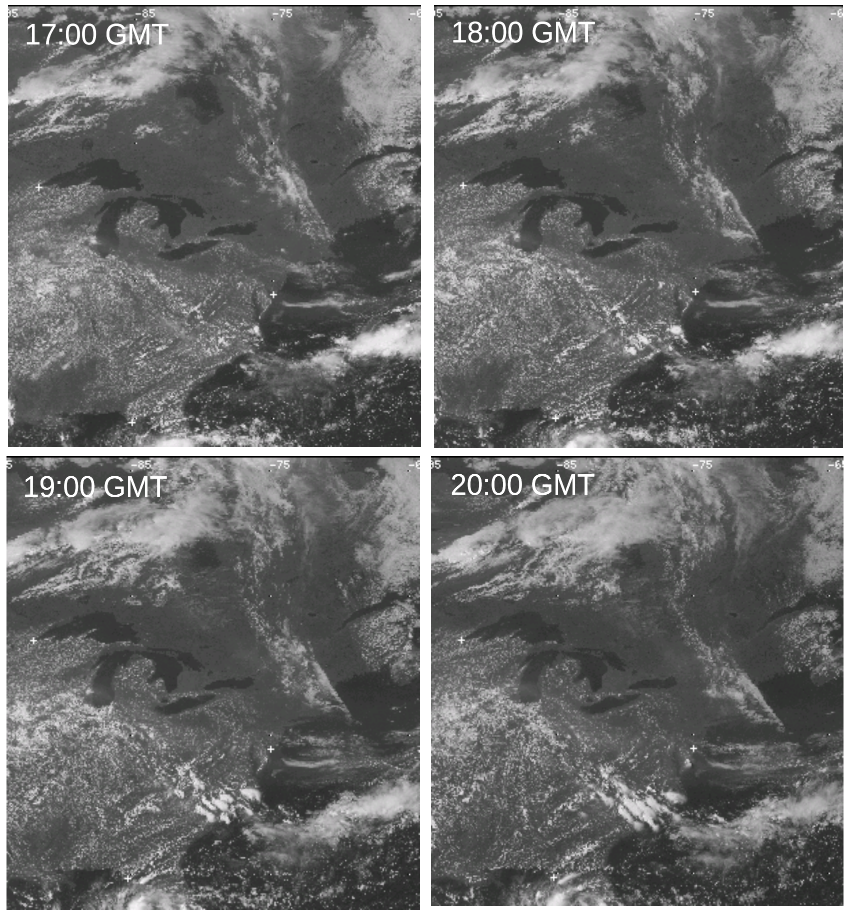


Fig. 4: Cloud cover distribution in eastern North America on 8/14/03 -- note that the area affected by the outage is almost cloud-free.

Access to comprehensive solar resource information opens door to a solid analysis capability which often opens door to new solutions, better planning, better targeted R&D, and faster, more intelligent, development of solar energy.

Therefore developing a comprehensive, multi facetted solar resource information base – including better models, validations, production of data, worldwide coverage, and worldwide access – and making this information available to research and planning communities, are pivotal issue. Such an effort will require international cooperation, effort continuity, exchange of information between producers of information and users of information, and last but not least, adequate budgeting

Developing the proper resource information is a small investment in light of the formidable development potential of solar energy.

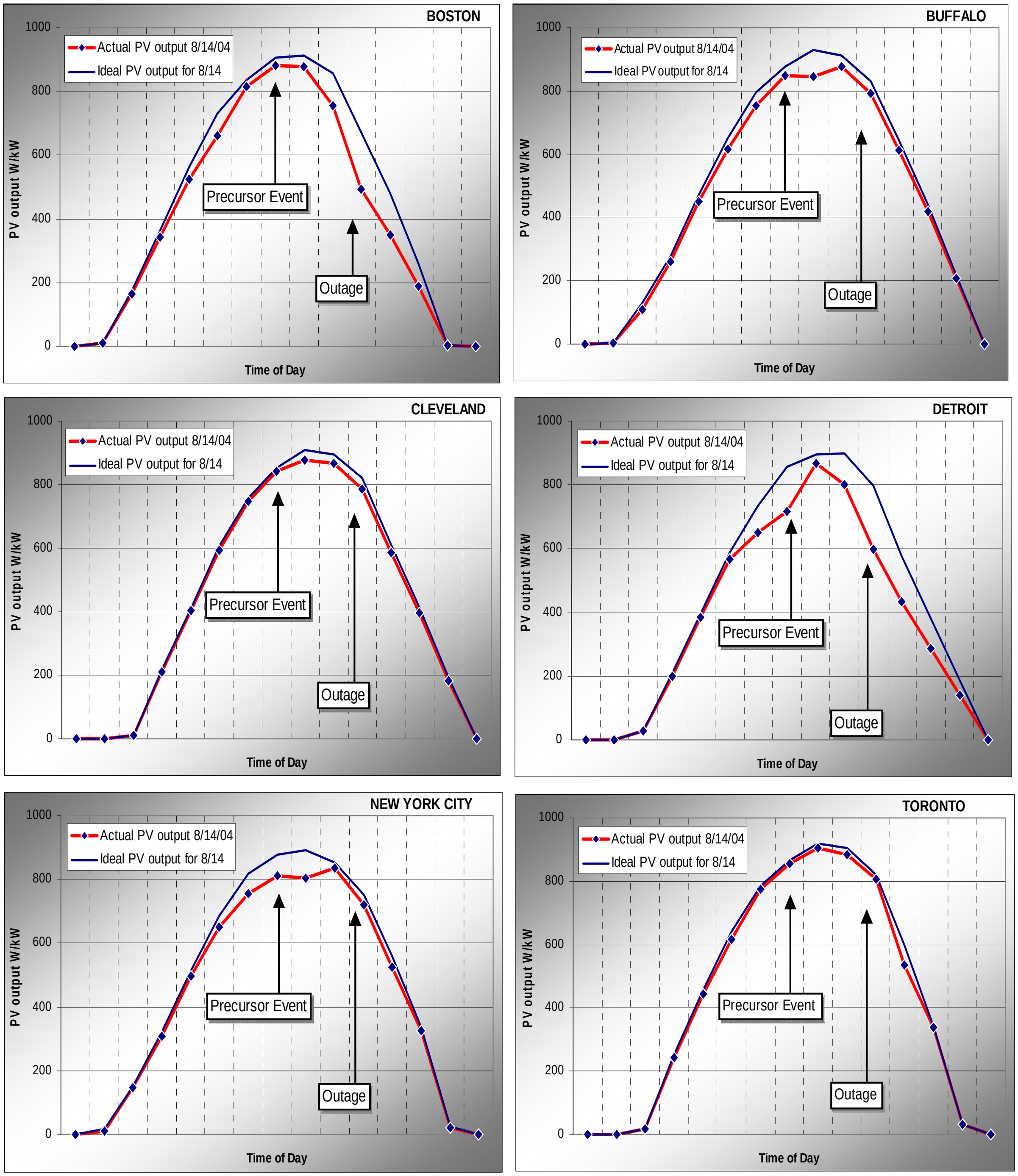


Fig. 6: Actual vs. Ideal simulated output of fixed-optimized PV arrays on 8/14/04 in major eastern American cities.

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