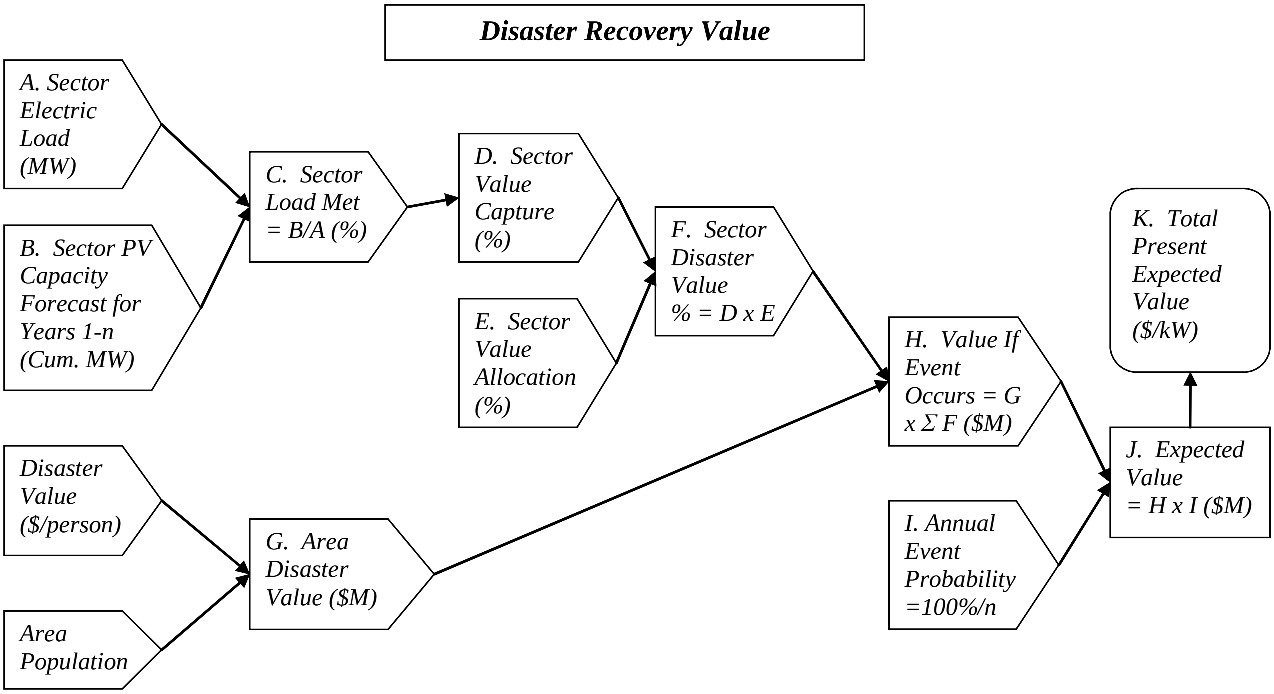
EXECUTIVE SUMMARY

The Katrina disaster serves as a reminder of the staggering cost of weather related disasters and the fact that resulting power outages compound the cost of disaster recovery, prevent timely damage mitigation and extend the time required for the afflicted region to recover economically. Over the past 25 years more than sixty weather related disasters have struck the US, i.e. about 1 for every 4 million US citizens at the time, causing an economic loss of more than $400 billion in 2005 dollars. Historical data shows clear and rapid upward trends in disaster frequency as well as geographic patterns that suggest Austin's one million inhabitants will be directly affected by a major weather related disaster during the coming 25 year period.

Significant deployment of solar electricity systems in the Austin area would change the region's energy security profile, especially if a large share of the systems deployed were "solar secure", i.e. coupled with sufficient electricity storage capability to support continuing use of homes, stores and selected public buildings, essentially no matter how long grid restoration takes. Deploying solar in this way would involve extra cost. What would be the extra value, and would it compensate for the extra cost? To answer this question, a spreadsheet model has been developed which allocates disaster value, up to a specified amount per person, determined based on relevant experience, according to the relative extent, timing and application focus of solar secure power deployment. The flow chart below summarizes the model's key inputs and calculations. A base case was defined and analyzed. Preliminary results suggest that the disaster recovery value of solar deployment in the Austin area can in the same range as the value of solar deployment to normal utility operations, i.e. greater than $1000/kW and less than $3000/kW. The model provides a tool that can be used to design PV incentive programs and/or optimize the economic benefits to the Austin community of targeted PV deployment on its schools and public buildings.



PURPOSE

The Value of Solar study conducted by Clean Power Research for Austin Energy includes a sub-task addressing the value of solar in disaster recovery. Its purpose is to quantify this value so that it can be used in a "stacked benefits" analysis specific to Austin Energy. The sub-task addresses the following topics:

1. Value Model
2. Deployment Scenarios

Results are summarized here. Subsequent work should use the model to evaluate alternative deployment scenarios by weighing the incremental value of solar in disaster recovery against the incremental cost[1] of capturing this value under different assumptions regarding deployment strategy. It is also recommended that model assumptions be reviewed in the light of actual disaster experience and on-going disaster recovery planning. For example, base case results assume a recovery scenario that would assign more value to solar deployment at commercial sites than residential sites. More thorough and detailed scenario definition is recommended as solar deployment proceeds.

SPECIAL INTRODUCTION

Item: "....The captain assigned a sergeant to get cheap battery-powered walkie-talkies from Wal-Mart – the kind you use for hunting or skiing and have a range of a few hundred yards – because with the power out, the police radios were going to be useless. A lieutenant was ordered to come up with a simple system of hand communication that the officers could learn in a few minutes. Despite all their preparations, the Kenner Police Department was headed back to the Stone Age. The situation at the New Orleans Police Department was even worse...."[2]

Item: "As floodwaters rose around Charity Hospital, the rescuers needed their own rescuing. Charity's backup generator was running out of diesel fuel. Nurses hand-pumped ventilators for patients who couldn't breathe. Doctors canoed supplies in from three nearby hospitals. 'It's like being in a Third World country. We're trying to work without power. Everyone knows we're all in this together. We're just trying to stay alive,' said Mitch Handrich, a registered nurse manager at the state's biggest public hospital."[3]

In the past, there have been mega-disasters for which preparations and response have been demonstrably inadequate. This experience has led to significant adjustments in emergency planning and infrastructure hardening. Such adjustments are likely in the years following Hurricane Katrina. No attempt is made here to anticipate what these changes may be. The Katrina disaster serves as a reminder of the staggering cost of weather related disasters and the fact that resulting power outages compound the cost of disaster recovery, prevent timely damage mitigation and extend the time required for the afflicted region to recover economically.

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[1] To have non-zero disaster recovery value, a solar electricity system must include provisions for energy storage, and these provisions add cost.

[2] Source: Philipp Meyer, "Katrina Through the Eyes of an EMT", Home Section, Austin Chronicle, September 2, 2005, http://www.austinchronicle.com/issues/dispatch/2005-09-02/pols_feature2.html

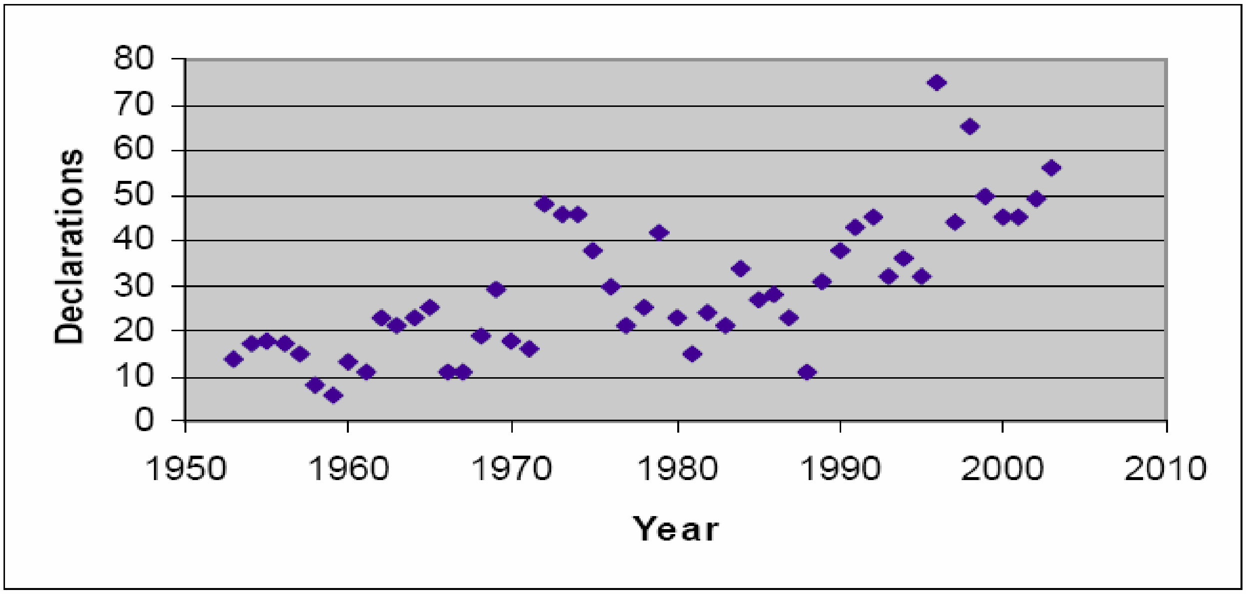
[3] Source: Source: http://news.yahoo.com/s/ap/20050831/ap_on_re_us/katrina_medical

AUSTIN’S VULNERABILITY

Major disasters are rare but enormously costly. Over the past 25 years more than sixty weather related disasters have struck the US, i.e. about 1 for every 4 million US citizens at the time, causing an economic loss of more than $400 billion in 2005 dollars. Such disasters are not only costly but Figure 1 suggests that their frequency is increasing.

Figure 2 suggests that a southern band ranging from central Texas to North Carolina is more vulnerable to weather related disasters than the remaining areas of the US. This pattern is confirmed by an analysis of global disasters summarized in Figure 2 that identifies southeastern Texas as subject to combined drought and hydrological events having high aggregate economic impact. It is thus likely that Austin’s one million inhabitants will be directly affected by a weather related disaster during the coming 25 year period.[4]

Figure 1: Disaster Declarations[5] [6]



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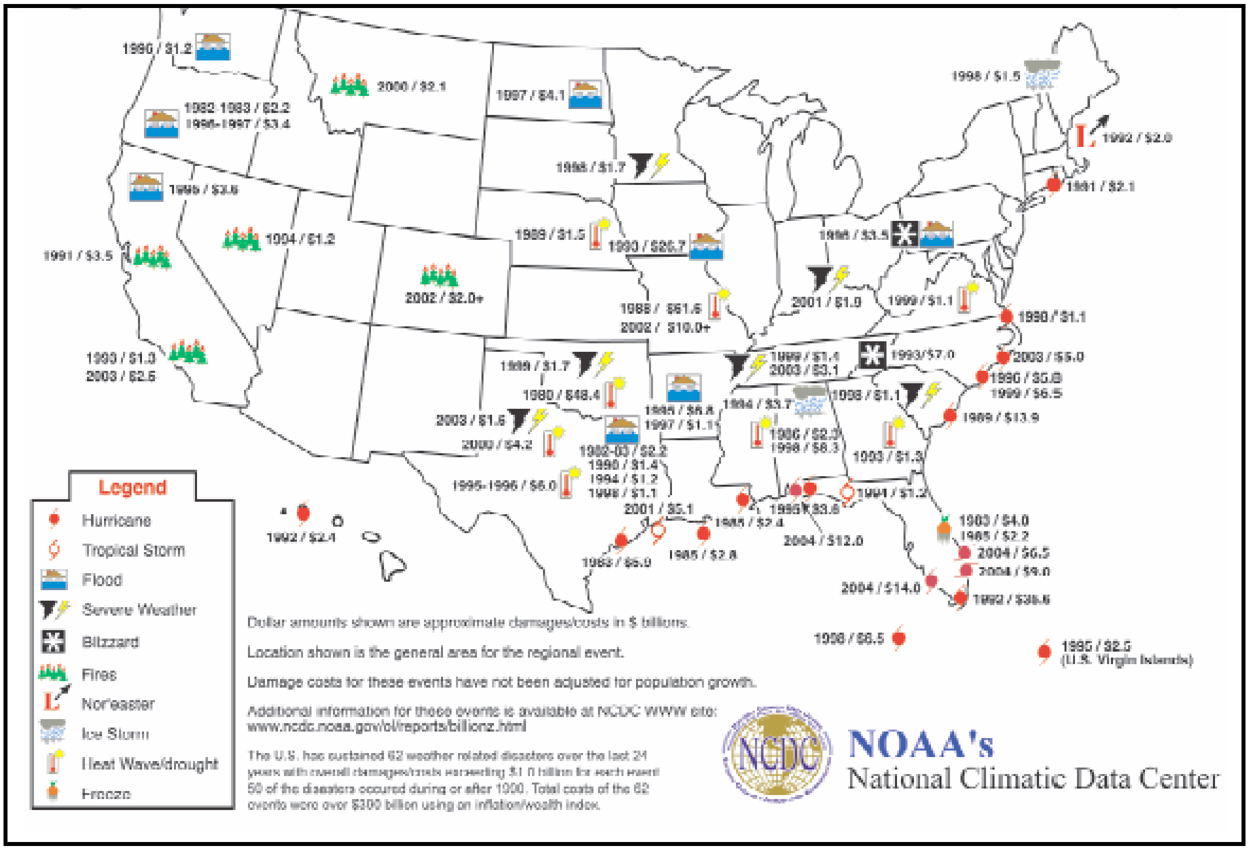
[4] For example, Austin area city and county emergency managers interviewed for this report indicated their worst case weather related disaster would be a Category 4 or 5 hurricane making landfall and sweeping inland as in the recent case of Katrina. Based on historical experience, another scenario would involve a heat wave over-stressing both local populations and the electric power infrastructure on which they rely for space cooling. A recent New York Times article (Gregory S. McNeal, “The Terrorist and the Grid, New York Times, August 12, 2005) discusses the threat of terrorism that could target switching critical computers and relays, resulting in outages lasting weeks as customized equipment is replaced or repaired.

[5] Source: Federal Emergency Management Administration, http://www.fema.gov/library/dis_graph.shtm

[6] Local and State governments share the responsibility for protecting their citizens from disasters, and for helping them to recover when a disaster strikes. In some cases, a disaster is beyond the capabilities of the State and local government to respond. The Robert T. Stafford *Disaster Relief and Emergency Assistance Act*, Public Law 93-288, as amended (the Stafford Act) was enacted to support State and local governments and their citizens when disasters overwhelm them. This law establishes a process for requesting and obtaining a Presidential disaster declaration, defines the type and scope of assistance available under the Stafford Act, and sets the conditions for obtaining that assistance.

Figure 2: Billion Dollar Weather Disasters 1980-2004[7]



Dollar amounts shown are approximate damages/costs in $ billions.

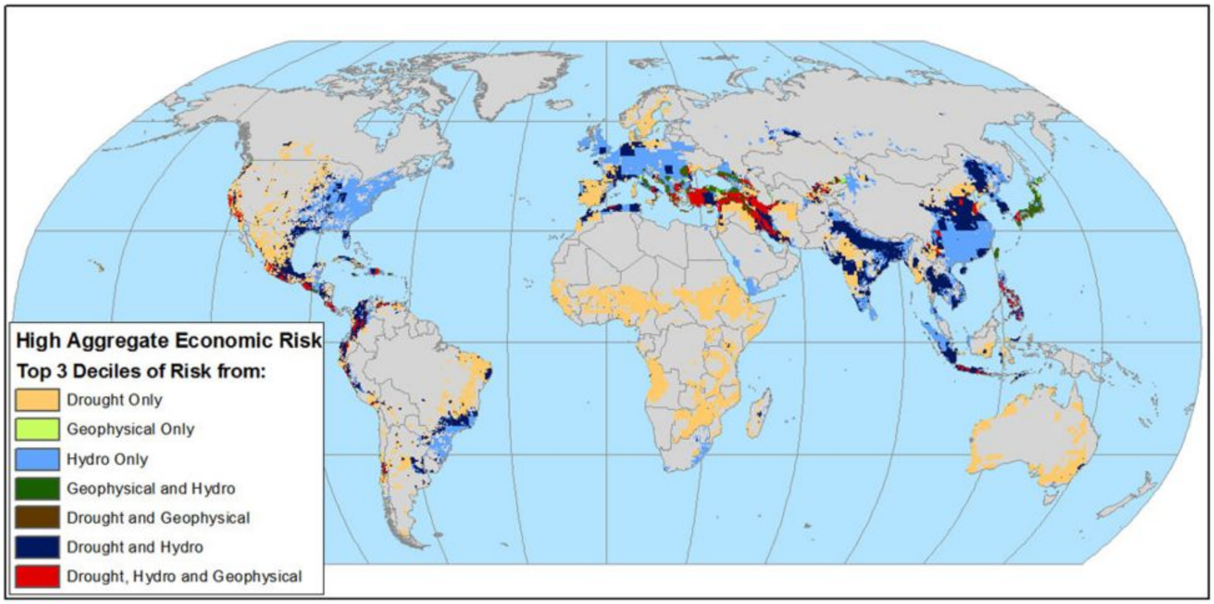
Location shown is the general area for the regional event.

Damage costs for these events have not been adjusted for population growth.

Additional information for these events is available at NCDC WWW site:
www.ncdc.noaa.gov/ol/reports/billionz.html

The U.S. has sustained 62 weather related disasters over the last 24 years with overall damages/costs exceeding $1.0 billion for each event. 50 of the disasters occured during or after 1990. Total costs of the 62 events were over $300 billion using an inflation/wealth index.

Figure 3: Disaster Risk Hotspots[8]



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[7] Source: US National Climatic Data Center

[8] Source: *LiveScience* web posting by Michael Schirber, "Global Disaster Hotspots: Who Gets Pummeled"

DISASTER RECOVERY VALUE MODEL

Assuming such a disaster does strike the Austin area, is it possible to estimate the value of solar power in to disaster response and recovery efforts? Can "avoided disaster recovery costs" be attributed to the solar power infrastructure imbedded in a disaster-stricken community?

A spreadsheet model has been developed for use in estimating disaster recovery value of targeted Austin area solar deployment. Primary inputs to the model include:

- The expected value of disaster recovery costs and economic impacts for the Austin area over the next twenty-five years.
- Austin area solar deployment targets over the same 25 years
- Results of interviews with relevant Austin area public agencies that were arranged by Austin Energy

These inputs will be discussed before describing the model and presenting base case results. Exercise of the model requires consideration of market and technology realities of solar power and "solar secure power", i.e. the use of solar energy in conjunction with energy storage. Appendix A summarizes these considerations.

DISASTER RELATED MODEL INPUTS

Forecasting the timing and cost of any future disasters in the Austin area is of course impossible. What can be done is to make nominal assumptions based on general experience and use considerations of disaster vulnerability to suggest a range around the nominal value.

Disaster Cost

The literature divides the many types of disasters in to two main categories, weather related and technological. The latter category includes airline crashes, urban fires, chemical spills, etc. Of the two, weather related disasters are on the average more costly and more frequent than comparably costly technological disasters. For simplicity, only vulnerabilities and cost data for weather related disasters will be considered.

There is data relating to economic impacts of disasters that can be used to generate nominal disaster costs for a multi-year planning period. Specifically, The United States sustained 62 weather-related disasters in the 25 years 1980 to 2004 in which overall damages and costs were $1 billion or more at the time of the event. The total cost of these disasters (mostly) in 2002 dollars and deaths has been estimated at $390 billion and 490 respectively.[9] Taking, for convenience, a disaster planning horizon for the Austin area of 25 years starting in 2005 and supposing, conservatively, that the total cost of disasters across the US will be the same over the next 25 years as it was over the preceding 25 years, then a city having a growing population of roughly 1 million, i.e. one three hundredth of the current US population, could expect its proportional share of major US disaster costs over the next 25 years to be in the neighborhood of at least $1.3 billion, or $1300 per person.

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[9] http://www.livescience.com/forcesofnature/disaster_chronology_1980_2004.html#list

Disaster Propensity

An important question: Is Austin's cost is likely to be proportional? The literature contains analysis that can help identify whether Austin and surrounding areas are more or less vulnerable to weather related disasters than other areas of the US. Based on the above discussion of vulnerability, Austin is in a geographic band that appears disaster-prone. Further, Figure 1 suggests a significant upward trend in major disaster frequency in the US.

While an extremely conservative analysis might ignore disaster propensity and assume the proportional cost of $1300 per person, a worst-case analysis might assume a cost several times this figure. There is no known analytical basis to assume other than the proportional cost, but, subject to client advice, the present analysis will assume a range of (twenty-five year) costs between $1500 per person and $3000 per person.

The proposed range of disaster cost is unlikely to cause over-estimation of the disaster recovery value of solar deployment.

Base Case Disaster Scale and Timing

As a base case, a single disaster costing $2000 per person will be assumed to occur with equal annual probability during the 25 year period 2006 through 2030.

SOLAR DEPLOYMENT RELATED MODEL INPUTS

Emergency Power

The prospect and economic consequences of grid outages are the primary motivation for installation of emergency power supplies. The size range of available emergency power supplies ranges from battery-based portable power supplies found in small laptop computers capable of delivering a few Watts to multi-MW fuel based generators coupled with dedicated long term fuel storage. Technology options for emergency power have proliferated in the years since computer use began to mushroom, but all of the options in current widespread use, *except one*, involve either or both: 1) storing electricity from the grid, or 2) on-site power generation using stored or pipeline fuel.

Solar Emergency Power

The exceptional option stores electricity from PV arrays rather than from the grid. This option has been used commercially for decades where relatively small amounts of highly reliable continuous power are needed and the power grid is not cost-effectively accessible. A small percentage of grid-tied PV systems do include battery storage (for purposes of enhanced power reliability), but most do not, primarily because most are purchased under incentive programs premised on using the grid to back up the grid-tied PV system rather than vice versa.

Austin Energy recognizes that the value of grid-tied PV resources may exceed the value of comparably rated conventional resources and intends to deploy PV to the extent its cost can be justified by its economic value to Austin Energy. Targets adopted by the community are 15MW by 2007 and 100MW by 2020. A rebate program is underway that shares the cost of customer-purchased PV systems to the extent of $4.5/W for residential applications and $4.5/W for commercial applications up to a maximum of $100,000 per project.

Austin Energy also offers its customers a “green electricity” purchase option based on wind energy feeding into the Austin area from West Texas. Customers pay a premium rate based on wind energy costs. The rate is capped for a period of years, making it attractive to customers who expect the cost of non-renewable power sources to continue to escalate. The extent to which this option will draw customers away from investing in PV is a consideration in projecting the timing and extent of PV deployment.

The terms of Austin Energy’s rebate program, along with customer concerns about future grid electricity price escalation and reliability degradation, will determine the pace of Austin area PV deployment. Interview results suggest that such customer concerns are minimal at this time. Interview results also suggest that the PV rebate level will be determined by the avoided cost value of the installed PV to Austin Energy, a value that can change based on changes in operating costs of other Austin Energy generation resources. An assumption consistent with Austin Energy fuel price forecasts would be that such operating costs and the retail electricity prices they influence will not increase significantly from their current levels over the next fifteen years.

A conservative assumption regarding PV system cost is that installed PV system costs will continue to trend downward at about 2-3% per year in constant 2005 dollars. Such an assumption is consistent with historical rates of PV cost reduction over the past two decades. Austin Energy anticipates technology and market breakthroughs during the coming fifteen years that would accelerate this trend later in the fifteen year period, but this effect is ignored in the present analysis for the sake of conservatism. Absent the competing “green electricity” offering by Austin Energy, a gradual acceleration of PV deployment might be expected during the fifteen year period, but it is reasonable to assume that wind energy costs will also trend downward along with PV costs. Thus, for the sake of a first order forecast, a steady rate of deployment of 7MW per year between 2006 and 2020 can be assumed, consistent with the above-mentioned 2007 and 2020 targets.

To a first approximation, PV has no value in a disaster recovery context without coupled energy storage; therefore, assumptions have to be made about the extent of coupled energy storage. For purposes of developing and testing the disaster recovery value model, the base case assumes that all installed solar is coupled with energy storage sufficient to provide limited operational continuity during disaster response. This 100% solar secure base case is one extreme outcome – the other extreme, i.e. PV deployed without coupled energy storage, delivers essentially no disaster recovery value. The model will allow evaluation of intermediate cases as well as the 100% solar secure case. Further discussion of solar secure deployment considerations can be found in Appendix A.

EMERGENCY MANAGEMENT CONSIDERATIONS

Greater Austin and Travis County

Postulating a representative disaster scenario for Austin requires local knowledge, especially regarding emergency management plans and experience, facilities used during disaster recovery, and plans for PV deployment. Accordingly, to acquire this information, interviews were conducted with representatives of the following local organizations:

- Austin Energy
- American Red Cross of Central Texas
- City of Austin Emergency Management
- Travis County Office of Emergency Management
- Austin Independent School District

Emergency Management Plans and Experience

Austin is subject to heat waves as well as localized flooding and high winds, e.g. tornados spun off from category 4 and 5 hurricanes. Severe weather events are not rare. Five population shelters had to be opened last November, and serious localized flooding occurred a week prior to the above interviews. Austin area emergency planning, in addition to dealing with the safety of local residents, addresses the need to handle evacuation overflow from the Houston area when hurricanes threaten to make landfall there.

Emergency management priorities include radio and central telecom sites as well as hospitals. Emergency generators at critical facilities require significant maintenance and in some cases are vulnerable to being disabled by localized flooding. In periods between major disasters, their readiness tends to degrade, resulting in high failure rates and fuel shortages when they are operated under emergency conditions.

The Austin Independent School District has favorable experience with grid reliability and so does not make provision for emergency power at its facilities. This could be a problem waiting to happen. However, AISD and Austin Energy both point out that power outages are typically of short duration and that conditions leading to extended outages, e.g. ice storms, also result in conditions that do not favor school operation, e.g. in the wake of ice storms that cause power outages, roads are also icy, temporarily compromising the safety of transportation to and from school.

Facilities

Austin area emergency managers are involved in planning to determine emergency operations facility expansion needs in 5, 10 and 20 years. For example, the Austin area emergency operations center needs a new parking structure on which a solar array might serve the dual purpose of emergency power and shading. The local American Red Cross chapter house and the United Way call center are also critical to emergency operations.

Austin/Travis County plans for mass care of its own evacuees as well as displaced populations from coastal areas and has 30 designated shelters for this purpose, including schools, churches and recreations centers. Some are designated as special needs shelters serving evacuees under medical care or requiring medical attention. The list is being expanded to 70 designated shelters by adding all local area middle and high schools. Greater Austin is a major sheltering area for refugees and evacuees from other areas, with planned capacity to handle up to 45,000 people evacuating from coastal areas struck by a hurricane or tropical storm. Local field houses and recreation centers, some of which have large emergency generators, are used to serve evacuees from coastal areas.

VALUE ANALYSIS

A spreadsheet model has been developed which allocates disaster value, up to a specified amount per person, determined based on relevant experience, according to the relative extent, timing and application focus of solar secure power deployment.

The valuation model hinges on the well established link between electricity consumption and economic productivity, a well correlated relationship under normal conditions. Obviously, some economic effects of disasters are simply costs of replacement and repair of damaged or destroyed assets. Other effects relate to the loss of economic productivity. An implied premise of the value analysis is that if some, rather than no, electricity supply is available throughout the stricken area, both asset and economic productivity loss will be mitigated in proportion to the amount of the non-grid electricity supply still available and operating.

The effect is assumed to be segment-specific, i.e. some segments are more economically critical during disaster recovery. It is also assumed to be non-linear, i.e. essential economic activity, loss prevention and acceleration of recovery times can be supported with limited electricity supply, provided it is widely accessible.

Disaster recovery value can be estimated for each year in the solar deployment period using a spreadsheet model that enables local knowledge to drive key assumptions. The flow chart in Figure 4 summarizes key inputs and calculations. Primary steps A through K the model are described as follows in more detail:

A. Organize electric load data for the planning area according to sector, i.e. residential, commercial, industrial and public

B. Forecast solar capacity deployment in terms of deployment rate (MW/year) and sector (% allocation) in order to project cumulative capacity for each sector over the planning period, i.e. for year 1 through n.

C. Calculate the percentage of sector load met by solar secure capacity for years 1 through n.*

D. Determine disaster value capture in each sector as a function of percent sector load met. See Figure 5 for a plot of base case lookup table data.[10]

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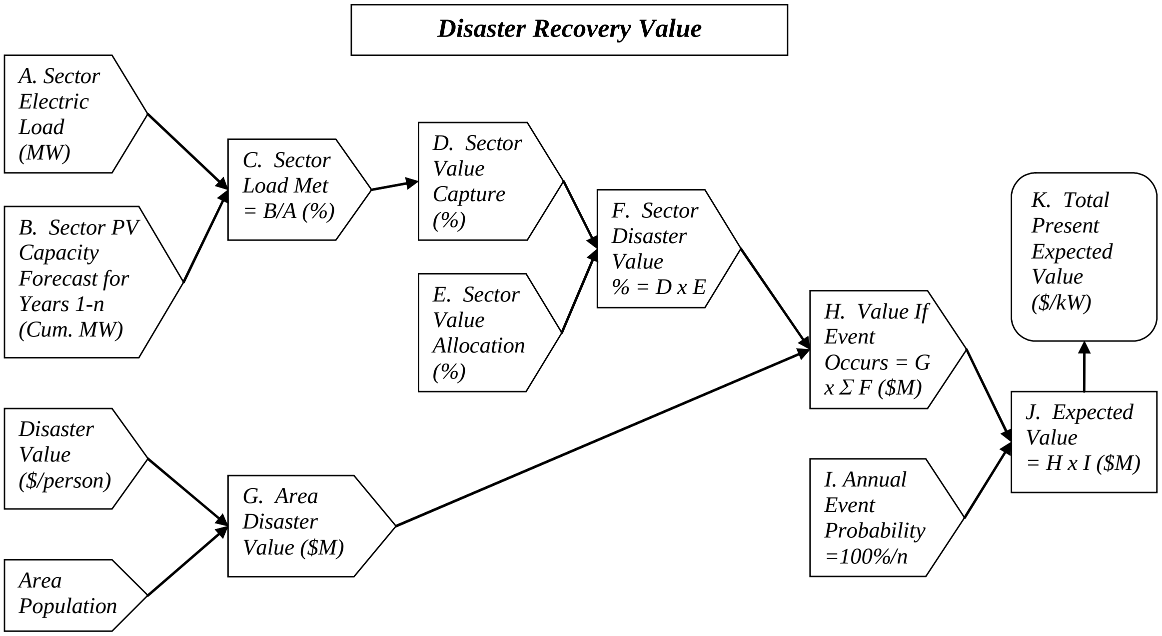
[10] Solar secure power will not be cost-effective for on-site industrial power in most cases, i.e. plants that run more than one shift. Further, industrial load would be minimal until after significant recovery in other sectors, since industry depends on local labor and infrastructure. Accordingly, the model assigns no value to solar secure power at industrial sites and also assumes no deployment in this sector. Residential and commercial sectors are given equal weight in general, since they are generally inter-dependent. People need food, shelter, and public services, or they'll

E. Determine sector value percentages by applying judgment and experience.
F. Estimate the percentage of total disaster recovery value for each sector in each year as the product of the disaster recovery value percentage times the sector value percentage
G. Setting the total potential disaster recovery value by multiplying the assumed disaster cost per person (discussed above) times the affected population
H. Determining the value if the event occurs in a given year by summing the sector percentages in F and multiplying the result by the total disaster value.
I. Determining the probability of occurrence for each year by assuming the disaster occurs during the planning period its probability of occurrence is the same each year.
J. Determining the expected value for the year by multiplying disaster recovery value (H) by the probability of occurrence (I).
K. Apply an assumed discount factor to and then add the yearly discounted expected values to determine total present value.

* This can be done two ways, i.e. by calculating the solar percentage based on peak capacity or based on energy delivery. Solar capacity factors are typically much less than grid system load factors, so the energy basis results in more conservative values.

Figure 4: Disaster Recovery Value Flow Chart



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evacuate if they can. Unless the public sector can at least provide for public safety and relief operations, residential and commercial power is devalued for lack of people to use it. Likewise, if people cannot get food either from markets or retail food services, they may evacuate. Accordingly, serving small percentages of public sector critical load is highly valuable and more valuable than serving small percentages of commercial load, which is more valuable than serving small percentages of residential load. Serving critical food services and retail building supply loads of the commercial sector has higher value than serving the remainder, e.g. shopping malls, which relies on discretionary spending.

Figure 5: Base Case Value Relationships

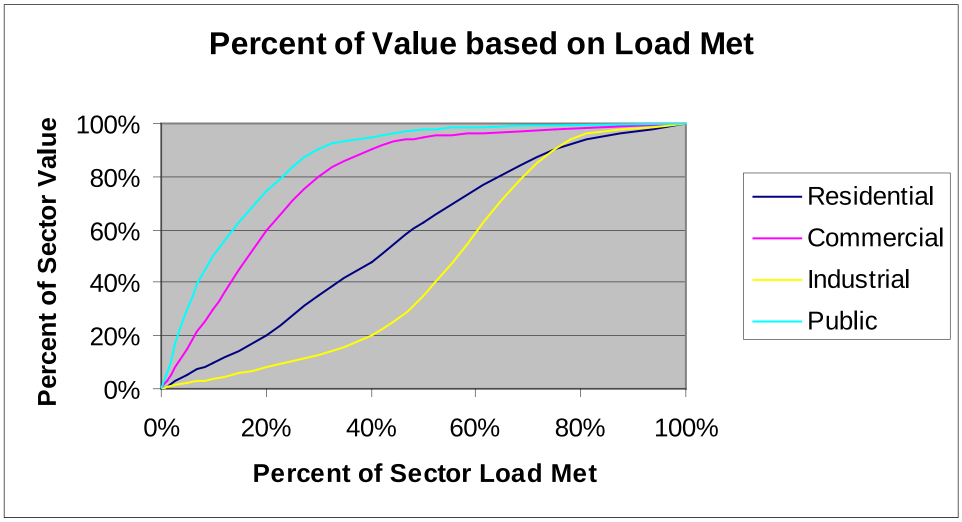
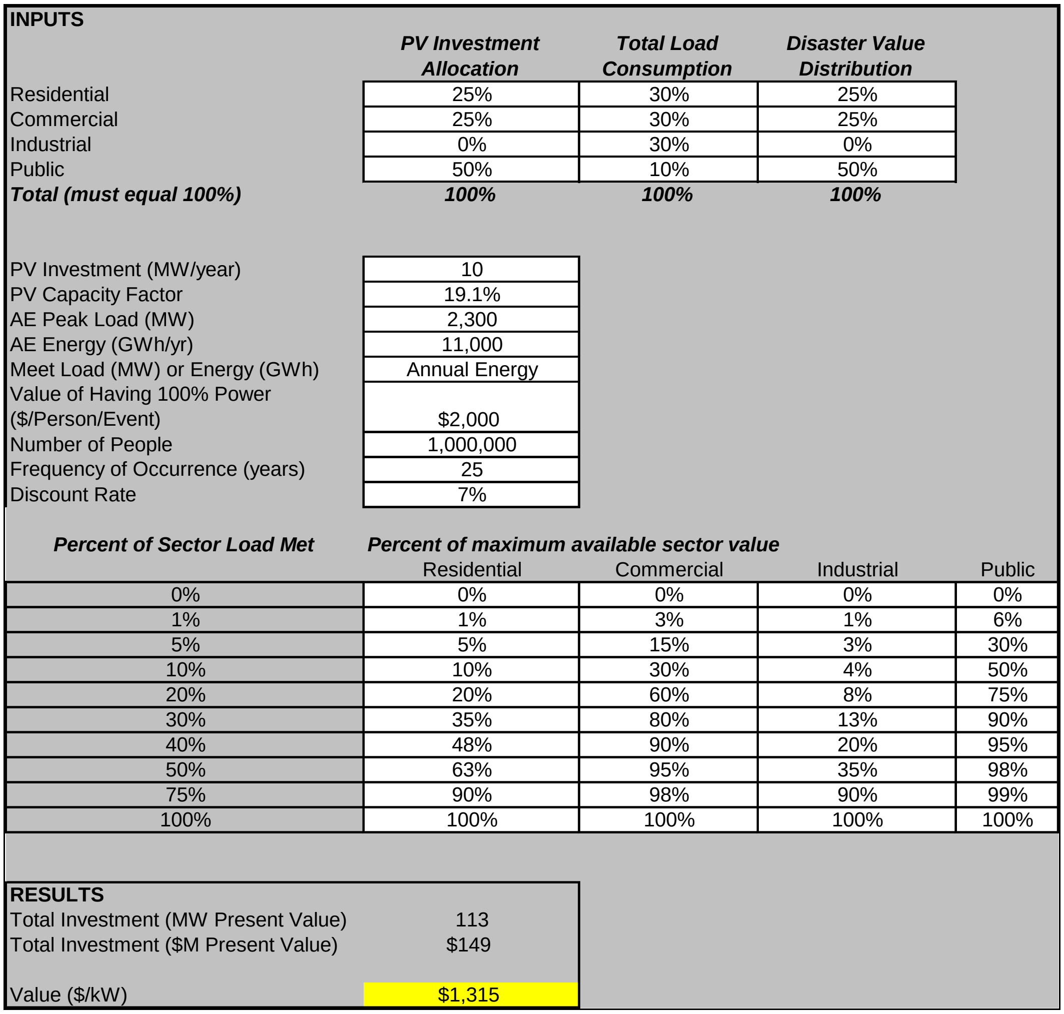


Figure 6: Base Case Assumptions and Results (annual energy basis)



INPUTS

	PV Investment Allocation	*Total Load Consumption*	*Disaster Value Distribution*
Residential	25%	30%	25%
Commercial	25%	30%	25%
Industrial	0%	30%	0%
Public	50%	10%	50%
Total (must equal 100%)	*100%*	*100%*	*100%*

PV Investment (MW/year)	10
PV Capacity Factor	19.1%
AE Peak Load (MW)	2,300
AE Energy (GWh/yr)	11,000
Meet Load (MW) or Energy (GWh)	Annual Energy
Value of Having 100% Power ($/Person/Event)	$2,000
Number of People	1,000,000
Frequency of Occurrence (years)	25
Discount Rate	7%

Percent of Sector Load Met	*Percent of maximum available sector value* Residential	Commercial	Industrial	Public
0%	0%	0%	0%	0%
1%	1%	3%	1%	6%
5%	5%	15%	3%	30%
10%	10%	30%	4%	50%
20%	20%	60%	8%	75%
30%	35%	80%	13%	90%
40%	48%	90%	20%	95%
50%	63%	95%	35%	98%
75%	90%	98%	90%	99%
100%	100%	100%	100%	100%

RESULTS

Total Investment (MW Present Value)	113
Total Investment ($M Present Value)	$149
Value ($/kW)	$1,315

PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

Base case results (Figure 6 and Appendix C) support the general conclusion that solar can have a significant value related to avoiding and mitigating economic costs of disasters and speeding disaster recovery. The value can be economically significant, i.e. in excess of $1000/kW, in cases where solar is deployed in conjunction with appropriate amounts of energy storage. Obviously, the valuation methodology is inexact. Calculations based on energy production result in a lower value, i.e. around $1300/kW (Figure 6), and calculations based on peak capacity result in a higher value, i.e. around $2600/kW (Appendix C). There is probably a threshold level of solar deployment that must be achieved before the value becomes proportional to installed solar capacity (as assumed). The levels defining the base case probably are above this threshold.

The present analysis did not consider the potential load shifting and peak shaving value of PV-coupled energy storage either to Austin energy or to Austin Energy customers. Likewise, the analysis did not consider the reliability enhancement value of a PV-coupled UPS capability in carrying through typical or extended non-disaster related grid outages. These values are primarily attributable to energy storage, not solar, but should be considered in setting deployment targets and designing incentive programs.

NEXT STEPS

The results suggest the interesting possibility (to be addressed next using the model described here) of optimizing solar disaster recovery value by intentionally locating at least some of the targeted Austin area PV installations at facilities designed and/or designated for use in emergency operations. For example, emergency operations centers are likely to be equipped with adequate back-up power capability, but facilities used opportunistically for mass care and special medical care of refugees and evacuees may not be. Schools, for example, especially in the Austin area, have not yet been subjected to the effects of extended grid outages and so are not investing in back-up power capabilities. Meanwhile, all Austin middle schools and high schools are being added to the list of designated evacuation shelters, and over time, their reliance on information technology will increase, making them more vulnerable to the effects of grid outages that lead commercial enterprises to invest in back-up power. Their favorable recent grid reliability experience may be encouraging under-investment in backing up critical loads and in anticipation of extended grid outages and in preparation for crisis operations.

There is another dimension of optimization still to be addressed, i.e. the relationship of value to cost. Storage costs vary with storage capacity, and other studies have suggested that capacities necessary to provide some level of extended operational continuity would be significantly greater than those needed to carry loads over for two or three hours. On the other hand, in most cases sizing criteria for stand-alone PV/battery hybrid systems would be excessive, i.e. economically inappropriate. Recent studies have suggested that storage capacity consistent with disaster recovery needs would add about 25% to the cost of the basic solar power system in most cases. As opportunities emerge to couple the storage capacity of plug-in hybrid vehicles to basic solar power systems, the incremental cost of solar secure capabilities would be much less than 25%, probably in the 5% range. Additional cases should be analyzed to quantify scenario effects and cost/value trade-offs.

Appendix A: Solar Deployment Considerations

Determining the "avoided costs" that can be attributed to the availability of solar power infrastructure in a disaster-stricken community requires some general understanding of the interplay of grid and solar power supply systems and emergency management resources and processes.[11] Key points guiding the present analysis include:

- Disasters that threaten populations and disrupt economic activity in many cases also damage or disable the local power grid.
- Extended power grid outages during or in the wake of disasters compound the difficulty, risks and costs of disaster recovery.
- Some regions of the US are more prone to specific weather related or human-induced disasters than others, but even within a given region, each disaster is unique in terms of impact, geographic extent and duration.[12]
- There is little or no documented experience with use of economically significant local solar power resources in disaster recovery.[13]
- Austin Energy's current solar incentive programs would result in PV systems averaging around 5kW (average is 3 kW for residential and 15 kW for commercial). An equal number of kW in each category at these sizes would result in an average size of 5kW.

Initial "Solar Secure" Deployment

Grid-tied PV systems decoupled from energy storage capability have little or no disaster recovery value. (Typically, they have no value at all if the grid to which they are connected becomes disabled – most grid-tied inverters require a signal from the grid to operate.) So, it is important to envision the rate and extent to which grid-tied PV systems will either be installed with storage included or later upgraded to couple with on-site energy storage. It is also important to envision technology options that may lower the cost and remove other barriers to deployment of on-site PV-compatible energy storage.

Stationary batteries represent the current commercially available option, and their costs are well known. Including sufficient battery storage and related power control and conditioning capability to provide emergency power during an extended grid outage would add about 25% to the cost of the basic PV system, more or less independent of system size.[14] The large and

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[11] Hurricane Hugo which hit the coast of South Carolina in 1989 provides an illustration. Hugo' major impact on lifelines was the failure of the local electric supply system, which collapsed in winds of only 70mph. Only 23 percent of residents in the Charleston area had power eight days after the hurricane. Source: Disasters by Design: A Reassessment of Natural Hazards in the United States, by Dennis Mileti, Joseph Henry Press, 1999

[12] Mitigation and recovery is typically an exercise in crisis management and opportunistic use of volunteer, donated and often portable resources, not fixed resources dedicated to the purpose (other than emergency management operations centers).

[13] The reasons are worth mentioning, i.e.: 1) the grid-tied solar electricity market is still concentrated in a few countries and regions, 2) typical grid-tied PV inverters are rendered inoperable by grid outages, and 3) typical PV incentive programs apply only to generating solar power and not to storing it.

[14] See G. Braun, P. Varadi, and J. Thornton, "Energy Secure Schools: Technology, Economic and Policy Considerations", Solar 2005 Proceedings. Additional detail is available in a soon to be published NREL report entitled "Solar Secure Schools"

profitable UPS industry is now starting to introduce "PV-compatible" products, and alternative products having comparable functionality are also in development.

Future "Solar Secure" Deployment

Importantly, Austin Energy and other major utilities and energy experts across the US envision a scenario involving "plug-in hybrid" vehicles, i.e. hybrid vehicles with expanded battery capacity, allowing their use as electric-only commuter and fleet vehicles. The technology barriers to this scenario are minimal, and the economic drivers (gasoline-equivalent "fuel" costs under $1/gallon) are compelling. It is beyond the current scope to envision how, where and how rapidly the plug-in hybrid scenario will be realized, but once it is established, it will provide a much more cost effective option for "solar secure" deployment than a "business as usual" scenario involving stationary batteries configured in PV-compatible UPS products.

By 2020, there will likely be enough plug-in hybrid vehicles on the road in the Austin area to allow any installed or planned residential PV system there to be made "solar secure" at an additional cost in a range starting around $1000, or an additional 5% (vs. the current 25%) above the basic PV system cost. It may be assumed that in the first 10 years of Austin area PV deployment, 2005-2015, conventional UPS configurations will predominate and, over the following decade, 2015-2025, solar coupled UPS systems will recede in favor of using the imbedded and portable energy storage capacity inherent in plug-in hybrid vehicles. It is reasonable to assume that by 2020 all or nearly all new PV systems will have provisions to couple to plug-in hybrids, thus avoiding the current 25% cost penalty incurred using stationary batteries.

PV Deployment Pattern

If PV deployment is primarily an outcome of an incentive program of the current design, then it is reasonable to expect a fairly even geographic distribution of residential and commercial systems in the 2kW to 25kW size range. This deployment pattern has value in disaster recovery and but steps can be taken to direct solar deployment toward loads that are critical to disaster recovery. A supplemental analysis will seek to define the additional disaster recovery value in the event PV is deployed preferentially on, for example, schools and other facilities that play a critical role during disaster recovery.

Appendix B: Base Case Calculations (annual energy basis)

CALCULATIONS									
Total Value ($/Event)	$2,000,000,000								
	2007	2008	2009	2010	2011	2012	2017	2022	2026
PV Investment (MW)									
Incremental Investment	10	10	10	10	10	10	10	10	10
Cumulative PV Investment	10	20	30	40	50	60	110	160	200
Cumulative PV Investment (MW)									
Residential	2.5	5	7.5	10	12.5	15	27.5	40	50
Commercial	2.5	5	7.5	10	12.5	15	27.5	40	50
Industrial	0	0	0	0	0	0	0	0	0
Public	5	10	15	20	25	30	55	80	100
PV Output (GWh)									
Residential	4.1829	8.3658	12.5487	16.7316	20.9145	25.0974	46.0119	66.9264	83.658
Commercial	4.1829	8.3658	12.5487	16.7316	20.9145	25.0974	46.0119	66.9264	83.658
Industrial	0	0	0	0	0	0	0	0	0
Public	8.3658	16.7316	25.0974	33.4632	41.829	50.1948	92.0238	133.8528	167.316
Load by Sector (MW)									
Residential	690	690	690	690	690	690	690	690	690
Commercial	690	690	690	690	690	690	690	690	690
Industrial	690	690	690	690	690	690	690	690	690
Public	230	230	230	230	230	230	230	230	230
Total	2,300	2,300	2,300	2,300	2,300	2,300	2,300	2,300	2,300
Energy by Sector (GWh)									
Residential	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300
Commercial	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300
Industrial	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300
Public	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Total	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000
Percent of Sector Load or Energy Met by PV									
Residential	0.1%	0.3%	0.4%	0.5%	0.6%	0.8%	1.4%	2.0%	2.5%
Commercial	0.1%	0.3%	0.4%	0.5%	0.6%	0.8%	1.4%	2.0%	2.5%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Public	0.8%	1.5%	2.3%	3.0%	3.8%	4.6%	8.4%	12.2%	15.2%
Percent of Sector Load Met by PV (Cap)									
Residential	0.1%	0.3%	0.4%	0.5%	0.6%	0.8%	1.4%	2.0%	2.5%
Commercial	0.1%	0.3%	0.4%	0.5%	0.6%	0.8%	1.4%	2.0%	2.5%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Public	0.8%	1.5%	2.3%	3.0%	3.8%	4.6%	8.4%	12.2%	15.2%
Percent of Sector Value (based on Lookup table)									
Residential	0.1%	0.2%	0.3%	0.5%	0.6%	0.7%	1.2%	2.0%	2.5%
Commercial	0.3%	0.6%	0.9%	1.5%	1.8%	2.1%	3.6%	6.0%	7.5%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Public	4.2%	8.4%	12.0%	18.0%	21.0%	27.0%	42.0%	55.0%	62.5%
Maximum Percent of Total Value By Sector									
Residential	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%
Commercial	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Public	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%
Estimated Percent of Total Disaster Value									
Residential	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.5%	0.6%
Commercial	0.1%	0.2%	0.2%	0.4%	0.5%	0.5%	0.9%	1.5%	1.9%
Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Public	2.1%	4.2%	6.0%	9.0%	10.5%	13.5%	21.0%	27.5%	31.3%
Total	2.2%	4.4%	6.3%	9.5%	11.1%	14.2%	22.2%	29.5%	33.8%
Disaster Value if Event Occurs ($M)	$44	$88	$126	$190	$222	$284	$444	$590	$675
Probability of Occurrence	4%	4%	4%	4%	4%	4%	4%	4%	4%
Expected Value ($M)	$2	$4	$5	$8	$9	$11	$18	$24	$27
Discount Factor	100%	93%	87%	82%	76%	71%	51%	36%	28%

Appendix C: Base Case Assumptions and Results (peak load basis)

INPUTS

	PV Investment Allocation	***Total Load Consumption***	***Disaster Value Distribution***
Residential	25%	30%	25%
Commercial	25%	30%	25%
Industrial	0%	30%	0%
Public	50%	10%	50%
Total (must equal 100%)	***100%***	***100%***	***100%***

PV Investment (MW/year)	10
PV Capacity Factor	19.1%
AE Peak Load (MW)	2,300
AE Energy (GWh/yr)	11,000
Meet Load (MW) or Energy (GWh)	Peak Load
Value of Having 100% Power ($/Person/Event)	$2,000
Number of People	1,000,000
Frequency of Occurrence (years)	25
Discount Rate	7%

Percent of Sector Load Met	***Percent of maximum available sector value*** Residential	Commercial	Industrial	Public
0%	0%	0%	0%	0%
1%	1%	3%	1%	6%
5%	5%	15%	3%	30%
10%	10%	30%	4%	50%
20%	20%	60%	8%	75%
30%	35%	80%	13%	90%
40%	48%	90%	20%	95%
50%	63%	95%	35%	98%
75%	90%	98%	90%	99%
100%	100%	100%	100%	100%

RESULTS

Total Investment (MW Present Value)	113
Total Investment ($M Present Value)	$300
Value ($/kW)	$2,645