MAXIMIZING THE VALUE OF CUSTOMER-SITED PV SYSTEMS USING STORAGE AND CONTROLS

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ABSTRACT

This paper determines how the value of customer-sited PV can be increased with battery storage by enhancing the load management and outage protection attributes of PV. Case studies in San Jose, CA and Long Island, NY for residential and commercial PV applications are used for a quantitative illustration of storage value enhancement. Results indicate that: (1) a small amount of storage for local load control and a larger amount of storage for emergency load protection significantly increases the value of distributed PV to the customer; (2) the value of PV combined with emergency storage exceeds the sum of the value of these options implemented separately; and (3) there is a potential opportunity to use dispersed PV + storage to enhance grid security (capturing this value, however, will require regulatory and policy changes).

1. INTRODUCTION

Consumers in the U.S. have become increasingly accustomed to a highly reliable source of electricity. As a result, outages such as the one that occurred on August 14, 2003 in the northeastern US caught many people unprepared and cost upwards of $8 billion [1, 2]. The cost of all outage-related power disturbances in the US has been estimated at $100 billion per year [3].

Distributed PV generation (including customer-sited PV) has been shown to provide relief to stressed power grids by providing peak time capacity [4, 5] thereby reducing the risk of generalized power outages [6, 7]. This capability may be enhanced with a small storage reserve – Minimum Buffer Energy Storage (MBES) and/or solar load control (SLC) [8]. The same storage/control system can also be used to provide an insurance against outages should they occur (e.g., for reasons other than high demand-induced stress, such as severe weather or terrorism). Properly designed customer-sited PV installations that include emergency storage/backup (at a modest additional installed cost) could provide enough minimal emergency load power to keep businesses and residences going almost indefinitely during an outage.

2. METHODOLOGY

On-site storage can add value to a customer-sited PV installation in three ways:

1. **Load management**: maximize customer demand reduction; this could be provided in combination with demand-side load control [8]
2. **Outage prevention**, provide utilities with an *"outage-preventive"* resource to supplement the ability of PV to relieve stress on their transmission and distribution systems via instantaneous dispatching part of the on-site storage systems
3. **Outage recovery**: provide customers with an *"outage-reactive"* capability by supporting local critical loads and keeping businesses or residences up in case of localized or generalized outages regardless of their cause

The first value element can be captured directly for commercial/industrial users by minimizing demand billing. The second value element cannot be captured directly at this time because utilities do not currently provide a conduit to capture this value. Note, however, that the value of outage protection is partially captured via demand reduction (item #1) because demand billing reflects the capacity limitation of the power grid. The third value element is the value of the insurance a customer is willing to place on maintaining critical loads at all times.

Figure 1 illustrates a customer-sited PV installation with on-site storage designed to meet all three value objectives. Ideally, a different portion of the storage capacity would be designed to serve different strategies with a unique, cost effective, set of controls/charger/inverter.

Four case studies were selected to investigate how load control and emergency storage affect the value of a PV installation. The case studies include two residential and two commercial customers located respectively in Long Island, New York, and San Jose, California. The net present value (NPV) was calculated for the residential and commercial customers for the following configurations: PV-alone; PV + emergency UPS storage; and emergency UPS storage without PV. A case with PV + MBES to maximize demand reduction was also calculated for commercial customer.

The technical and financial assumptions are reported in Table 1. The key assumptions are briefly discussed below.

PV systems cost \$8,000/$kW_{AC\text{-}PTC}$ for the 3 kW residential applications, and \$6,000/$kW_{AC\text{-}PTC}$ for the 100 kW commercial systems. The battery sizes necessary to maintain a critical load equal to 15% of average load in the residential and commercial cases are respectively 3 kWh and 800 kWh as determined from QuickQuotes™ simulations [9, 10]. Storage requirements to maintain minimum loads without PV are respectively 4.5 kWh and 1,100 kWh [9]. Batteries cost \$300/kWh for the small residential systems and \$150/kWh for the larger commercial systems [9]. The battery lifetimes are respectively 7 and 10 years -- assuming a better maintenance for the commercial systems.

For the commercial customers, the probability of summer peak load reduction with PV alone is 40%. With two PV-hours of load management MBES, peak load reduction probability is increased to 100% of installed PV capacity (e.g., see [8]).

The outage protection value, i.e., the insurance a customer would be willing to place on uninterrupted emergency power, is estimated by prorating the average yearly cost of outage-related disturbances (\$100 billion per year in the US [3]) to the relative size of the considered

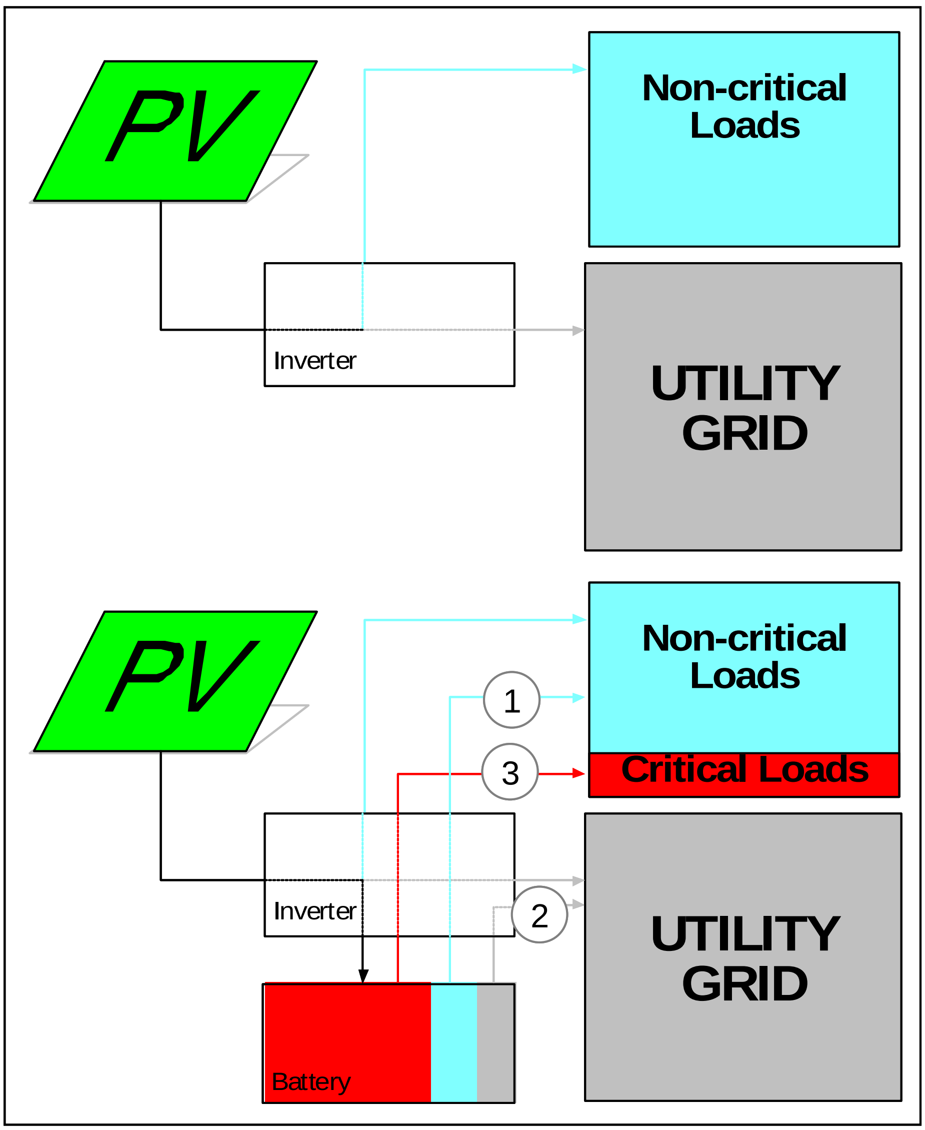

Figure 1: Contrasting the PV-alone and PV + storage options where storage is used for (1) local load management, (2) utility load management and (3) emergency critical load storage

TABLE 1
Selected Technical and Financial Inputs

	RESIDENTIAL CUSTOMER L. Island, NY	RESIDENTIAL CUSTOMER San Jose, CA	COMMERCIAL CUSTOMER L. Island, NY	COMMERCIAL CUSTOMER San Jose, CA
CUSTOMER DATA				
Energy usage (kWh/yr)	9,200 kWh/yr	9,200 kWh/yr	1,000,000 kWh	1,000,000 kWh
Peak Load	N / A	N / A	375	375
PV SYSTEM				
PV system size (kW-ac)	3 kW-ac	3 kW-ac	100 kW-ac	100 kW-ac
Turnkey cost	$8,000 / kWac	$8,000 / kWac	$6,000 / kWac	$6,000 / kWac
PV system life	30 years	30 years	30 years	30 years
PV output degradation	1% per year	1% per year	1% per year	1% per year
PV resale value at life's end	$1,000 / kWac	$1,000 / kWac	$1,000 / kWac	$1,000 / kWac
Energy production: yearly capacity factor	18%	22%	18%	22%
Probability of Summer PV Peak Load reduction	N / A	N / A	40%	40%
LOAD CONTROL BATTERY				
Battery size for load reduction	N / A	N / A	200 kWh	200 kWh
Probability of Summer Peak Load reduction with battery/control	N / A	N / A	100%	100%
Life time of batteries	N / A	N / A	10 years	10 years
Cost of batteries / controls			$150 / kWh	$150 / kWh
LOAD RECOVERY BATTERY				
Battery size for emergency	3 kWh	3 kWh	800 kWh	800 kWh
Life time of batteries	7 years	7 years	10 years	10 years
Cost of batteries / controls	$300 / kWh	$300 / kWh	$150 / kWh	$150 / kWh
Battery size without PV	4.5 kWh	4.5 kWh	1100 kWh	1100 kWh
Inverter/charger cost without PV	$1,100 / kWac	$1,100 / kWac	$1,000 / kWac	$1,000 / kWac
Outage protection value	$245 / year	$245 / year	$25,000 / year	$ 25,000 / year
FINANCIAL				
Buy-Down per kW	$4,000	$2,565	$400*	$4,000
Customer Equity	10%	10%	10%	10%
Loan term	25 years	25 years	25 years	25 years
Loan Rate	7%	7%	7%	7%
State tax Credit	25%	7.70%	N / A	N / A
Federeal tax credit	N / A	N / A	10.40%	10.40%
Depreciation	N / A	N / A	1 & 6 yrs. Federal, 11 years State	1 & 6 yrs. Federal, 11 years State
Marginal State income tax rate	7.50%	9.00%	7.50%	8.80%
Marginal Federal Income tax rate	33%	33%	34%	34%
Inflation	3%	3%	3%	3%
Energy inflation	4%	4%	4%	4%
Energy value (winter)	11.79 ¢/kWh	14.50 ¢/kWh	9.50 ¢/kWh	9.59 ¢/kWh
Energy value (summer)	13.67 ¢/kWh	16.00 ¢/kWh	11.54 ¢/kWh	12.14 ¢/kWh
Demand value (summer)	N / A	N / A	$9.99 / kW	$15.77 / kW
Demand value (winter)	N / A	N / A	$8.88 / kW	$6.04 / kW
Operation and Maintenance	1 ¢/kWh	1 ¢/kWh	1 ¢/kWh	1 ¢/kWh

** capped at $40K -- above value is for 100 kW PV*

customers. This equals $245/year for the residential customer and $25,000 per year for the commercial customer. Note that these estimates are not inconsistent with PV-alone insurance value estimates obtained from an entirely different source by polling the insurance industry [11].

3. RESULTS

Residential customers: The cumulative cash flows, contrasting the PV-alone and PV + emergency storage options are plotted in Figure.2. Note that the higher buy-down and the existence of a larger state tax credit in New York make for a better cash flow in the early years, but that the higher energy yield and higher utility rate in San Jose lead to a better long term value. The emergency storage option provides a substantial net benefit to the PV installation s in both locations, doubling their net present value.

Commercial customers: The cumulative cash flows contrasting the PV-alone, PV + MBES and PV + emergency storage options are presented in Figure 3. The value of the emergency storage option with and without PV is compared in Figures 4 and 5.

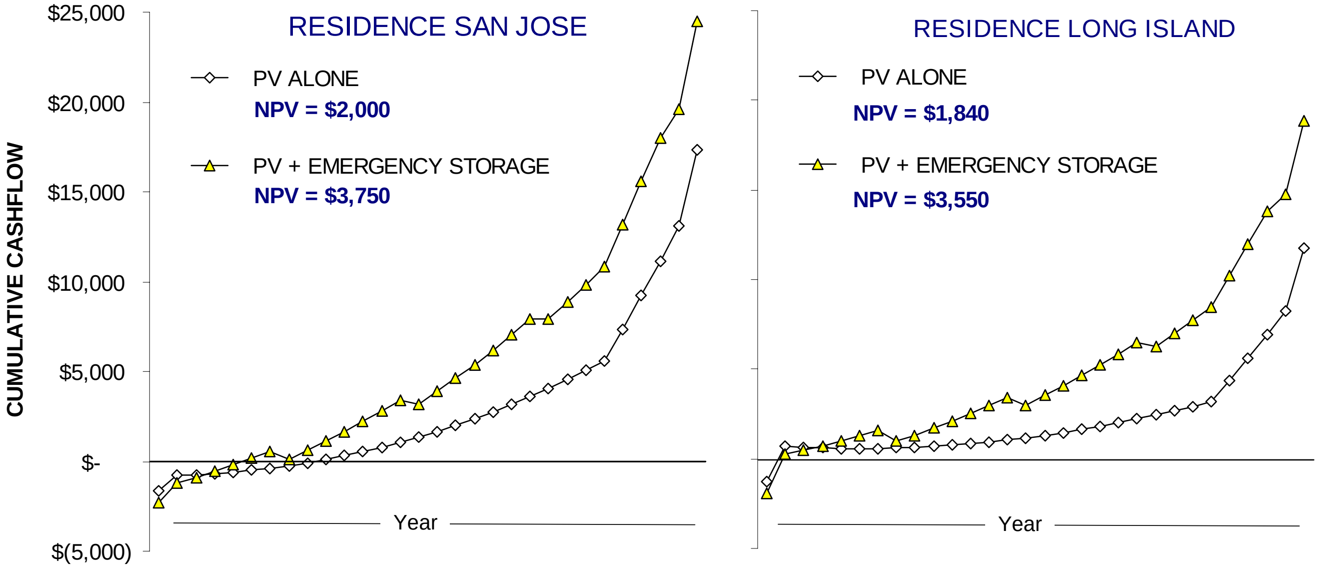

Figure 2: Cumulative cash flow for residential customers – comparing PV alone and PV + emergency storage options

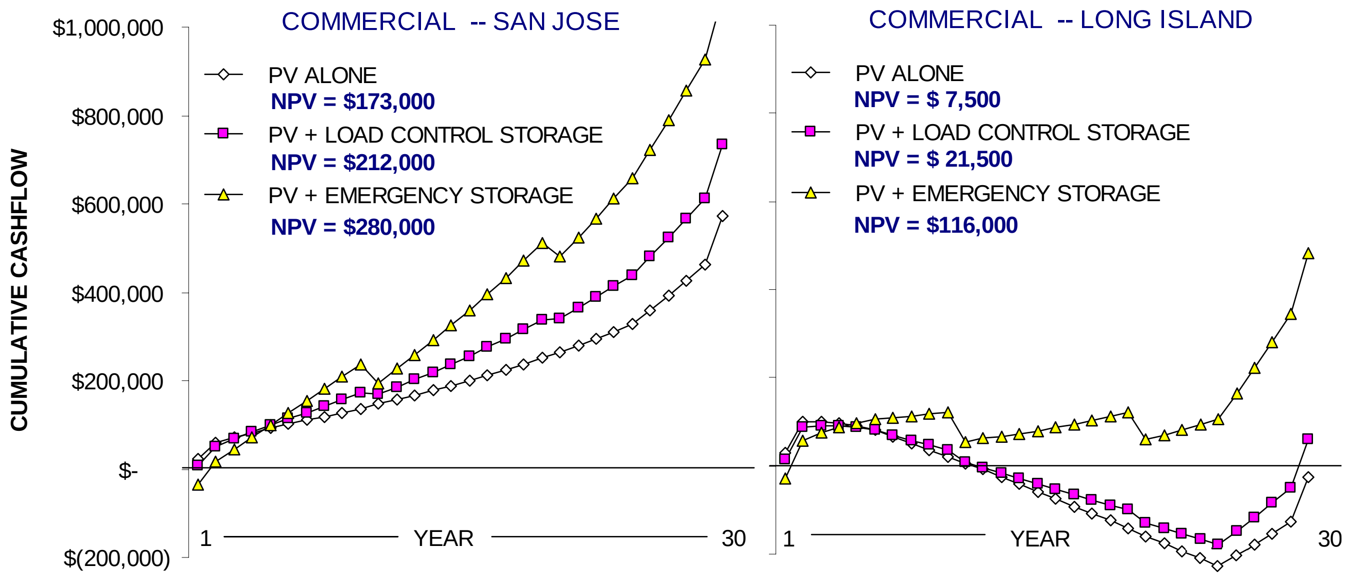

Figure 3: Cumulative cash flow for commercial customers – comparing PV alone, PV + local load management (MBES) storage and PV + emergency storage options

The economic picture in Long Island, although profitable, is not as attractive as in San Jose. This is largely due to the difference in buy-down incentives (capped at $40,000 in Long Island) and the summer energy and demand rates which are noticeably higher in San Jose. The MBES option has a noticeable positive impact on the bottom line in both locations. The emergency storage option has en even larger positive impact.

The synergy between PV and emergency storage is clearly apparent in Figures 4 and 5, both in Long Island and San Jose. Because the PV system allows for a modest reduction in the size of the emergency storage, the value of PV + emergency storage is higher than the sum of the value of these options considered separately. For example, the results for the commercial customer are $116,000 NPV vs. $47,500 NPV in Long Island, and $280,000 NPV vs. $213,000 NPV in San Jose.

Note that in some cases, even more value could be achieved for the commercial PV + emergency storage option because it would allow the customer the flexibility to switch to a non-firm rate structure and use the emergency storage system for utility-requested curtailments. In San Jose, for instance PG&E has a medium and large demand general service rate (E-19) for non-firm service. In order to qualify, a customer may be requested to curtail, on a pre-emergency basis, up to five times per year, each pre-emergency curtailment lasting no more than five hours with a 30 minutes notice before each curtailment. PG&E will request at least six pre-emergency curtailments during any rolling three-year period. The summer demand charges for this rate

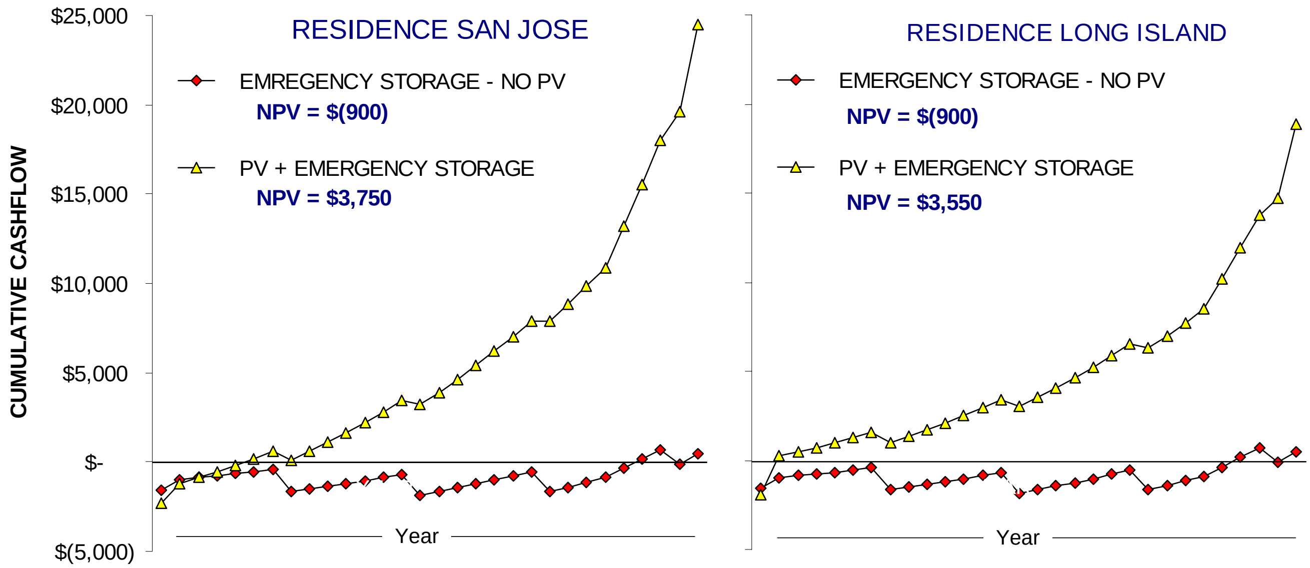

Figure 4: Cumulative cash flow for residential customers – comparing emergency storage options with and without PV

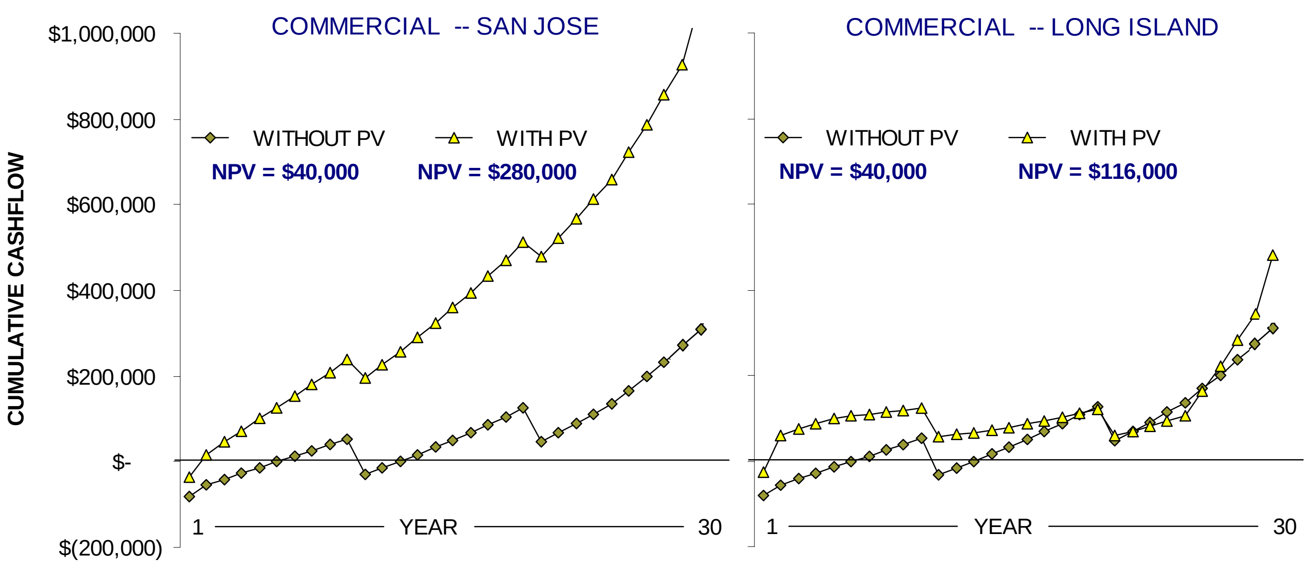

Figure 5: Cumulative cash flow for commercial customers – comparing emergency storage options with and without PV

are almost 50% lower on a non-firm rate, and energy rates are about 10% lower. In San Jose the rate switch would increase the PV+ emergency storage NPV from $280,000 to $440,000.

4. DISCUSSION

The case studies clearly show that the addition of a small amount of storage for local load control, and a larger amount of storage for emergency load protection are beneficial to the economics of customer-sited PV.

The results obtained for emergency storage are, of course, dependent upon the value selected for critical load protection insurance, and upon the willingness of prospective PV owners to account for this factor in their planning. High visibility events, such as the August 14th, 2003 northeast blackout, which are a reflection of increased demand/transfer stress on the aging power grid infrastructure, and an increasing concern for severe weather and terrorism disruptions, should highlight the need for some form of insurance and foster the development of and incentives for PV + storage installations instead of PV alone.

The results also suggest that the UPS market where customers have already made the choice of purchasing load protection insurance via energy storage may be an attractive near-term target for PV developers. Adding a PV installation to a planned UPS is a very attractive option because of the synergy observed between PV and storage.

Finally, results indicate the existence of a potential opportunity for utilities and grid-operators to use dispersed PV + storage installations to enhance grid security through dispersed, immediately dispatchable emergency generation. The value of this PV + storage option will only be fully quantifiable when utility-to-customer business protocols are defined and made operational.

5. ACKNOWLEDGEMENT

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