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Army
Analysis**

RENEWABLE ENERGY ANALYSIS FOR STRATEGIC RESPONSIVENESS 2
(REASR 2)

DECEMBER 2002

CENTER FOR ARMY ANALYSIS
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The analysis of renewable energy within a hybrid electric generator system for remote military applications has not been studied. This report highlights the potential of new, photovoltaic thin-film composite arrays to augment fossil fuel generators for military power applications in remote areas. Because the photovoltaic phenomena works only during daylight hours and is also dependent on latitude for sun power, this study examined renewable hybrid electric generation in areas of poor sun (Hanau, Germany) and in areas of good sun (Ft. Irwin, California). This report investigates the value-added that renewable energy can bring to tactical operation centers and remote power stations (for purposes of homeland security) in terms of increased operational readiness, reduced cost, energy savings and pollution abatement.

14. SUBJECT TERMS
Keywords: Photovoltaics (PV), hybrid electric, military remote power applications, GENSET, CIGS (copper, indium, gallium, diSelenide), Amorphous Silicon (A Si), direct current, power inversion, cost-benefit, M101, M105, TOC, TACS, renewable energy

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RENEWABLE ENERGY ANALYSIS FOR STRATEGIC RESPONSIVENESS 2

SUMMARY

THE PROJECT PURPOSE

To continue the analysis of deployable photovoltaic (PV) systems in support of various Army unit and installation missions. The Renewable Energy Analysis for Strategic Responsiveness (REASR 2) will examine issues regarding PV and strategic logistics, economics and operational readiness.

THE PROJECT SPONSOR

Logistics Integration Agency
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Attn: Mr. Grant Keath

THE PROJECT OBJECTIVES are to:

(1) Analyze strategic responsiveness of PV – focusing on deployability, agility, versatility, sustainability and maintainability at different sites

(2) Evaluate the operational readiness of PV in the sustaining base

(3) Provide an economic analysis of deployable PV based on future potential

THE SCOPE OF THE PROJECT

This project evaluates photovoltaic energy at Ft. Irwin, California (National Training Center) and Hanau, Germany during the summer of 2001.

THE MAIN ASSUMPTIONS for the cost benefit analysis are

- Operational TEMPO (OPTEMPO) for training = 1600 hours per year
- Fuel is always available (and tested)
- 20 year life-cycle costs for both Tactically Quiet Generators and PV Hybrid Generator
- Ft. Bragg Ambient Conditions for life-cycle costing
- FY02 Dollars ($)
- Cost of fuel is $.76 / gal (Defense Energy Support Center)

THE PRINCIPAL ECONOMIC FINDINGS are**:**

1. Tactically Quiet Generator O & M Costs and Initial System Costs are the primary factors in the economic payback analysis
2. Military deployments pay increased costs per gallon for delivered JP8 to and beyond the FEBA. This increased cost drives the economic paybacks for electric hybrid generation down to 1 or 2 years.
3. Future costing issues such as economies of scale can play a large part in the reduction of electric hybrid capital costs

THE PRINCIPAL INSIGHTS are that tactically deployed hybrid electric systems can:

1. support unit and installation applications
2. improve operational readiness
3. help to reduce logistics footprint

THIS STUDY ACCOMPLISHED THE FOLLOWING:

(1) Provided the basis to suggest renewable energy language be included within future Capability Development Documents (formerly called Operational Requirement Documents).

(2) Located the funding for future refinements and production of an additional two (2) hybrid electric systems

(3) Demonstrated two tactical, alternating-current hybrid electric systems in Hanau, Germany and Ft. Irwin, California.

(4) Established air-lift loading requirements for hybrid electric vehicle transport via military C-17 and C-130 aircraft.

(5) Fostered Congressional interest and support in renewable energy capabilities for electric power applications at remote sites

THE PROJECT EFFORT was conducted by Hugh Jones, Resource Analysis Division (703) 806-5389 (office), 301-792-6187 (cell).

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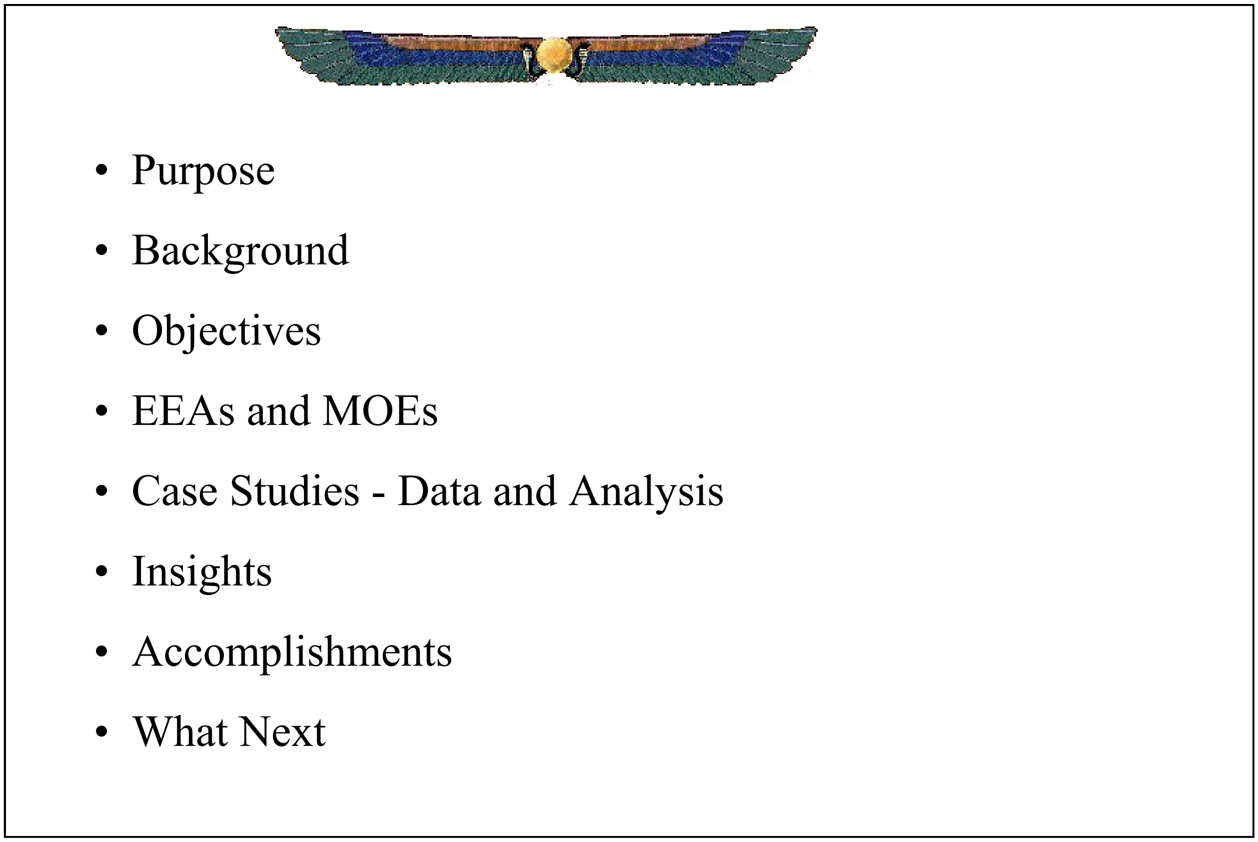
1 INTRODUCTION

1.1 Final Report

This project was completed in December 2002 for the Logistics Transformation Agency, Ft. Belvoir, Virginia and New Cumberland, Pennsylvania. It encompasses a range of exercise sites that included both the National Training Center at Ft. Irwin, California and Hanau, Germany.

The hybrid electric, trailer mounted power system called the Tactical Alternating Current Power System (TACS) was demonstrated at these and other locations since 1998. For additional background information on this topic, see the CAA reports entitled the Analysis of Deployable Applications of Photovoltaics in Theater (ADAPT) and the Renewable Energy Analysis for Strategic Responsiveness (REASR).

1.2 Agenda



- Purpose
- Background
- Objectives
- EEAs and MOEs
- Case Studies - Data and Analysis
- Insights
- Accomplishments
- What Next

Figure 1. Agenda

The ancient Eqyptians worshipped the sun and thought of it as a god. They also provided a name to this god of the sun and called it “RA”. The ancient symbol of the sun god RA can be seen on Figure 1 as two wings, attached by a golden orb (symbolizing the sun and its movement across the sky). The US Army recognizes the sun as a continuing, pollution free energy resource – a renewable energy resource. The Army is only now beginning to use the sun’s energy in new and different ways.

One such way is to harness the sun’s particle energy (Einstein called this energy “photons”) and to produce electric energy from this resource. This is not an easy accomplishment because of the difficulty in (a) collecting the energy, (b) storing the energy, (b) inverting the energy from direct current to alternating current (if necessary).

The cost of these challenges is significant given the prototype equipment being used and the small economies of scale involved (8 prototype systems built to-date). However, an analysis can be done to hypothesize both cheaper equipment and large scale efficiencies over the long term.

This study analyzed both the costs and benefits of the photovoltaic (PV) system employed as a hybrid system to complement diesel (JP8) and gasoline generator sets (GENSETs) used by the deployable Army and installations. A follow-on effort to include other field demonstrations of the hybrid PV

System will be detailed in REASR 3: Grafenwoehr Army Training Center (ATC), February 2003, Ft. Lewis, Washington, 2004.

A glossary is provided at section 12.7 of this report to facilitate the reader's technical understanding of certain energy terminology and military acronymns.

1.3 Purpose

To continue the analysis of deployable photovoltaic (PV) systems in support of various Army unit and installation missions. The Renewable Energy Analysis for Strategic Responsiveness (REASR 2) will examine issues regarding PV and strategic logistics, economics and operational readiness.

REASR
June 2000 – April 2001

- ☑ **RIMPAC, Pohakoloa Training Area**
- ☑ **Field Training Exercise, Ft. Bragg**
- ☑ **Marne Focus, Ft. Stewart**

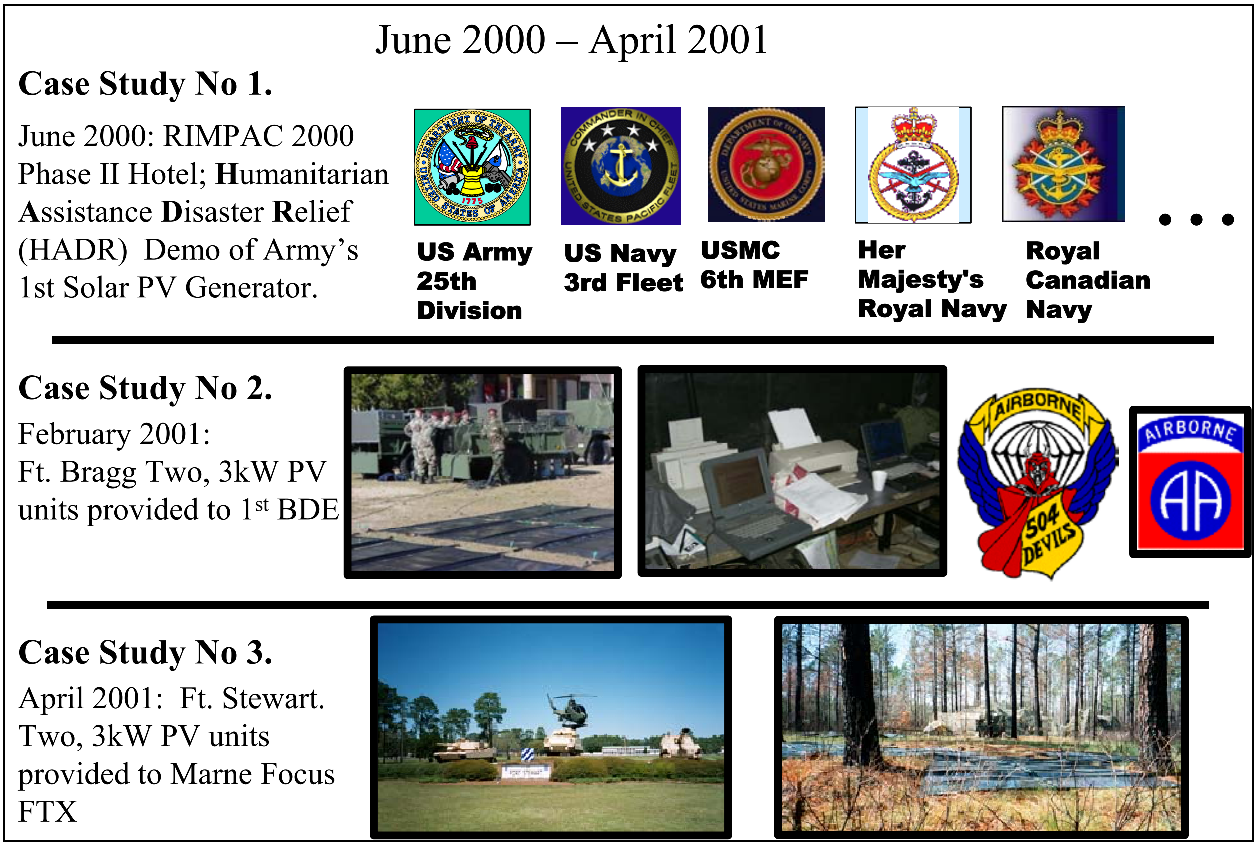
REASR 2
April 2001 – December 2002

- ☐ **FTX, Ft. Irwin**
- ☐ **V Corps, 18th MP BDE, 709th MP BN, Hanau, GE**

Figure 2. Purpose

The US Army Concepts Analysis Agency used this second study opportunity to conduct a cost-benefit analysis illustrating the military value-added of hybrid PV systems both in the field and for installation electric energy. This prototype of photovoltaic, hybrid electric power employed more efficient photovoltaic arrays and more battery storage than previous variants.

1.4 Review of 3 Initial PV Demos (REASR)



June 2000 – April 2001

Case Study No 1.

June 2000: RIMPAC 2000 Phase II Hotel; **H**umanitarian **A**ssistance **D**isaster **R**elief (HADR) Demo of Army's 1st Solar PV Generator.

Case Study No 2.

February 2001:
Ft. Bragg Two, 3kW PV units provided to 1st BDE

Case Study No 3.

April 2001: Ft. Stewart. Two, 3kW PV units provided to Marne Focus FTX

Figure 3. Review of 3 Initial PV Demos (REASR)

Background. The REASR series of studies is a cost / benefit analysis that provides insights into the feasibility and potential of using hybrid PV energy systems in the Army sustaining base and for strategic deployments. PV power is being evaluated as to its value added in providing enhanced strategic responsiveness, improved operational readiness, cost savings, energy savings and pollution prevention.

The initial REASR study helped to facilitate the acquisition of 8 solar power units paid for by DARPA, DCSLOG and the ACSIM for purposes of providing remote power to army units-in-the-field.

These demonstrations of deployable PV eventually moved to areas outside the continental US (CONUS) to better understand PV's strategic value for the Army in different parts of the world. Because PV works most efficiently near the equator and at high altitudes, it was important to study PV at different times of the year, in different geographical locations and with different military units to insure a good mix of study variables along with soldier interaction with the PV generator system called TACS: Tactical Alternating Current System. The three phases of the data gathering portion of the cost / benefit analysis for the 1st REASR done in 2001 were:

- PV Demonstration at United Nations & Military Pacific Rim (RIMPAC) Exercises
- Sustaining Base deployment (and Joint Readiness Training Center rotation) with the 82nd Airborne
- PV European deployment with elements of the 7th US Army

1.5 Previous CAA Energy Studies

1992 - Present

- Renewable Energy Efficiency Planning (REEP)[1]
- Renewables & Energy Efficiency Sustainable Investment (REESIN)[1]
- Planning Environmental Resource Strategy Evolution and Utilization
- Synthesizing Energy Worth
- Pollution Abatement and Prevention Analysis
- Analysis of Deployable Applications of Photovoltaics in Theater
- Renewable Energy Analysis for Strategic Responsiveness (REASR)[2]
- REASR 2

[1] Wilbur Payne Memorial Award

[2] Secretary of Energy Award

Figure 4. Previous CAA Energy Studies

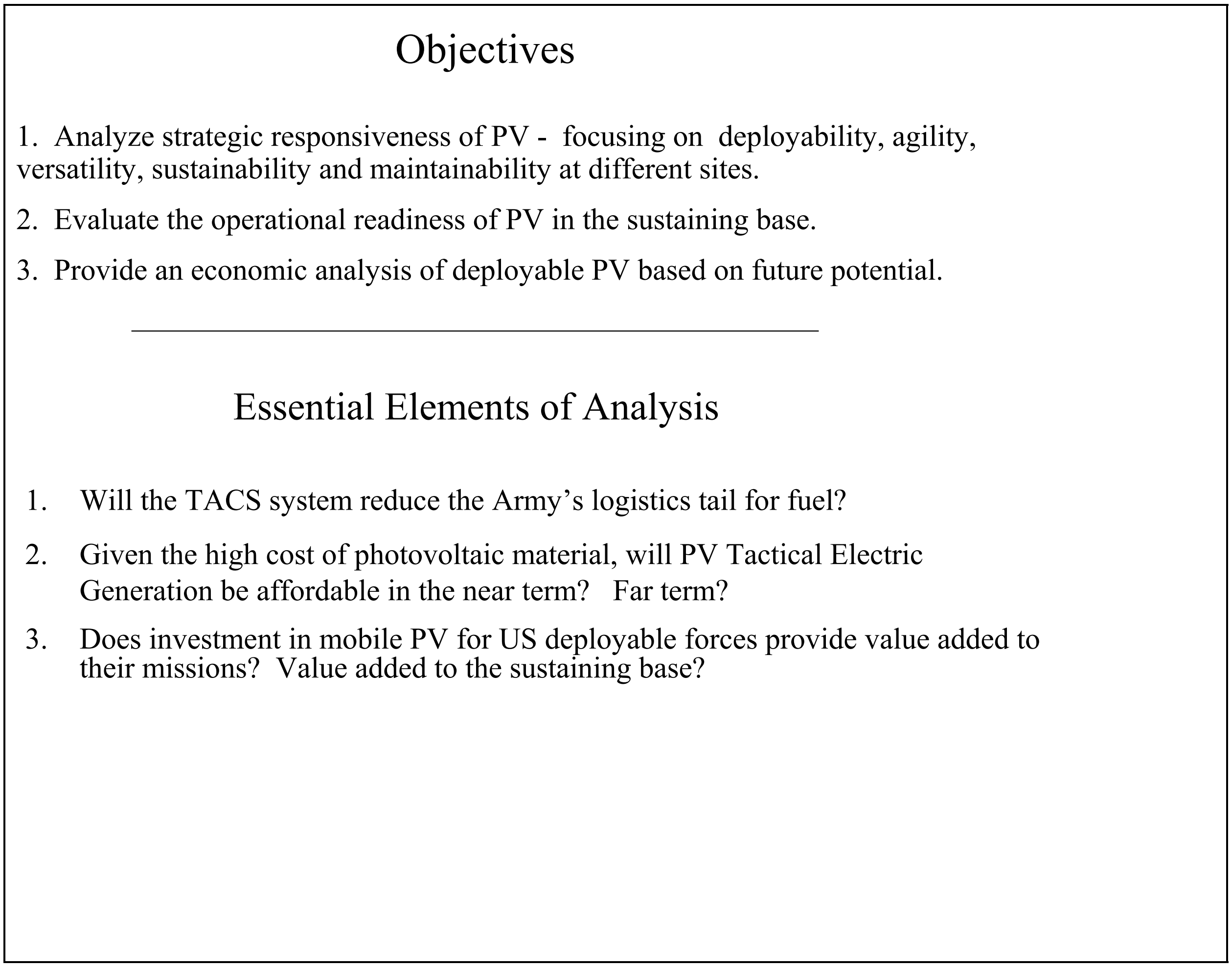
The Center for Army Analysis (CAA) has over a decade of expertise in providing cost / benefit analysis to Headquarters, Department of the Army. Some of this experience lies in collecting first-order energy data from field assets, while other experience lies in energy system modeling and in mathematical optimization analyses.

Over this past decade, troops and command staffs from the US Army's XVIIIth Airborne Corps, 7th US Army Europe (V Corps), Special Operation Forces, Army Science Advisors and various Directors of Public Works at Army CONUS installations have provided invaluable insights into this emerging field of renewable energy deployment and analyses.

The Center has also played pivotal roles in getting these new energy alternatives to troops in the field for their use, review and feedback. This has entailed forging new relationships with private sector manufacturers, special materiels scientists, environmental regulators and other public sector program administrators across various governmental departments. Departments of Energy and Interior as well as the US Navy, US Marine Corps and US Air Force have all contributed to many parts of this work as well.

Any accolades received by the Center over the years in the area of energy analysis are directly attributable to the high level of professional cooperation between these many Agencies and Departments. However, special recognition has to go to Army troops in the field and Army installation managers for being involved in every step of this effort. Without their help, field experience, after-action reports and support, none of this work could have been accomplished.

1.6 Objectives



Objectives

1. Analyze strategic responsiveness of PV - focusing on deployability, agility, versatility, sustainability and maintainability at different sites.
2. Evaluate the operational readiness of PV in the sustaining base.
3. Provide an economic analysis of deployable PV based on future potential.

Essential Elements of Analysis

1. Will the TACS system reduce the Army's logistics tail for fuel?
2. Given the high cost of photovoltaic material, will PV Tactical Electric Generation be affordable in the near term? Far term?
3. Does investment in mobile PV for US deployable forces provide value added to their missions? Value added to the sustaining base?

Figure 5. Objectives and Essential Elements of Analysis

REASR began the effort to better understand PV in a proof of concept framework. REASR 2 continues this effort and adds additional elements of strategic responsiveness to include different locations with different solar radiation levels.

Supplying fuel to deployed army forces is a critical, expensive and labor intensive function. One of the major missions of the Deputy Chief of Staff for Logistics (DCSLOG) is to reduce the Army's logistics tail in which fuel is a major component. Theoretically, there are many ways to accomplish this goal such as by (1) reducing fuel consumption, (2) relying on new, more efficient energy technologies and (3) reducing ancillary, related costs for fuel (i.e. fuel transport, fuel storage and fuel inspection). However in practice, achieving the goals in steps 1 – 3 is much harder to do. The reasons for this are numerous and complex but include a continued heavy army reliance on fossil fueled mobile electric power coupled with little demonstration or development in reliable, alternative energy sources.

Furthermore, photovoltaics in its current state is an expensive alternative to fossil fuel energy with 20% effective modules (used for the space station) costing as much as $200 per watt. Current costs for less efficient PV is about $4 per watt for crystalline silicon (glass) PV and $20 per watt for thin-film (Copper Indium Gallium Di-selenide) PV. Because of this expense, this study analyzes various costing factors which contribute to the high cost of photovoltaics in its current form and offers an analysis of future costs.

Economy of scale through mass production is not a new concept, but this concept makes it difficult to compare Army PV TACS systems with Army fossil fuel generator sets (GENSETs). The reason for this is that the Army has built only 10 PV TACS systems at a high cost per each system manufactured. On the other hand, fossil fuel GENSETs which are mass produced and enjoy a large economy of scale (i.e. cheaper GENSETs because of the large purchase volume) make economic net-present value comparisons between these two complementing systems difficult.

1.7 Cost Benefit Analysis Approach

Evaluate PV in terms of these

investment criteria (MOEs):

- Operational Readiness / Strategic Responsiveness (military assessment)
  - Deployability
  - Agility
  - Versatility
  - Sustainability
  - Maintainability
- Energy Savings (gal)
- Pollution Prevention (lb)
- Economics ($$$)

Figure 6. Cost Benefit Analysis Approach

The investment criteria listed above provide analytical, economic information to assess potential real world value. Some of these measures are in gallons and pounds and even dollars. These are all “real world”, simple, understandable measures of effect that can be estimated or computed.

The other criterion is operational readiness. This measure of effect is perhaps the most important of these criteria because this is related to the value added to the mission of the soldier on the ground, or to the installation. So, if the energy system being studied saves energy, reduces pollution and is economically viable but does not meet operational readiness expectations of the Army – then this system will never be fielded. The inverse of this analogy may be true too. That is, if the troops give the TACS system high marks for operational readiness, then the system’s merits are less likely to depend on the other three: energy savings, pollution prevention and system cost.

However, in these days of constrained budgets and fiscal belt-tightening to make the Army lean and mean, economics – next to operational readiness will always be the next major analytical hurdle. Here then lies the reason for the in-depth current and future economic analysis provided in this report.

1.8 Study Sponsorship

The REASR series of analysis will provide a cost / benefit analysis of deployable PV systems to include an assessment of logistics footprint, strategic responsiveness and operational readiness.

Sponsor and Players:

•**Deputy Chief of Staff for Logistics** (Logistics Transformation Agency is sponsor)

•Assistant Chief of Staff for Installation Management

•XVIII Airborne Corps

•Army Materiel Command (Science Advisor) US Army Europe and 7th Army

• Defense Advanced Research Projects Agency (DARPA)

• Project Manager for Mobile Electric Power (PM-MEP)

Figure 7. Study Sponsorship

The REASR series of analytical studies have been made possible through the funding from three sources:

1.The Defense Advanced Research Projects Agency (DARPA)

2.The Logistics Integration Agency (LIA)

3.The Assistant Chief of Staff for Installation Management (ACSIM)

The REASR 2 study was performed under the auspices of LIA for the reasons listed earlier as essential elements of analysis. The REASR 3 study is being sponsored by the office of the ACSIM.

A number of partnerships have been undertaken in this continuing effort to be better energy stewards for the Army. First, the Tri-Service Renewable Energy Committee (TREC) has general responsibility to keep Congress informed as to installation related energy initiatives and to act as contracting representatives whenever new energy forms such as fuel cells, micro-turbines, wind, biomass and photovoltaics are installed. Although CAA has a seat on this committee, the POC is the Army's Construction Engineering Laboratories (CERL), located in Champagne, Illinois.

Another partner in this work is the office of the Program Manager's Office for Mobile Electric Power (PM-MEP), located at Ft. Belvoir, Virginia. This office monitors the analytical work being done by CAA and others and provides technical engineering guidance as required. PM-MEP also is examining other renewable programs to include "midnight sun", photovoltaics in the ultra-violet spectrum of light.

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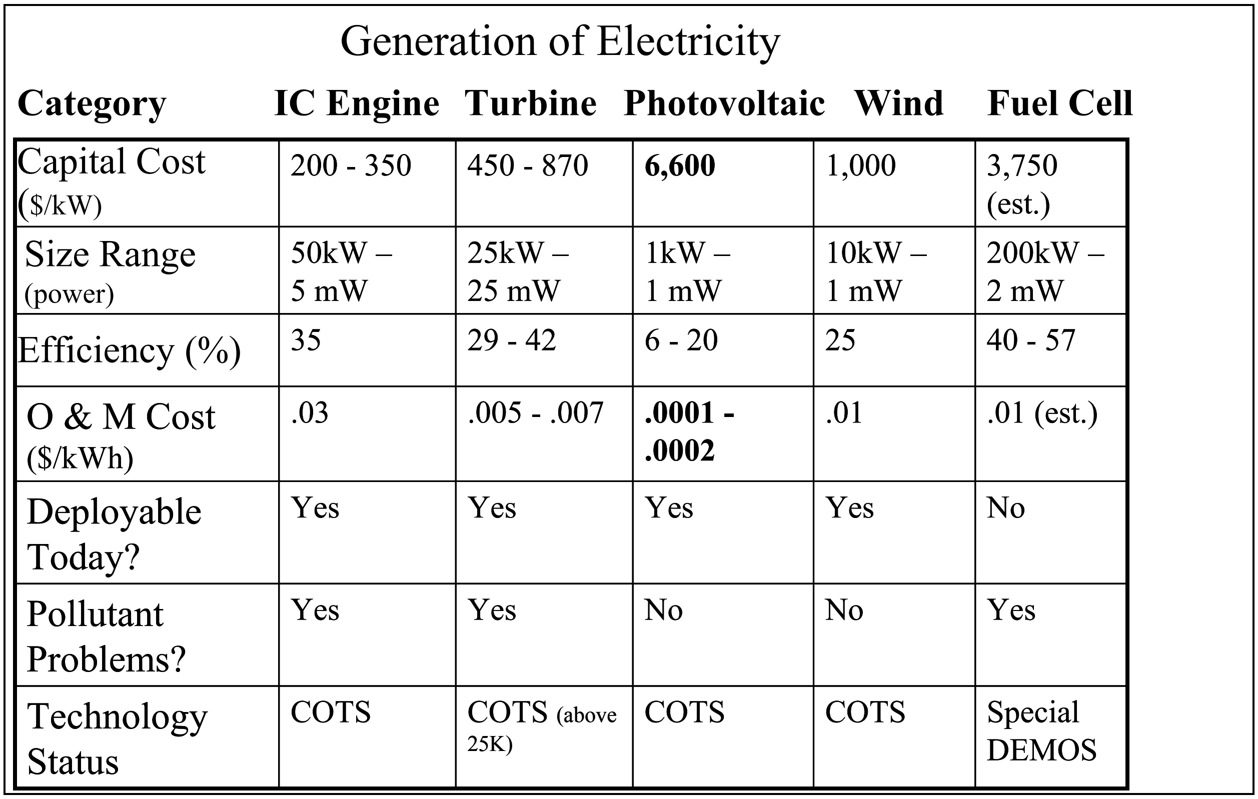
2 BACKGROUND

2.1 Energy Technology Comparison



Generation of Electricity

Category	IC Engine	Turbine	Photovoltaic	Wind	Fuel Cell
Capital Cost ($/kW)	200 - 350	450 - 870	**6,600**	1,000	3,750 (est.)
Size Range (power)	50kW – 5 mW	25kW – 25 mW	1kW – 1 mW	10kW – 1 mW	200kW – 2 mW
Efficiency (%)	35	29 - 42	6 - 20	25	40 - 57
O & M Cost ($/kWh)	.03	.005 - .007	**.0001 - .0002**	.01	.01 (est.)
Deployable Today?	Yes	Yes	Yes	Yes	No
Pollutant Problems?	Yes	Yes	No	No	Yes
Technology Status	COTS	COTS (above 25K)	COTS	COTS	Special DEMOS

Figure 8. Energy Technology Comparison

This technology chart illustrates the relative capabilities, costs, and availabilities for photovoltaics as compared with other competing energy sources. As stated previously, PV is currently the most expensive of all the energy categories listed above, yet has only 6-20% of its maximum potential efficiency (and energy) tapped - given the physical nature of the materials allowing for current solar energy transformation into electricity.

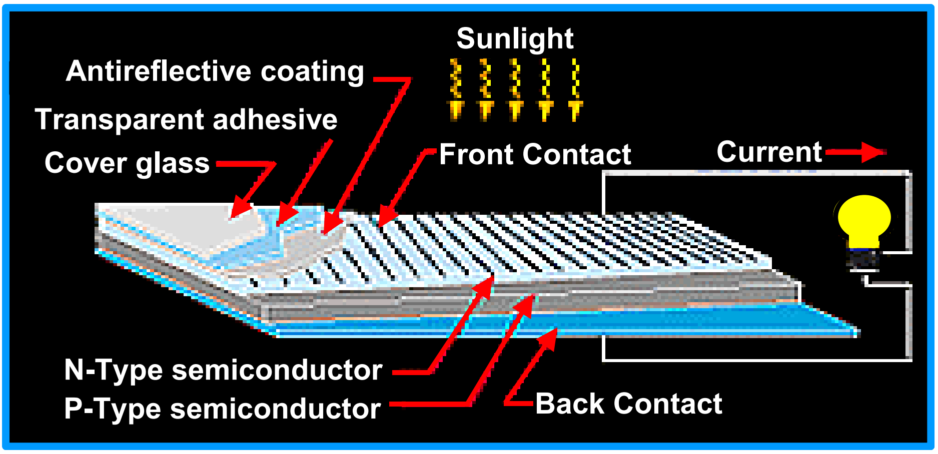
Cost for PV is the single most dominating, prohibitive factor in its selection and purchase for military applications. Although this will undoubtedly change as newer, more efficient materials are introduced – the current outlook as stated above remains at.about $4 per watt for crystalline PV and up to $20 per watt for thin film.

Crystalline PV is familiar to most Americans as the bluish – black panels that provide power to beltway and motorway signs, remote telephones and lights. This form of PV is hard, glass encased and easily damaged. It is also relatively heavy at about 15 pounds for a 1’ x 4’ panel.

Thin-film PV is a newer product development within the last 5 years that is very light (about 1 pound for the same 1’ x 3’ panel) and extremely flexible and durable. The military is currently using this form of photovoltaics for several demonstrations including all of the REASR series of studies.

2.2 How PV Works

Background: Photovoltaics (PV)



Hybrid PV Systems use batteries to store energy until it's needed.

PV Power: As a "rule of thumb", for a single poly-crystal type module, one can expect between 100-200 watts per square meter.

- 1980's PV technology was limited to capturing less than 5% of the sun's available wattage per square meter
- Today, industry is approaching 25% efficiency with new forms of silicon semi-conductors.

Figure 9. How PV Works

PV energy is generated by passive chemical energy. This chemical energy is based on poly-crystal semiconductor technology combined with lead-acid batteries. Similarly, because PV energy comes from the sun, it is necessary for night-time power requirements to be met via a battery bank of stored PV energy - to be recharged the next day. PV energy is not as efficient as fossil fuel generators on a British Thermal Unit (BTU) basis of comparison. For example, PV technology today can at best convert a maximum 20% of an available 1000 watts / hour of sun energy per square meter. Converting this wattage to BTUs gives us 2,500 BTUs available to use from the PV system.

In comparison, when a gallon of diesel fuel is converted to BTUs, the translation yields about 130,000 available BTUs for power production. Taking into account that gasoline generators are at best 30% efficient (.30 x 130,000 = 39,000 BTU) and diesel generators 50% efficient (.50 x 130,000 = 65,000 BTU), more power per available BTU can be obtained from fossil fuel generators than from PV. (Diesel GENSETs produce 65,000 – 2,500 = 62,500 *more* BTUs than PV arrays operating at 20%)

However, fossil fuel generators convert both mechanical and chemical energies into power. The chemical combustion of fossil fuels combined with the mechanical energy (i.e. moving parts) that produces friction are the primary reasons why generators create so much heat as a by-product. Likewise, generators require periodic maintenance and part-replacement because of wear and tear. Unlike generator power, PV energy is produced with no moving parts and with no combustibles and requires much less maintenance than generators do.

3 POLLUTION FROM FOSSIL FUELS

3.1 Background

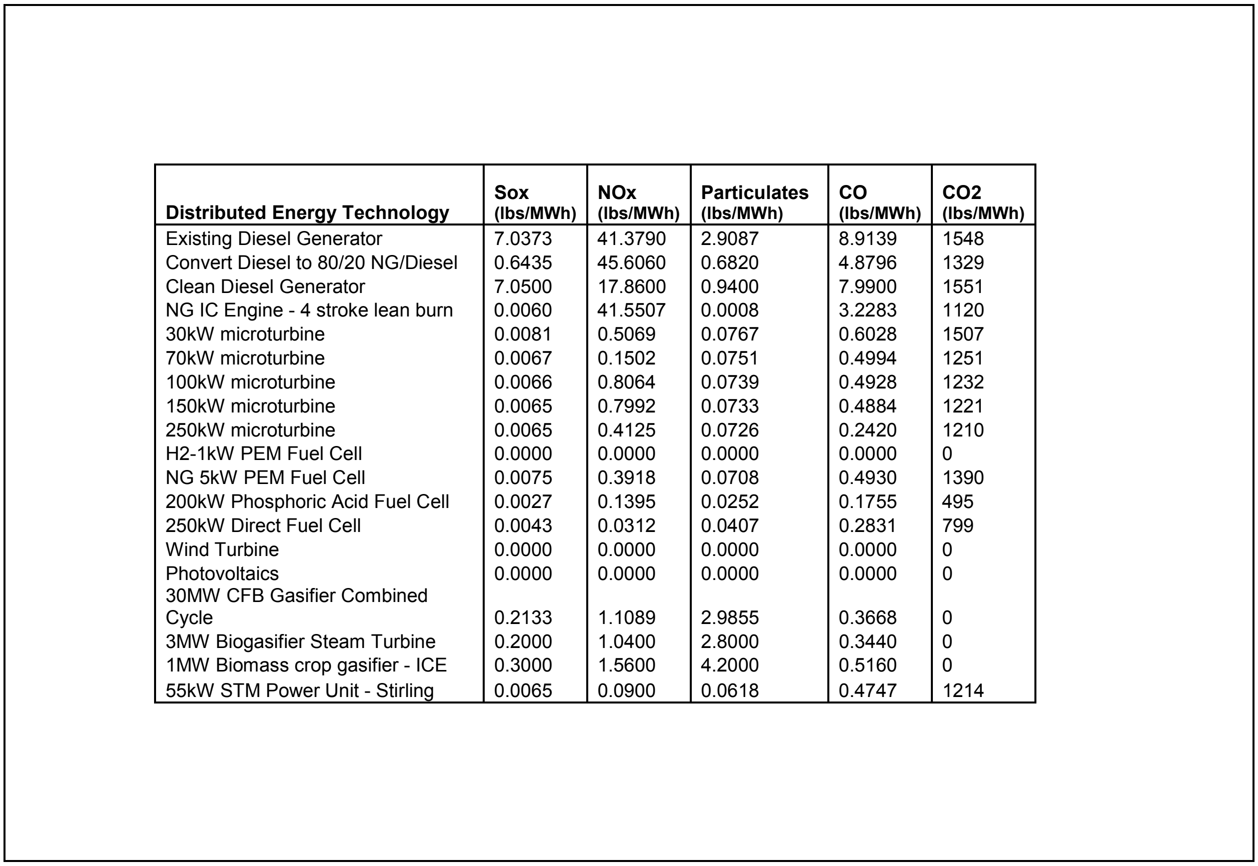
Pollution is a major challenge for the Federal Government in general and the Environmental Protection Agency (EPA) in particular. EPA also works with state and local governments to reverse ground, water and air pollution caused by the Federal Government at current and former federal facilities. This includes (but is not limited to) buried and unexploded ordnance, landfills with toxic chemicals, waste water pollution, and air pollution. The rest of this chapter will concentrate on this latter topic as a function of fossil fuel combustion.

State governments are beginning to provide for their own inspections of air pollution compliance with federal air quality standards at federal facilities within their respective state jurisdictions. For example, during the west coast energy crisis of 2000, the Fort Lewis Department of Public Works applied for a waiver to run its indigenous, auxiliary diesel power plants to augment power during electrical brown-outs. The Washington State pollution authority and the EPA reviewed this waiver from Ft. Lewis and vetoed the concept because state pollution standards would have been far exceeded. Such is the seriousness of pollution as generated from fossil fuel sources.

The Pollution Prevention Act of 1990 and Presidential Executive Order 12856 (August, 1993) provide for pollution reduction and set federal standards and goals for pollution reduction at Federal Facilities. Each year, federal installations are reviewed as part of a detailed Installation Status Report. This installation “report card” is an evaluation of many factors and includes pollution abatement and pollution prevention as pillars of an installation’s viability, safe environment and energy control.

The following table outlines the pollution by certain chemical types introduced into the atmosphere by different sizes of fossil fuel generators. Note that in this case, natural gas is being included as a “fossil fuel”, but is arguably a renewable energy source as well. This argument is beyond the scope of this report and is not intended to support either side of this debate. However, the table below does illustrate that natural gas (NG) generators have reduced levels of emissions as compared to diesel fuel.

Figure 11 (below) was provided by the US Army Corps of Engineers’ Research Laboratory (USACERL) located at Champagne-Urbana, Illinois. It details the levels of sulphur dioxide (SOx), nitrogen dioxide (NOx), particulate matter, carbon dioxide and carbon monoxide vented as emissions into the atmosphere as a function of generator size and type. The reader will note that the cleanest forms of energies illustrated in Figure 11 are wind power and sun power (i.e. photovoltaics).



Distributed Energy Technology	Sox (lbs/MWh)	NOx (lbs/MWh)	Particulates (lbs/MWh)	CO (lbs/MWh)	CO2 (lbs/MWh)
Existing Diesel Generator	7.0373	41.3790	2.9087	8.9139	1548
Convert Diesel to 80/20 NG/Diesel	0.6435	45.6060	0.6820	4.8796	1329
Clean Diesel Generator	7.0500	17.8600	0.9400	7.9900	1551
NG IC Engine - 4 stroke lean burn	0.0060	41.5507	0.0008	3.2283	1120
30kW microturbine	0.0081	0.5069	0.0767	0.6028	1507
70kW microturbine	0.0067	0.1502	0.0751	0.4994	1251
100kW microturbine	0.0066	0.8064	0.0739	0.4928	1232
150kW microturbine	0.0065	0.7992	0.0733	0.4884	1221
250kW microturbine	0.0065	0.4125	0.0726	0.2420	1210
H2-1kW PEM Fuel Cell	0.0000	0.0000	0.0000	0.0000	0
NG 5kW PEM Fuel Cell	0.0075	0.3918	0.0708	0.4930	1390
200kW Phosphoric Acid Fuel Cell	0.0027	0.1395	0.0252	0.1755	495
250kW Direct Fuel Cell	0.0043	0.0312	0.0407	0.2831	799
Wind Turbine	0.0000	0.0000	0.0000	0.0000	0
Photovoltaics	0.0000	0.0000	0.0000	0.0000	0
30MW CFB Gasifier Combined Cycle	0.2133	1.1089	2.9855	0.3668	0
3MW Biogasifier Steam Turbine	0.2000	1.0400	2.8000	0.3440	0
1MW Biomass crop gasifier - ICE	0.3000	1.5600	4.2000	0.5160	0
55kW STM Power Unit - Stirling	0.0065	0.0900	0.0618	0.4747	1214

Figure 10. Pollution by Generator Type

4 HOW THE HYBRID PHOTOVOLTAIC SYSTEM WORKS

4.1 Details of the Tactical Alternating Current System (TACS)

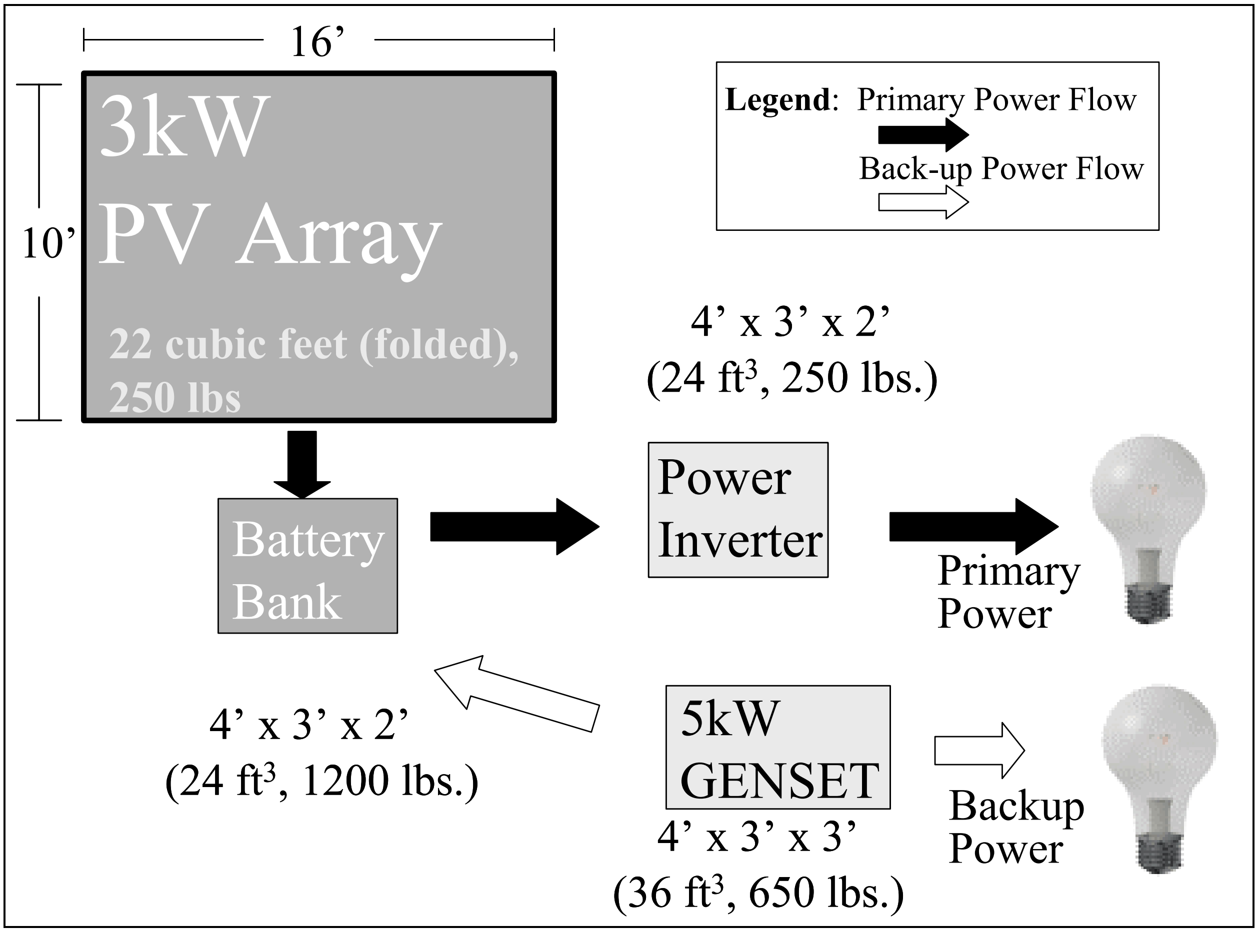


Figure 11. How the Hybrid PV System Works

The hybrid PV System obtains power from two sources:

- the sun (which powers the 3kW PV array) and
- the 5kW fossil fuel generator (GENSET)

The hybrid PV System then stores this power in a battery bank. Typically, this system fits on either an Army M101 (3/4 ton trailer) or a M105 (3 ton trailer). For the M105, four 24 volt, direct current (VDC), 187-amp-hour (aH) battery bank modules, each comprised of two Concorde sealed batteries, provide a total stored energy capacity of 750 aH. For the M101 variant, two 24VDC, 187 aH battery bank modules, each comprised of two Concorde sealed batteries, provide a total energy capacity of 374 aH.

The diesel GENSET is an Onan 5500, 120-volt alternating current (VAC), 60 Hz, producing 4950 watts of power. The on-board diesel fuel capacity is 18 gallons.

Gross vehicle weight (loaded) in the M105 trailer is 2,700 pounds. The lighter 3/4 ton trailer (M101) gross vehicle weight is 1,800 pounds – most of which is the battery weight.

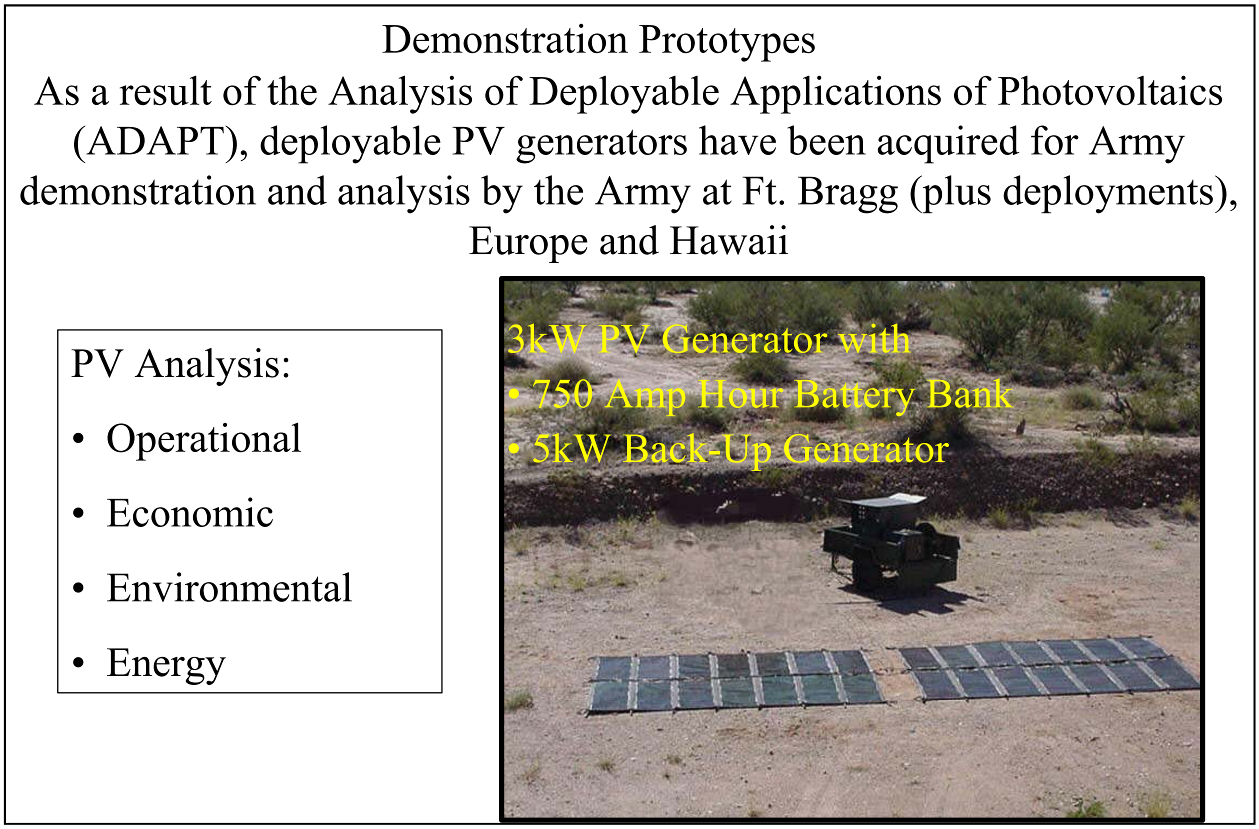
The object of the hybrid PV System is to minimize fossil fuel use by maximizing power from the sun. This is accomplished with the use of a battery bank which stores energy from both the GENSET and the solar array.

Power normally flows from the battery bank to meet any electric load demand (amps) and is monitored by the power inverter. Information such as battery bank state-of-charge and current draw is continually monitored by the inverter once the PV System is turned on. At night or in inclement weather, when little or no energy is available from the sun, all power must be taken from the battery bank or from the GENSET. In a back-up mode, all power can be taken directly from the GENSET itself.

One might ask the question: "Why would the Army require two systems to provide power? Wouldn't the current GENSET, operating by itself provide the necessary capability without the PV System?"

Under most situations for Army Tactical Operations Centers (TOCS) from battalion level through Corps, the Army *always employs two* GENSETS standing by as both a primary and a backup. The PV System for this report is viewed as the primary system and the GENSET as the backup.

4.2 Army Photovoltaic (PV) System



Demonstration Prototypes

As a result of the Analysis of Deployable Applications of Photovoltaics (ADAPT), deployable PV generators have been acquired for Army demonstration and analysis by the Army at Ft. Bragg (plus deployments), Europe and Hawaii

PV Analysis:

- Operational
- Economic
- Environmental
- Energy

3kW PV Generator with
- 750 Amp Hour Battery Bank
- 5kW Back-Up Generator

Figure 12. Army Photovoltaic (PV) System

There are two versions of the PV TACS pictured above. The first houses a 374 amp hour battery bank with a 3kW PV array and 5kW fossil-fuel generator. This variant is mounted on an Army M101, ¾ ton trailer.

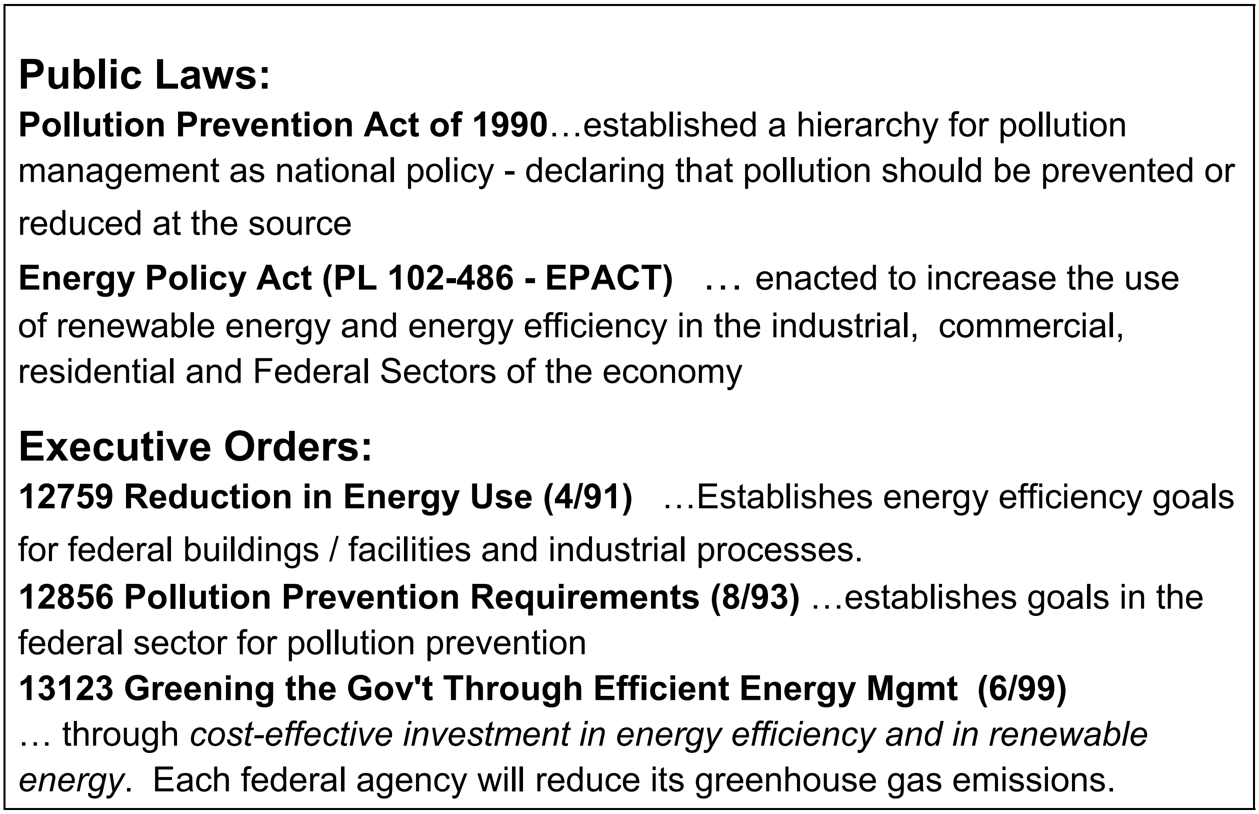
The second type includes a 750 amp hour battery bank and is mounted on an Army M105, 3 ton trailer. Both PV TACS variants have been deployed and exercised in various locations and in all types of weather conditions by various Army forces.

Five of the six PV TACS that have been built to date operate with 110V, standard power. The sixth PV TACS was built to invert DC to AC power at 220V, 50 cycles (hertz). This application was for the European Theater where equipment – bought off the local economy – operates in the 220V range.

Although PV is very quiet and does not emit a heat signature – as a target, the PV array which was demonstrated (see above photo) was not camouflaged and had to be laid flat on the ground to avoid ground detection due to glint – or mirroring from sunlight.

Recent developments by private industry, Sandia National Laboratories and by the US Army's Communication and Electronics command show promise to develop either injected camouflage dye into the PV cells themselves (CECOM) or else to cover the PV modules with a gel-like substance (Sandia National Labs) or to provide array modifications (Global Solar Energy) to reduce glint and to provide system camouflage.

4.3 Background: Army Policy



Public Laws:

Pollution Prevention Act of 1990…established a hierarchy for pollution management as national policy - declaring that pollution should be prevented or reduced at the source

Energy Policy Act (PL 102-486 - EPACT) … enacted to increase the use of renewable energy and energy efficiency in the industrial, commercial, residential and Federal Sectors of the economy

Executive Orders:

12759 Reduction in Energy Use (4/91) …Establishes energy efficiency goals for federal buildings / facilities and industrial processes.

12856 Pollution Prevention Requirements (8/93) …establishes goals in the federal sector for pollution prevention

13123 Greening the Gov't Through Efficient Energy Mgmt (6/99) … through *cost-effective investment in energy efficiency and in renewable energy*. Each federal agency will reduce its greenhouse gas emissions.

Figure 13. Background: Army Policy

These are the primary laws and executive orders governing energy policy in the Army. The purpose of much of this legislation is to protect the environment; the air we breath, the water we drink and the land we live on. Because fossil fuels are a "non-renewable" energy source, it makes sense to conserve this resource as much as possible.

In June of 1999, President William J. Clinton signed into law Executive Order number 13123 "Greening the Government Through Efficient Energy Management". This order provided a requirement that cost-benefit analysis be performed for all energy sources used by the Federal Government.

As stated earlier, REASR 2 outlines a number of current and future, detailed cost / benefit analyses whereas previous studies in this series provided only a cursory investment outlook.

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5 DATA

5.1 Data & Analysis

- US Military Deployments (REASR 2)
  - Strategic Responsiveness
  - Operational Readiness
- Solar Radiation (10 year average)
  - National Renewable Energy Labs (Modeling Support)
- TACS Deployment Analysis
  - National Training Center (Ft. Irwin, CA)
  - Germany (Fleigerhorst Kasern)
- Power Consumption
- Energy Savings
- Pollution Savings
- Economic Issues and Challenges

Figure 14. Data & Analysis

The power consumption data was taken directly from the TACS unit as it was being employed for each of the varying missions over the past year. However, although there were several different missions comprising OPTEMPO exercises, this analysis focuses on only two. One is a 10-day exercise at Fleigerhorst Kasern, Germany, while the other is a 14-day rotation at the National Training Center, Ft. Irwin California.

Energy and pollution savings were estimates from life cycle costing that projected out 20 years into the future. This analysis incorporates a comparison of fossil fuel GENSETs operating independently and then contrasts this with the hybrid case of PV plus GENSET as outlined in this report.

The economic issues and challenges are born both of necessity and invention. From necessity – President George W. Bush in his February 2003 State of the Union Address talked about various ways to reduce America's dependence on foreign oil through new energy innovations. Obviously, PV can be one of these solutions but not without its own set of challenges. The PV array "invention", around since 1921, is continually undergoing changes and modifications in its structure and efficiencies. However, the stark fact remains that worldwide production of PV material for 2001 was only 450 megawatts of power. This is a “drop in the bucket” compared to other renewables such as wind, biomass or obviously – hydro power. Although there are some breakthroughs, the general PV crystalline and thin-film manufacturing process is a slow, multi-step, labor intensive, inefficient and difficult process to streamline.

5.2 U.S. Military Deployments: 1990 - 2000

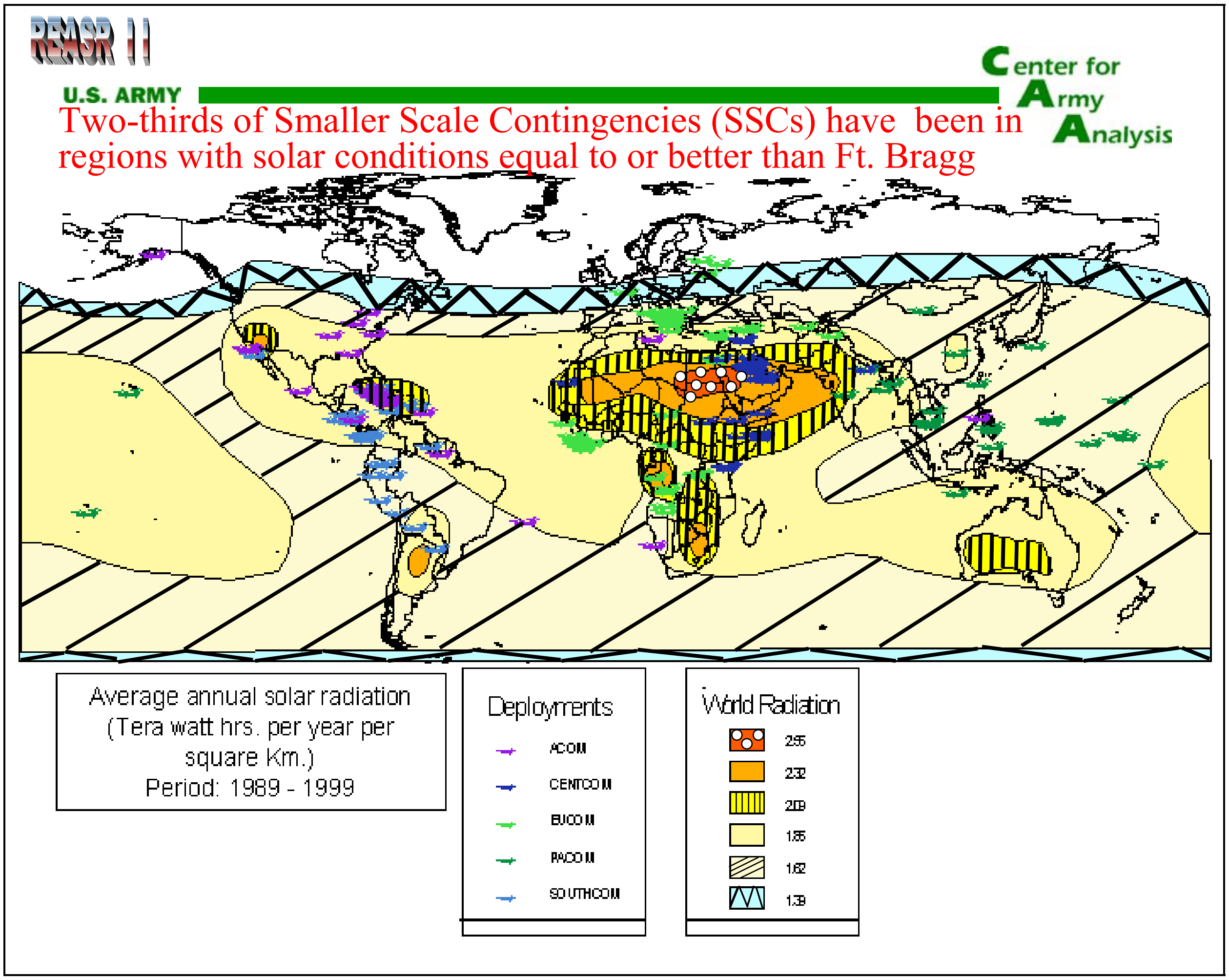


Figure 15. U.S. Military Deployments: 1990 - 2000

Let us continue to examine the relationships between solar radiation and geographical location (to include altitude) that significantly impact on PV applications. First, PV works better in areas where solar insolation values are high. The highest solar radiation can be found at locations on or near the earth's equator.

This chart shows the last 10 years of U.S. military deployments as broken down by major command. The chart above illustrates that over 60% of all deployments have been to areas that were equal to or better than the solar radiation found at the first tactical PV demonstration site at Ft. Bragg, North Carolina.

This illustration was based on over 200 deployments during the past decade. Half of these deployments were to the highest sun radiation areas in or near the Persian Gulf. Solar radiation in these areas is between 2.32 and 2.55 tera[1]-watts per year per km^2.

This project demonstrated PV capabilities to army units that support PV as a viable power potential alternative. As a result, units currently stationed in Kosovo have contacted CAA about the status of this study and continue to push for prototypes *even though they're not in an area of the world noted for good solar radiation.* The requesting unit in question is the 3rd Battalion, 504th Parachute Infantry Regiment located in Camp Bondsteel, Task Force 3504, Kosovo. This unit is continuing to observe weather conditions there and is providing first hand accounts of feasible military PV applications (in writing) that they feel can overcome any deficit in solar radiation.

[1] Tera = trillion

5.3 TACS Strategic Responsiveness

1. Strategic:

- TACS airlifted from Davis-Montham AFB, Martinsburg AFB, Dover AFB and Ramstein AFB (to other OCONUS destinations). TACS was up and running (without waiting for fuel) the same day upon reaching its destination(s).
- Load plans have been developed which include requirements for safe handling and shipment (e.g. empty fuel tanks, disconnected battery power cables)

2. Operational:

- PV TACS was deployed to NTC with 3/504 82nd AB (Ft. Bragg, NC to Ft. Irwin, CA), Kosovo with 709th MPs, Ft. Stewart, Georgia with 1/504 82nd AB, remote gate-guard missions at Fleigerhorst Kasern with 127th MP Company.

3. Tactical:

- TACS used for battalion level TOC power for GWAT missions in Afghanistan and Kosovo (REASR 3).
- CPX exercises in CONUS (Ft. Bragg, Ft. Stewart) where non-interruptible power capabilities of the PV TACS were noted

Figure 16. TACS Strategic Responsiveness

The Army is trying to decrease the amount of time that it takes to transport fighting units to its destination along with its TO&E. In order for this to happen, the Army continues to work with the United States Air Force (USAF), the Merchant Marine and the US Navy to shorten the time it takes to bring American military force to bear in a particular region of the world.

One such mechanism that the USAF and the Air National Guard use are documents called "loading plans" that illustrate to a loadmaster how a particular piece of equipment should be loaded aboard an aircraft such as a C-130 Hercules or a C-17 or C-5A. Once established, these plans help the loadmaster to understand the weight, volume and hazardous components of any type of military cargo.

Over the past two years, the TACS system has been air lifted to a variety of destinations and has already undergone its load plan requirement. Currently, the USAF and Air National Guard have computerized, detailed plans for the TACS system which include its weight, volume and hazardous components. This is important in the military's scheme to strategically lift any cargo.

With each TACS strategic deployment came the understanding that this was a system that did not require fossil-fuels to be immediately available for it to provide power. Usually, when fossil-fuel GENSETs are deployed with a force, they must wait for fuels to be delivered to the deployed location, tested and distributed to the military units. The TACS, however, could be powered up and refueled by the sun immediately upon reaching its destination.

5.4 TACS Strategic Deployments

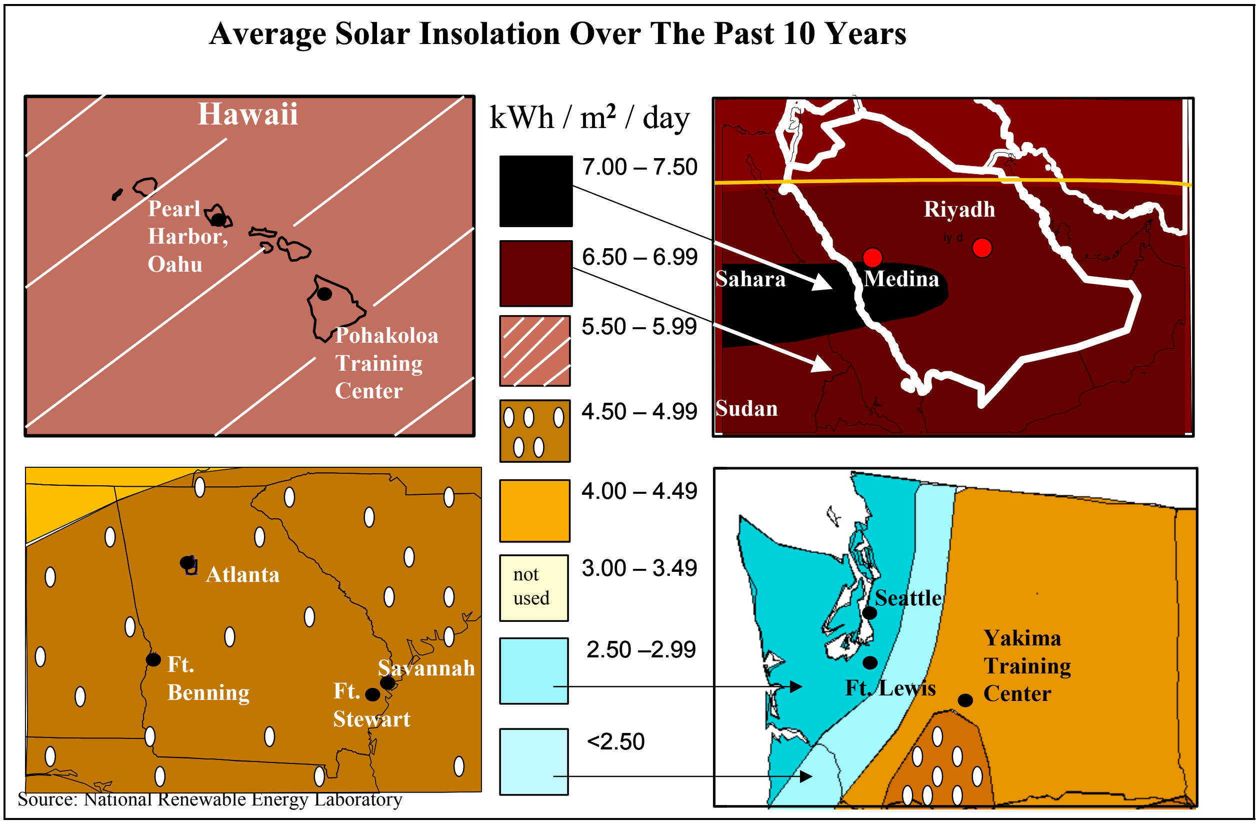
1. Strategic Deployments of TACS to:
    - Germany (18th MP BDE)
    - Bosnia (709 MP Bn)
    - Afghanistan (82nd Airborne, Ft. Bragg)
    - Kuwait (V Corps[1])
2. Strategic Lift Load Plans
    - Air National Guard
    - USAF

[1] See REASR 3 Study Report (to be published in August ’03) for details

Figure 17. TACS Strategic Deployments

Appendix C outlines the loading plans associated with safely and efficiently transporting the TACS via strategic lift. The follow-on cost / benefit analysis (REASR 3) also demonstrates strategic deployment to the Kuwait Theater of Operations (March ’03). This work is due to be published in August of 2003.

5.5 Localized Solar Radiation Data



Source: National Renewable Energy Laboratory

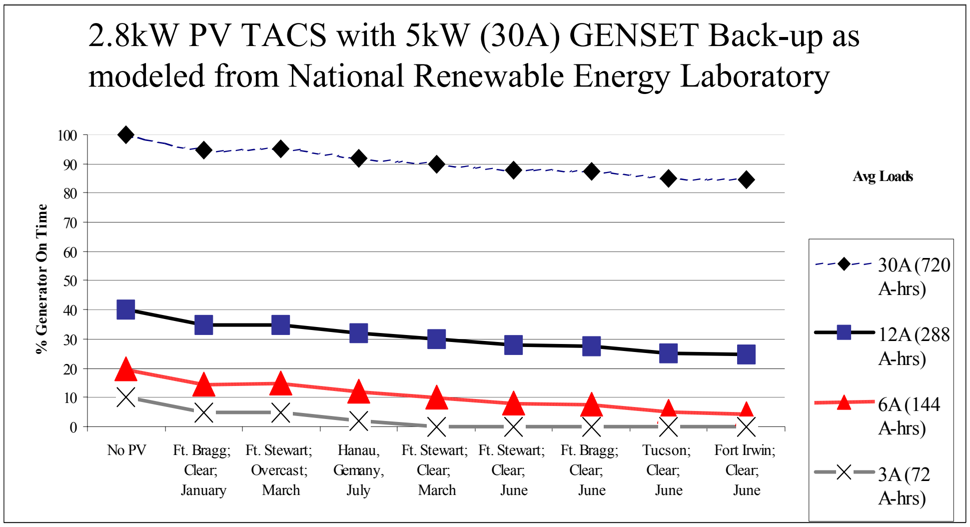
Figure 18. Localized Solar Radiation

Solar radiation varies as a function of geographical area and altitude. For example, some of the best working PV is located in space, at hundreds of thousands of feet altitude. But if not in space, the best solar radiation is at locations at or near the equator. Note from the above charts the different capabilities that the same PV array would have simply by being located at these different locations. The first ADAPT and REASR studies examined the investment opportunities of tactical PV based on demonstrations in Hawaii and Ft. Stewart. The REASR 2 work (as will be discussed later) occurred in southern California and in west-central Germany. The REASR 3 analysis will use Ft. Lewis, Washington and the Persian Gulf region as its prime locations for its PV geographic locations.

Obviously, if the solar radiation is better in one part of the world than in another, then this means that the savings will be better in those locations as well. For example, if in Kuwait the levels of solar radiation are twice that in Ft. Lewis, then the savings will be greater in Kuwait than at Ft. Lewis. How much greater? This depends on a number of other factors including the types of military missions and their electricity demand, the costs of fossil fuels in those regions, the temperature, age of the TACS system (and batteries) as well as how the arrays are deployed. It can be a very complicated process to measure precisely.

This is why CAA is looking at the analysis of similar military units, with similar electricity demands in different locations. This tends to make the only variable factor the “geographical location” which in turn drives the savings of energy (i.e. fossil fuel) and the pollution reduction.

5.6 Predicted GENSET On-Time



- Array sizing was performed to provide a target of 6 amps (continuous) from 6% PV efficient material (see red-line above)
- Should expect target of about 5% GENSET on-time at Ft. Irwin
- Should expect target of about 12% GENSET on-time at Hanau, GE
- Reduced GENSET On-Times should translate to reduced unscheduled maintenance

Figure 19. Predicted GENSET On-Time

An important aspect of any experiment is to know the problem so well so as to identify certain boundary conditions that lend to reduced dollar costs and understandable limitations of the system being studied. In the case of the hybrid PV system (now called TACS), being able to analyze critical power elements for best and worst conditions *before building* the system would save money and provide for a matched power-to-load system.

Saving money is important to any system prototype experiment because the manufacturer does not want to critically redesign the system every time a new boundary condition is encountered. In this work, knowing a priori how much photovoltaic power was going to be available at different geographical locations would be important in correctly sizing and manufacturing the PV array. Likewise, knowing the power requirement is also critical.

For example, in our hybrid TACS case, it was known that with today’s PV materiel efficiencies to produce approximately 6 amps of continuous AC power, the array size would need to be manufactured to a size of approximately 10’ by 16’. This would also match light infantry battalion tactical operations center’s power requirement of about 6 amps (continuous alternating current) that we knew existed from previous work. Reading from the above chart, this means that a 2.8 kW PV array in Germany in July would provide 6 amps of continuous electric power. The flip side of this is that to make up for night time periods when no energy is available from the sun, the GENSET must operate for 12% of the time. Similarly, GENSETs at Ft. Irwin, California in June would be expected to be on for only about 5% of the time.

Lastly, if one could always run a GENSET at its optimal settings, always perform prescribed preventative maintenance, provide loads that match manufacturer recommended rpm, then most GENSETs would last for twenty years. But in the real world, failure to provide any combination of the aforementioned preventative maintenance can cause GENSET failure. It makes sense to minimize fossil fuel GENSET operation (called “on-time”) by providing “hard-work” when the GENSET does come on-line. One of the biggest problems that GENSETs have is simply idling for long periods of time while waiting for a challenging work-load which in turn, causes generator failure.

6 ANALYSIS ON FT IRWIN CASE STUDY

6.1 Analysis of Photovoltaic System at Ft. Irwin, CA

June 7-20, 2001

Fort Irwin, California is located in the American Mojave Desert near the city of Barstow, California. Its mission, as an Army Training and Doctrine Command Installation (TRADOC) is to provide training grounds for its tenant activity, the National Training Center.

The following analysis came from a fourteen-day training rotation in June, 2001 of the 1st Brigade, 504th parachute infantry regiment, XVIIIth Airborne Corps from Ft. Bragg, North Carolina. The POCs for the exercise were sergeants McClennan and Thompson.

6.2 Synopsis of Ft. Irwin Demo

Events

1. June 2001, 1 / 504 rail hauled PV systems to NTC from Ft. Bragg
2. Noted problems with trailer off-loading from rail (see photos)
3. Mechanical problems reduced mobility of PV system
4. Employed PV systems for 2 weeks:
   - – BN TOC Power
   - – Demo for BDE TOC Power
5. High winds made arrays “kite” (troops developed on-site fix which was later refined with tie-downs)
6. 3rd week of July, rail-shipped PV system back to Ft. Bragg (no further damage reported)
7. Borrowed all PV arrays and air-shipped them to Germany for follow-on demo (see note)

Figure 20. Synopsis of Ft. Irwin Demo

Rotations at the National Training Center, Ft. Irwin, CA are normal training events for military units. Some equipment is transported from the home duty station (in this case, Ft. Bragg, NC) and some equipment is maintained at the NTC. In this case, the TACS unit was shipped as part of the 1/504’s table of organization and equipment (TOE) from Ft. Bragg via rail to NTC.

Upon arrival at the NTC rail yard, a 60 ton crane was used to remove the TACS from its flat-bed railcar. Standard procedures for unloading the TACS were not followed by NTC rail yard personnel and substantial damage was done to the TACS trailer as a result (see above photos for details).

Because the damage was to the trailer and not to the photovoltaic generation equipment, the decision was made to transport the trailer (broken shocks and bent axle) into the NTC "box" for training. Reports back from the field indicated that although the trailer had no shock absorbers and pulled "like a mule", the power generation from the TACS itself operated as expected.

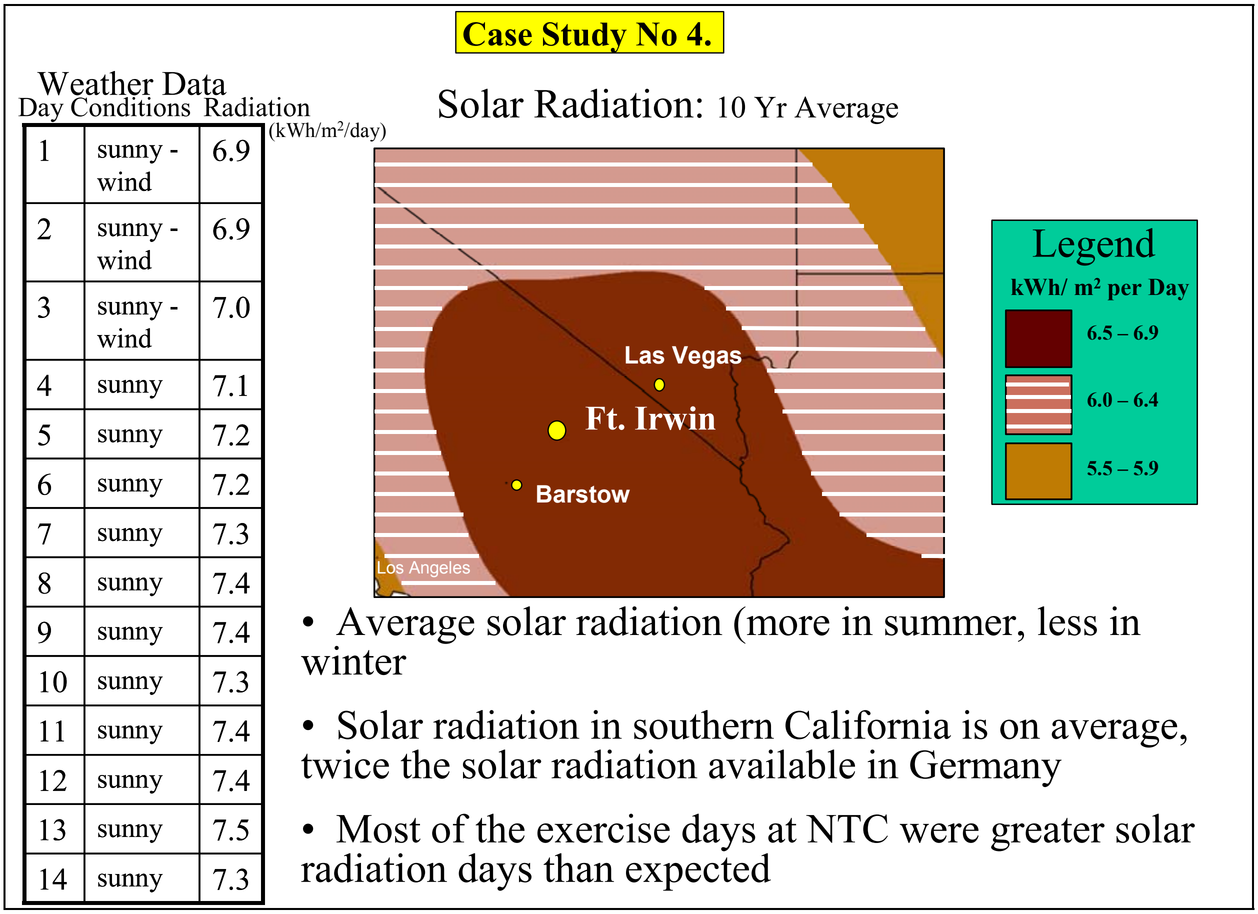
During this demonstration, Ft. Irwin experienced high winds which lifted the 250 pound PV array off the ground and made it fly, like a "kite". After this first instance of "kiting", troopers from the 1/504th used big stones, strategically placed along the edges of the PV array to hold it to the ground. Although it was thought that light-weight PV was an optimal solution for all aspects of military missions, in this case high winds proved us wrong.

The "kiting" problem was later corrected by providing soldiers with steel tent-pegs and tie-downs for the PV array.

Note: World wide production of photovoltaic material is approximately 500 megaWatts in FY03 with thin-film PV production at only one megaWatt. Unfortunately, this is not a lot of production capacity – but production levels are growing at about 40% / year.

At the manufacturing level, thin-film PV industry's primary concern is to stabilize module efficiency for purposes of mass production. As of this writing, thin-film efficiency is stabilizing at levels of about 10% per module. (Up from only 5% two years ago.)

6.3 Ft. Irwin Tactical PV System Data



Case Study No 4.

Weather Data

Day	Conditions	Radiation (kWh/m²/day)
1	sunny - wind	6.9
2	sunny - wind	6.9
3	sunny - wind	7.0
4	sunny	7.1
5	sunny	7.2
6	sunny	7.2
7	sunny	7.3
8	sunny	7.4
9	sunny	7.4
10	sunny	7.3
11	sunny	7.4
12	sunny	7.4
13	sunny	7.5
14	sunny	7.3

Solar Radiation: 10 Yr Average

Legend

kWh/ m² per Day

■	6.5 – 6.9
▤	6.0 – 6.4
■	5.5 – 5.9

- Average solar radiation (more in summer, less in winter
- Solar radiation in southern California is on average, twice the solar radiation available in Germany
- Most of the exercise days at NTC were greater solar radiation days than expected

Figure 21. Ft. Irwin Tactical PV System Data

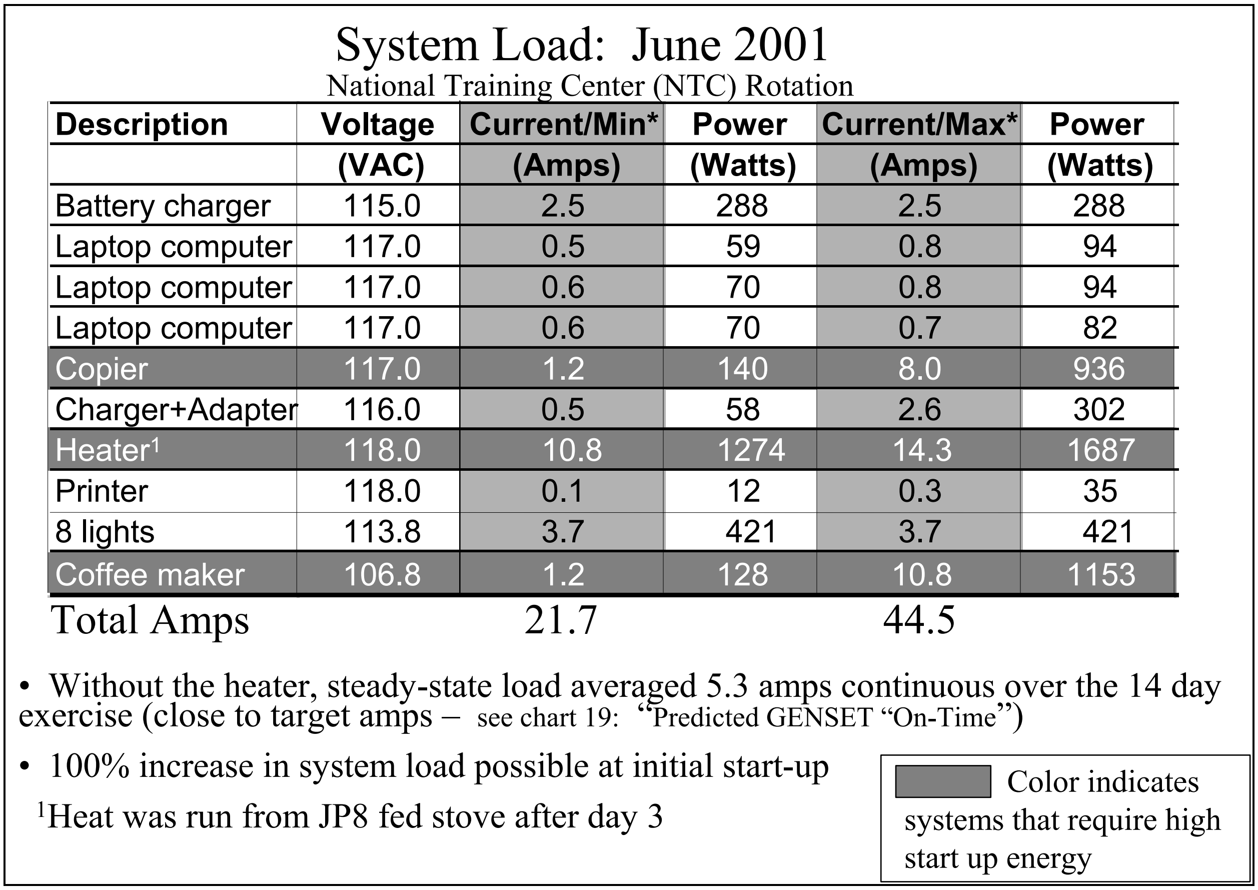
The reader will note that the “average” values from the colored figure from above represent a lower solar radiation (decreased PV efficiency) for yearly performance than do the “measured figures” from the column at left. Caution must be used when looking at analysis results from a small 14-day exercise “window” such as the case at the NTC rotation to not over-estimate or under-estimate general year-round performance characteristics. Certainly, fuel savings calculations and associated net present value economic calculations should always be done with yearly “average” values which would present the more accurate picture of PV capabilities within a hybrid energy framework.

Solar radiation is a phenomenon that changes from location to location and with altitude (i.e. PV works better at high altitudes near the equator than at sea-level near extreme northern or southern latitudes). This variability of PV performance underscores the need to apply econometrics to a variety of case studies and troop missions to better understand the strategic implications that photovoltaic power generation may bring to the soldier.

PV arrays work best if tilted at a 45 degree angle, facing southward in a shade-free environment. However, for tactical PV, this may not be possible nor desirable. This is why these field exercise demonstrations are necessary to understand the degradations placed upon the PV capabilities by the troops in order to meet their military requirements based on the missions at hand.

For example, although the PV array should be tilted for best performance, the Army has chosen to lay it flat on the ground for reasons of detection by an enemy. This degrades the PV's performance by about 5% overall from field trials. Furthermore, the PV array itself is black in color – and the military would prefer a more "camouflaged" appearance to the array-face. This is currently being worked by academia, Army research organizations and private industry. It is hoped that the camouflage itself will not degrade the PV further.

6.4 Ft. Irwin Demo Data



System Load: June 2001

National Training Center (NTC) Rotation

Description	Voltage	Current/Min*	Power	Current/Max*	Power
	(VAC)	(Amps)	(Watts)	(Amps)	(Watts)
Battery charger	115.0	2.5	288	2.5	288
Laptop computer	117.0	0.5	59	0.8	94
Laptop computer	117.0	0.6	70	0.8	94
Laptop computer	117.0	0.6	70	0.7	82
Copier	117.0	1.2	140	8.0	936
Charger+Adapter	116.0	0.5	58	2.6	302
Heater[1]	118.0	10.8	1274	14.3	1687
Printer	118.0	0.1	12	0.3	35
8 lights	113.8	3.7	421	3.7	421
Coffee maker	106.8	1.2	128	10.8	1153
Total Amps		21.7		44.5	

- Without the heater, steady-state load averaged 5.3 amps continuous over the 14 day exercise (close to target amps – see chart 19: "Predicted GENSET "On-Time")
- 100% increase in system load possible at initial start-up

[1] Heat was run from JP8 fed stove after day 3

▨ Color indicates systems that require high start up energy

Figure 22. Ft. Irwin Demo Data

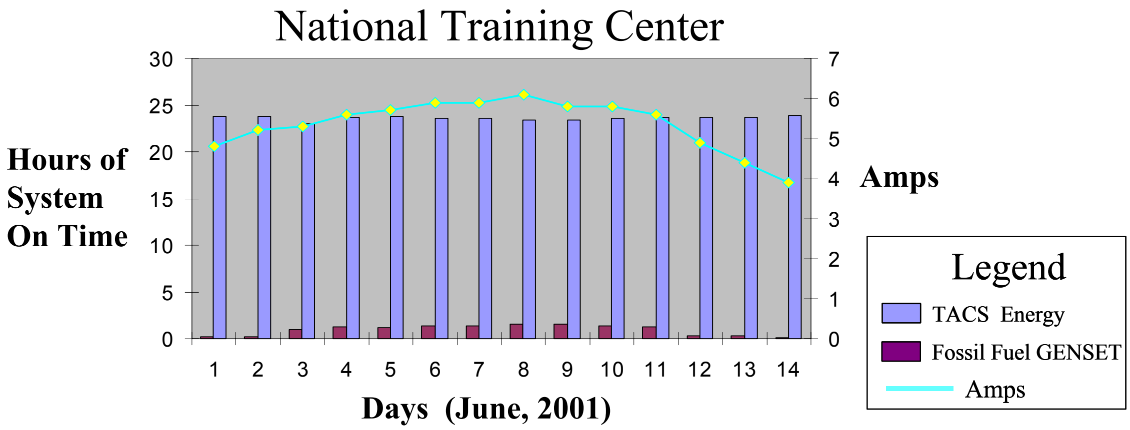
The National Training Center (NTC) is a desert area that can heat up to 120 degrees Fahrenheit during the daytime in the summer, but can also get very cold at night. Although the PV TACS system was designed for a 6 amp continuous flow, the norm was more like 21 amps. However, over 50% of that power draw came from a single source: the oil-based space heater that was employed in the TOC at night.

Most army communication, computer and command and control systems used for tactical applications do not require a great deal of power – especially those electronic systems employed in the field.

The reader will note that the rows highlighted in yellow represent the largest amp requirement – especially at initial start-up. In other words, looking at the above matrix, the coffee maker when initially turned on, requires 10.8 amps to make the coffee, but only 1.2 amps to keep it warm. Here, the issue is withdrawing this large amount of energy from the battery bank in such a small fraction of time.

One possible solution to this might be a mix of different storage devices other than lead acid batteries that are built (1) to hold a high charge, (2) to recharge much quicker than lead acid batteries and (3) to have longer cycle times (longer life) than lead acid batteries. The solution with all of these attributes is known as a charged capacitor, commercially available as “Super Caps”. The reader is probably familiar with these near-instantaneous charging devices as they are the prime component of the flash device (along with batteries) in flash cameras.

6.5 GENSET vs. TACS On-Time



- 13.3 hours of GENSET on-time over 336 hour exercise (3.9%)
- Average Amps of 5.3 (per day) were less than targeted range of 6 amps
- 5kW GENSET consumes ½ gal JP8 / hour
  - Exercise of 336 hours would use 336 X .5 = 168 gals of JP8 with no TACS
  - 13.3 hours of GENSET on-time consumed 13.3 X .5 = 6.7 gals JP8 with TACS

TACS employment saved 161 gallons of JP8 (96% fuel savings)

Figure 23. GENSET vs. TACS On-Time

As previously stated, the GENSET on and off times came from the field exercise as did operational feedback. The above chart answers two basic questions:

1. What was the power draw (in amps) over the course of the field exercise?

   Answer: On average, about 5 amps

2. What fraction of time was the fossil fuel GENSET on (and therefore using fuel)?

   Answer: On average, the GENSET was on 13 hours out of 336 total hours (3.9%).

In general, the better the sun, the less time that the GENSET will need to be on. Fort Irwin, California does have good sun for most of the year as seen previously. The GENSET's on time of 3.9% of the 14 day period can be broken down into hourly components as follows:

14 Day exercise = 336 hours

3.9% GENSET on time = 13 hours

96% TACS on time = 323 hours

Although this is important information to know and understand, it tells us about a very limited window of analysis. This analysis does point out the opportunity to save energy. Estimates of fuel savings – using only average solar radiation for the southern California locale – have been incorporated into the generalized energy savings opportunity further on in this report.

More important during this exercise was the opportunity to have the troops interact with this new energy alternative. During the exercise, the soldiers noted a decreased use of JP8, the uninterruptible power features of the TACS and the complete quiet with which the PV system works. These positive factors in the eyes of the soldiers made the TACS an essential piece of equipment for their follow-on deployments.

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7 FT IRWIN FINDINGS

7.1 Case Study #4: Ft. Irwin Findings

- 3kW PV System was sole power source for airborne regiment's tactical operations center (TOC, briefing tent)
  - Troops appreciated that the stored battery bank energy provided immediate power to the TOC without waiting for JP8 to arrive at their remote site
- Provided tactical quiet for security missions (zero decibels)
- TACS provided power for 96% of the exercise, GENSET 4%.
- Problems with TACS noted
  - M101 trailer shock absorbers destroyed at NTC rail yard and axle bent
  - High winds caused PV array to "kite"
- Fixes to problems:
  - Follow standard materiel offloading procedures
  - Tie downs supplied with future PV arrays
- No bad weather except for high winds
- Saved an average of 12 gals of JP-8 /day (TACS was alternate for 5kW Tactically Quiet Generator)
  - Estimated yearly OPTEMPO fuel savings: 800 gals.
  - Estimated yearly OPTEMPO pollution savings: 12,250 lbs

1st 504th PIR AAR (July '01)

Figure 24. Case Study #4: Ft. Irwin Findings

These short field exercises provide a window of understanding for soldiers and analysts alike. Given that army mobile power generation must work under a variety of situations, circumstances and weather environments, these TACS field demonstrations provide insights into the possibilities of hybrid electric power for soldiers in the field. This is the reason that this report uses "average" yearly solar radiation estimates – along with estimates of power draw so that long term, 20-year life-cycle computations can be made.

However, these short-duration exercises do provide for the inclusion of the soldiers' collective input into this new hybrid power alternative. In fact, their comments and criticisms were undoubtedly the most important part of this work. Problems and challenges still exist with this system – especially in the area where the US Army has adopted two separate power structures: 220v / 50hz (Europe) and 120v / 60hz (USA). For example, V Corps soldiers reported that "some of their German economy equipment" would not work with American 60 cycle GENSETs – including the TACS. Obviously, this is a serious problem that although not addressed directly in this report, can be addressed with a more expensive, dual-purpose TACS power inverter. (i.e. A power inverter that addresses both 220v and 120 v power requirements.)

The NTC TACS demonstration not only introduced the hybrid power system to soldiers of the 1/504th, but it also forged a bond with them for *continued use of the system to this day*. The REASR 3 study report (to be completed summer 2004) will address both the continued use of the TACS by soldiers already introduced to the PV alternative hybrid – but will also add new venues such as V Corps soldiers serving in the Persian Gulf and Department of Public Works applications at Ft. Lewis, Washington.

Soldiers from the 1/504th Parachute Infantry Regiment requested that the TACS have tie-down stakes for the photovoltaic array and that the control panel be rear-mounted for easier access. They also suggested that system programming defaults for the power inverter be taped to the TACS for ease of implementing changes in the field without referencing the user's manual.

8 ANALYSIS ON HANAU, GE CASE STUDY

8.1 Analysis of Tactical Photovoltaic System in Germany August 1-10, 2001

Fleigerhorst Kasern is located near the German city of Hanau, about 50 km due east of Frankfurt, Germany. There are a number of units stationed there as part of the US Army V Corps (Victory Corps) and include 709th Military Police, 127th Military Police Company, 1st Air Defense Aviation Brigade, 2-501 Aviation Battalion, 130th Engineer Brigade Headquarters, 18th Combat Support Battalion 5-7 Air Defense Artillery Battalion (Patriot), 19 Maintenance Company (Patriot), 69th Chemical Company 1-1 Cavalry, 5-7 Air Defense Artillery (Patriot), 502nd Engineering Company, 38th Engineering Company, 320th Engineer Topographical Company, 133rd Medical Detachment, 16 Corps Support Group Headquarters.

The following analysis came from a ten day field training exercise in August, 2001 of the 127th Military Police Company, 709th Military Police Battalion, 18th Military Police Brigade, V Corps, 7th US Army. The exercise point of contact was Motor Sergeant Simmons.

8.2 Synopsis of United States Army Europe (USAREUR) Demo

Events

1. Invited to demo PV System for V Corps (AMC Science Advisor's Office)
2. USAF Load Plans (C130, C17, C5A) used for part of Strategic Responsiveness Report
3. Shipped PV System (60 hertz) to Ramstein, AFB in July, 2001 from CONUS (Dover, AFB) via Davis-Monthan AFB, AZ
4. V Corps, 18th MP Bde (HQ: Mannheim), and 127/709 MP Company (Hanau) for applications in:
   - BN Maintenance
   - Gate Guard Duty
5. 2nd PV System (50 hertz) shipped to Ramstein, AFB in August, 2002.

- Soldiers measured the solar radiation coming from the 3kW PV array, battery state-of charge, GENSET on (and off) times and electric demand measured in amperes.
- The TACS PV array and battery bank was "on" 87% of the training days (209 / 240 hours), meaning that the GENSET was on 13% of the time (31 / 240 hours).
- Sunny days provided excellent solar power (see days 3, 6 and 7) while minimizing generator "on-time"
- Power was running 24 hours each day for 10 days with 90% average load reduction at night

Figure 25. Synopsis of United States Army Europe (USAREUR) Demo

The AMC Science Advisor to the United States Army, Europe during the summer of 2001 provided United States Army, Center for Army Analysis (USACAA) the above named unit as the first military unit outside the continental United States (OCONUS) to receive a solar-powered TACS system. This system was shipped to Ramstein Air Force Base during the summer of 2001 from Tucson, Arizona where the TACS was built by Global Solar Energy (GSE). From Ramstein, the TACS was transported to Hanau by the AMC Science Advisor's Office and powered up by military personnel on-site at Fleigerhorst Kasern as a part of their training with the new equipment.

In addition to the military presence, the other people present were the AMC Science Advisor, this author and a contractor from GSE. A one-day class was held to instruct the 709th in the proper use and care of the system along with miscellaneous administrative issues such as system ownership, spare parts and the agreement to allow CAA access to the system (if possible).

8.3 Germany Tactical PV System Data

Case Study No 5.

August 2001 One, 3kW PV System / 18th MP BDE, 709 BN, Hanau, GE.

Weather Data

Day	Conditions	Radiation (kWh/m²/day)
1	cloudy	2.9
2	cloudy	2.9
3	sunny	3.4
4	p/cloud	3.2
5	p/cloud	3.2
6	sunny	3.9
7	sunny	3.9
8	cloudy	3.0
9	rain	2.1
10	p/cloud	3.3

Solar Radiation: 10 Year Average

- Average solar radiation (more in summer, less in winter
- Solar radiation in Germany is on average, one-half the solar radiation from southern California
- Most of the exercise days in Germany were greater solar radiation days than expected

Figure 26. Germany Tactical PV System Data

Germany in the summer is much different than Germany in the winter. Sunny days in the German winter are few and far between so this data could have been different had these exercises been conducted in February rather than in August. Even so, independent simulation results show that the worst case scenario of a winter exercise near Frankfort, Germany would have seen GENSET on time rise to about 50% (instead of 13%).

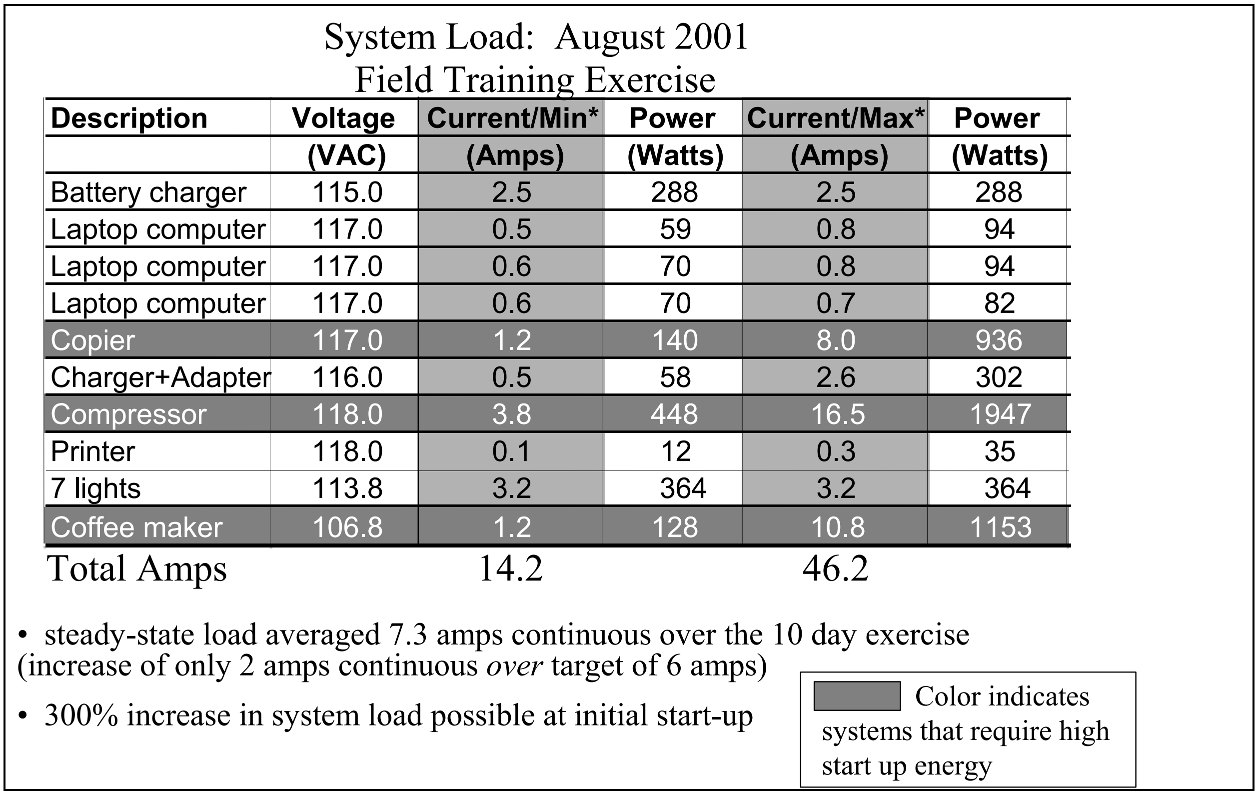
In this case, the majority of exercise days were sunny or partly cloudy days. This provided good sun which was easily converted into battery bank energy, providing power to the Tactical Alternating Current System's electric power inverter.

The following is a list of problems that were encountered with the TACS systems as provided to this author:

1. The GENSET was a Honda, 4kW that used gasoline as the fuel. The MPs requested that we trade out the gas GENSET for a diesel (JP8) GENSET.
2. Much of their equipment has been bought off of the German economy and will not run well on 110v, 60hz. Unfortunately, although this is NOT the case for all units in Germany – the 709th Military Police in Fleigerhorst Kasern did have a lot of 220v, 50hz equipment

that they would like to run with the current system. 127th Military Police suggested that a power inverter capable of running *both* the European 220v and US 110v systems would be of significant added value.

8.4 Germany Demo Data



System Load: August 2001
Field Training Exercise

Description	Voltage	Current/Min*	Power	Current/Max*	Power
	(VAC)	(Amps)	(Watts)	(Amps)	(Watts)
Battery charger	115.0	2.5	288	2.5	288
Laptop computer	117.0	0.5	59	0.8	94
Laptop computer	117.0	0.6	70	0.8	94
Laptop computer	117.0	0.6	70	0.7	82
Copier	117.0	1.2	140	8.0	936
Charger+Adapter	116.0	0.5	58	2.6	302
Compressor	118.0	3.8	448	16.5	1947
Printer	118.0	0.1	12	0.3	35
7 lights	113.8	3.2	364	3.2	364
Coffee maker	106.8	1.2	128	10.8	1153
Total Amps		14.2		46.2	

- steady-state load averaged 7.3 amps continuous over the 10 day exercise (increase of only 2 amps continuous *over* target of 6 amps)
- 300% increase in system load possible at initial start-up

▨ Color indicates systems that require high start up energy

Figure 27. Germany Demo Data

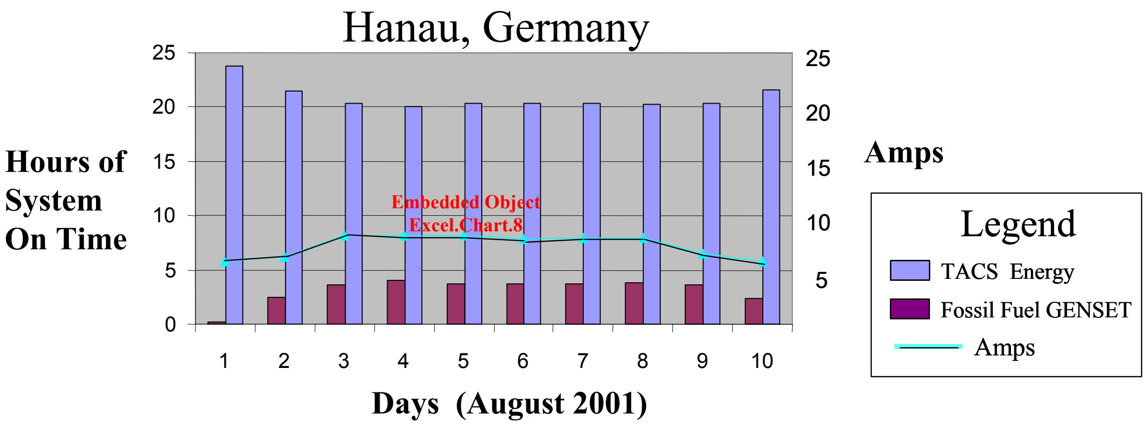
This data came from a variety of missions undertaken by the MPs at Fleigerhorst Kasern throughout the last quarter of 2002. These exercises included battalion maintenance, gate guard security and some field training exercises.

Note that the compressor was entirely used for the battalion maintenance activity whereas the coffee maker was used for all three missions.

Most of the systems noted above typically use less than an amp each. This is good news for PV which at current levels of materiel efficiency[1] takes substantial time to re-power the TACS battery bank. With good sun, the 3kW PV array could reconstitute the battery state of charge to its maximum of about 52 volts DC (assuming that there is no load) in about 6 hours. Working together, the PV and the GENSET can do this in about 3 hours. (note that this assumes new batteries and temperatures at ambient conditions)

[1] Thin-film PV can vary in efficiency from 6 – 12 percent, depending upon manufacturer. Efficiency is measured as that percent of 1000 watts / m2 of sun energy available at sea level for conversion into electricity. Therefore, a PV array that is 12% efficient is converting .12 x 1000 or 120 watts of power.

8.5 GENSET vs. TACS On-Time



- 31.2 hours of GENSET on-time over 240 hour exercise (13%)
- Average Amps of 7.3 (per day) were an increase over 6 amp target
- 5kW GENSET consumes ½ gal JP8/hour
  - Exercise of 240 hours would use 240 X .5 = 120 gals of JP8 with no TACS
  - 31.2 hours of GENSET on-time consumed 31.2 X .5 = 15.6 gals JP8 with TACS

TACS employment saved 104 gallons of JP8 (87% fuel savings)

Figure 28. GENSET vs. TACS On-Time

The above chart is illustrative of the TACS capability to provide a 6 amp power demand over a 10 day period in northern Germany. In general, the better the sun, the less time that the GENSET will need to be on. The reader should note that Hanau, Germany, gets about half the sun energy that Ft. Irwin, California, receives. The Hanau GENSET's on time of 13% of the 10 day period can be broken down into hourly components as follows:

10 Day exercise = 240 hours

13% GENSET on time = 31.2 hours

87% TACS on time = 208.8 hours

9 HANAU FINDINGS & OPERATIONAL FEEDBACK

9.1 Case Study #5: Germany Findings

- 3kW Army TACS used as prime power for 709th BN Maintenance Shop
- 3kW Army TACS used as prime power for Fleigerhorst Kaserne Gate Guard Duty
- Provided uninterruptible, tactical quiet for security missions (zero decibels)
  - Enlisted troops appreciated the value added of reduced fuel burden
  - 709th BN provided feed-back on requested changes (see notes page below)
- TACS provided power for 87% of the exercise, GENSET for 13%
- Bad weather (rain & overcast for ½ the exercise) degraded PV by ~18%.
- Saved an average of 11 gals of JP-8 /day (TACS was alternate for 10kW Tactically Quiet Generator)
  - Estimated yearly OPTEMPO fuel savings: 730 gals.
  - Estimated yearly OPTEMPO pollution reduction: 11,430 lbs
- Reduced demand for generator maintenance is currently unknown (but GENSET was off 87% of the exercise)

709th MP BN AAR (October '01)

Figure 29. Case Study #5: Germany Findings

The 127th Military Police company as of this writing is preparing to deploy to the Persian Gulf (February 2003) in support of US contingency force operations there. They will be taking their PV TACS with them. This says volumes about their positive experiences with the TACS itself, more in the forthcoming report REASR 3 (summer of 2004).

The TACS system provided the 127th MPs with all the power that they required for their field exercise (reported herein), remote gate-guard duties (not reported here), and for on-post battalion maintenance prime power.

The energy savings calculations were computed from an "average" PV day in the Hanau, Germany region, given the approximate on and off times of the fossil-fuel GENSET complementing the TACS. This was done to avoid overestimating the baseline capabilities of the TACS unit itself "on average days in Germany", to include wintertime.

The following is a list of corrections that the command of the 709th Military Police Battalion would like to see changed with their Tactical Alternating Current System generator:

1.Provide a JP8 GENSET to complement the PV. Gasoline, although plentiful at Fleigerhorst Kaserne, will not be plentiful when the unit is deployed to the Persian Gulf (note: when this TACS unit was built, it was built with the understanding that the unit would be used for installation energy only)

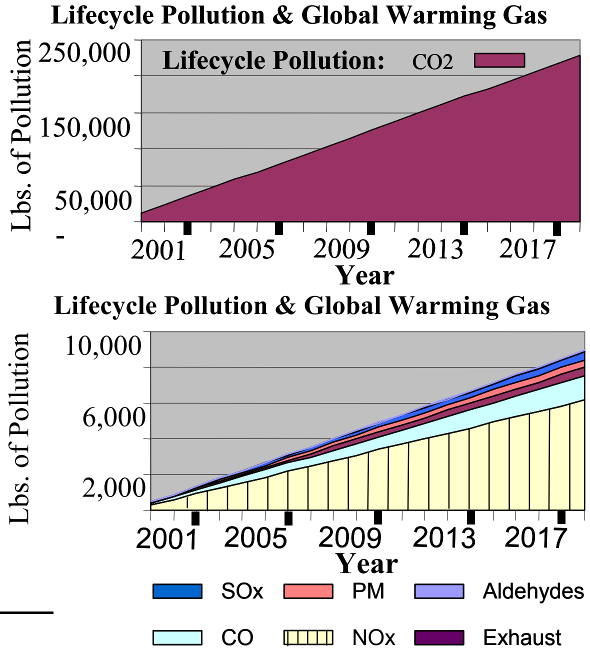
2.Provide a dual-purpose inverter with the TACS unit to operate both 120v and 220v power applications.

10 COST BENEFIT

10.1 PV Pollution Prevention

Pollutant	**20 Year Savings** (lbs of pollutants)
NOx (smog)	**6,007**
CO_2	**220,181**
CO	**1,105**
SOx (acid rain)	**374**
PM	**390**
Aldehydes	**89**
Exhaust	**440**
Crankcase	**12**
Total :	**228,598 lbs**

Figures are the differences between Conventional and TACS cases


Lifecycle Pollution & Global Warming Gas

Lifecycle Pollution & Global Warming Gas

Figure 30. PV Pollution Prevention

Because both the on and off times for both the National Training Center GENSET and the Germany GENSET were similar, the same can then be said for the pollution that would be prevented from either case – over a twenty year life cycle of the PV and GENSET.

One of the main benefits of the hybrid PV Case is pollution prevention. Fossil fuel burning generators produce many harmful pollutants which, in total, have negative impacts on the atmosphere and the earth.

This chart breaks down the pollution from fossil fuel generators into their various pollutant categories. There is no pollution from PV and so, there is no pollution to report.

Possibly the most harmful of all generator pollutants is carbon dioxide. Although this gas is produced in nature, too much of this gas is - according to the EPA - harmful to the earth's atmosphere. Carbon dioxide alone accounts for over 115 tons of harmful global warming gas over 20 years when comparing the difference between the hybrid PV Case and the Conventional Case.

10.2 TACS Energy Savings

Conventional Case:

3kW Military Standard, DED generator used for 1,600 hours per year over 20 years will require 96,000 lbs. of fuel. (Diesel Engine Driven Consumption = .4 gals / hour = 12,800 gals / 20 years)

TACS Case (localized values):

a. Fleigerhorst Kaserne: 20 year fuel use for a 3kW TACS with a 3kW array used for 1,600 hours per year with 3kW DED generator assist requires ~3,800 lbs of fuel.

   - ✓ Fuel Savings is: 96,000 – 12,480 = 83,520 lbs. of fuel saved (~ 11,136 gallons)

b. National Training Center: 20 year fuel use for a 3kW TACS with a 3kW array used for 1,600 hours per year with 3kW DED GENSET assist requires ~3,800 lbs of fuel.

   - ✓ Fuel Savings is: 96,000 –3,800 = 92,200 lbs. of fuel saved (~ 12,295 gallons)

Figure 31. TACS Energy Savings

Energy savings are important to the Army not just in terms of dollars saved but because of the sustained logistical impact as well. Given that fossil fuel such as JP8 must be stored, transported and delivered to its destination - this whole "logistical support system" is reduced by the positive impact that the TACS has on energy savings. In other words, for every truck load of fuel saved, this also means one less truck load of fuel delivered. In the long term, there are aspects of the entire logistical "tail" that would need to be reassessed because of this benefit.

Of course, every mission is not going to save as much fuel as the NTC case noted above. But consider this: If the NTC or Fleigerhorst Kasern case were only 50% TACS and 50% Conventional - would saving 50% of the normal fuel use be worth it? Would it be worth saving 50% of the fossil fuels that are currently being transported? And last, could further savings be made in the equipment that stores, tests and transports fuel if we were using only half of what we now use for selected missions?

These questions are posed because it is hoped that the purpose of REASR – strategic responsiveness in theater, can be further developed into "feasible uses of PV" by those commands requesting and procuring TACS generators. Each PV prototype would be tailored to meet the mission requirements of the requesting Agency or Division - in a manner similar to those military units mentioned in this report.

10.3 Sustaining Base Operational Readiness

- Since 9/11, 127th MP company at Hanau, GE is using the silent, 3kW PV system for remote power at gate control and battalion maintenance functions at Fleigerhorst Kaserne.
  - Provided uninterruptible, tactical quiet for security missions (zero decibels)
  - Enlisted troops appreciated the value added of reduced fuel burden
  - 709th BN provided feed-back on requested changes (see notes page at bottom of chart 32)
- Operational readiness of PV in the sustaining base (Exercises at Ft. Bragg 3/01, Ft. Stewart 4/01, Ft. Irwin 6/01)
  - Troops appreciated that the stored battery bank energy provided immediate power to the TOC without waiting for JP8 to arrive at their remote site
  - Provided tactical quiet for security missions (zero decibels)
- Given the choice between Military Standard generators and hybrid PV with Back-up, soldiers always chose the latter.

Figure 32. Sustaining Base Operational Readiness

One of the sponsors of the ADAPT and REASR studies has been the Assistant Chief of Staff for Installation Management (ACSIM). This army staff agency is continually looking for investment into new sources of energy to be used for installation applications.

This chart illustrates the installation applications to date, although there has been significant interest from several, US Army science advisors interested in Homeland Security remote power issues that PV might be able to supply.

Homeland Security is fueling a complete set of analytical works of its own, the scope of which is too broad to include in this work. CAA is involved in one such work whose title is **S**trategic **E**nergy **R**esource **I**nvestment **O**ptimization for the **US A**rmy (**SERIOUS-A**), sponsored by the ACSIM and performed by multiple partners to include US Army Construction Engineer Research Laboratory, Calibre Corporation, Energy Security Group and others.

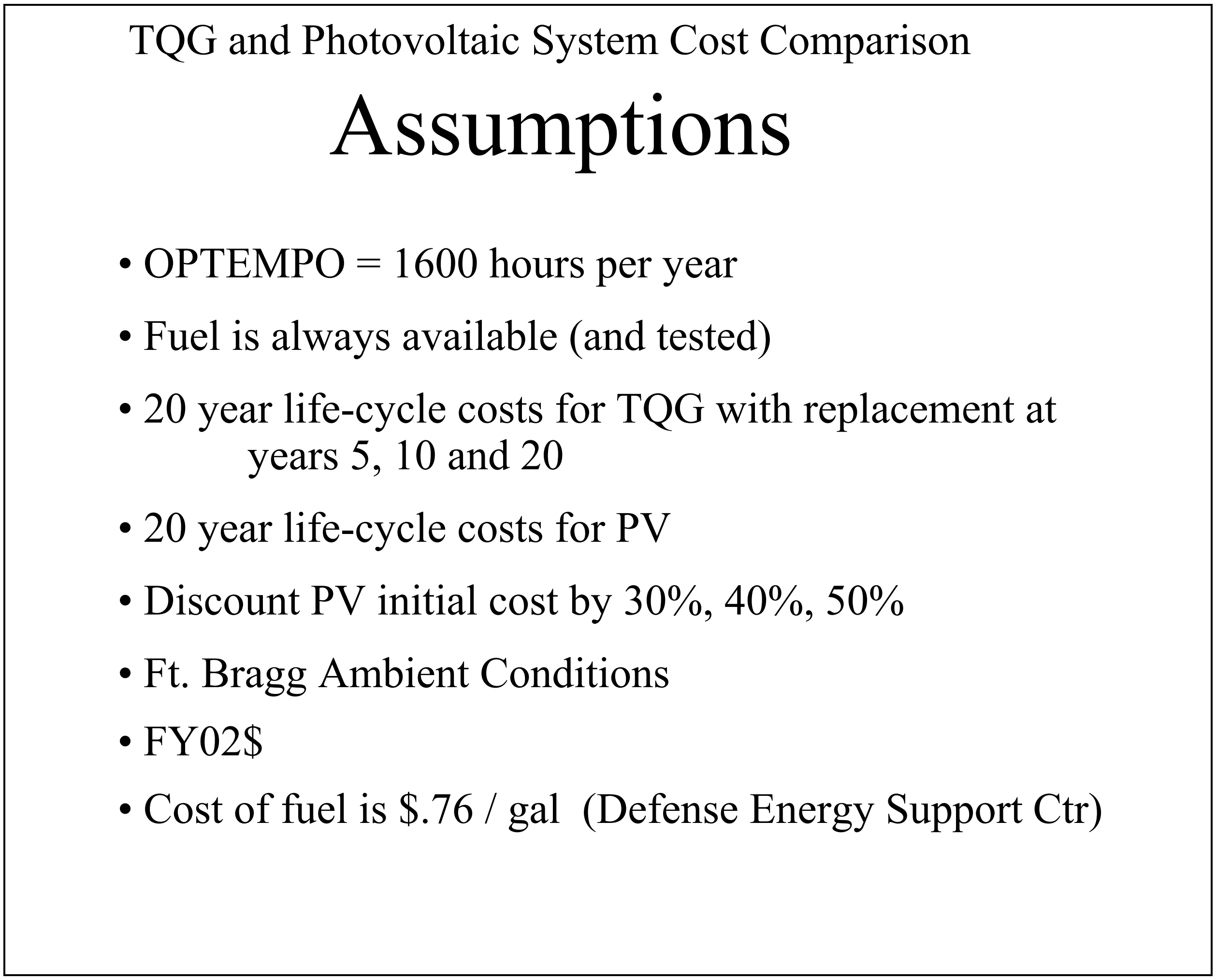
10.4 Economic Analysis

- Cost Factors (Parametric Analysis)
  - Initial System TACS and Fossil Fuel Generator Costs
  - Operations and Maintenance Costs (O & M)
    - Direct and general support costs for generator repair were based on the Logistics Integrated Database (LIDB)
    - Operations costs were provided by the Project Manager's Office for Mobile Electric Power
  - Labor Costs (based on wage board civilian (i.e. non-military, pay scale)
  - Replacement Costs
  - 20 Year Fuel Inflation Costs
- Net Present Value (20 year life cycle costing)
- Payback (years)

Figure 33. Economic Analysis

These are the cost factors and output variables that were used in the economic analysis.

10.5 Base Assumptions



TQG and Photovoltaic System Cost Comparison

Assumptions

- OPTEMPO = 1600 hours per year
- Fuel is always available (and tested)
- 20 year life-cycle costs for TQG with replacement at years 5, 10 and 20
- 20 year life-cycle costs for PV
- Discount PV initial cost by 30%, 40%, 50%
- Ft. Bragg Ambient Conditions
- FY02$
- Cost of fuel is $.76 / gal (Defense Energy Support Ctr)

Figure 34. Base Assumptions

These are the base assumptions behind the cost benefit analysis. The highlights in red are the variables for which a parametric analysis was performed around the fossil fuel GENSET. The blue highlights do the same for the values pertaining to the TACS unit.

10.6 Economic Analysis: 1st Year Data

High Cost (current)		**Most Likely Cost**		Low Cost	
Systems Cost:					
TQG Gen	TACS	**TQG Gen**	**TACS**	TQG Gen	TACS
$8,000	$45,000	**$8,000**	**$34,500**	$8,000	$22,500
Battery Costs:					
- 0 -	$7,000	**- 0 -**	**$3,500**	- 0 -	$2,000
O&M Costs:					
$3,100/yr	$40/year	**$1,050/yr**	**$40/year**	$500/yr	$40/yr
Labor Costs:					
$1,800/yr	$100/year	**$1,000/yr**	**$50/year**	$500/yr	$50/yr
Total Costs / 1st year:					
$12,900	$ 52,140	**$10,050**	**$ 38,090**	$9,000	$ 24,590

Figure 35. Economic Analysis: 1st Year Data

Because the TACS is a new equipment item, yet to be proven economically viable it suffers from lack of mass production. Economies of scale through mass production provide significant "first year" economic effect. Basically, the lower the initial first year cost, the better the economic pay back.

The purpose of the above chart is to find that acceptable estimate for the *most likely cost* for that economically critical first year. Current (FY02$) purchase price for the PV System is approximately $52,140. Another way to think about this price is the cost per watt of energy. Figuring only the PV related system cost of $45,000, and dividing this cost by the PV array size of 3,000 watts (3kW) gives us a cost / watt of $15. Likewise, the same type of calculation for the "most likely costs" yields an $11.50 / watt figure while the "low cost" comes in at $7.50. The $11.50 figure for "most likely cost" was chosen as the new first year starting cost because of its proximity to recent industry estimates for near-term, future PV manufacturing capability.

In order to ascertain these realistic near-term and far-term PV costs, this report employed an industry survey technique to predict the above manufacturing costs for thin-film PV product across a spectrum of three different companies: Unisolar, Global Solar Energy and BP Solar[1]. Predictive cost estimates from these three companies gave average values that were in the $10 - $12 / watt range for the near-term and $6 - $8 for the far-term (greater than 5 years). Therefore, the "most likely case" for FY02 price range seems to be reasonable given current, industry estimates of near-term future costs of thin-film PV material. This reasonable TACS system cost for the first year is therefore $38,090 and the corresponding GENSET discounted cost would be $10,050.

[1] Note that as of November, 2002 – BP Solar no longer produces thin-film material and instead, is focusing its corporate photovoltaic manufacturing on more traditional, crystalline PV.

10.7 TQG and Photovoltaic System Cost Comparison

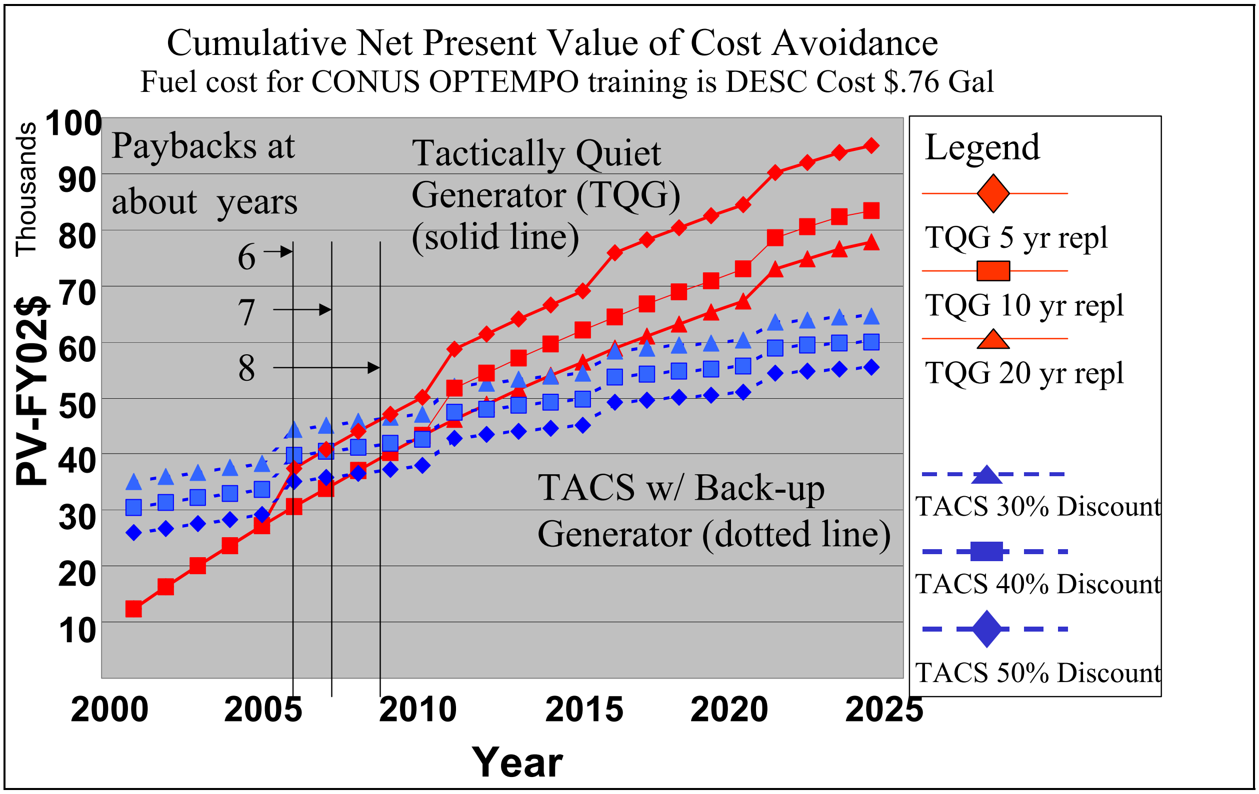


Figure 36. TQG and Photovoltaic System Cost Comparison

Using the previously calculated TACS "most likely" starting cost of $38,090 (a 30% discount from current FY02 prices) provides us an initial, reasonable first year cost for the TACS system (see the graph above, marked with triangles on dotted lines). Further discounts of the PV material for purposes of analytical comparison can also be seen (as the squares and again as diamonds on the dotted lines).

In contrast, the TQG iterations, illustrated as solid lines on the above chart, begins at its "most likely first year cost figure" of $10,050 with three different variants of the $8,000 GENSET replacement at the end of years 5, 10 and 20 respectively.

With these two complementary systems now illustrated, the cumulative, net present value of cost avoidance can be computed for 20-year life cycle costs as illustrated above. The intersection of the GENSET and TACS systems occurs at approximately years # 6, #7, #8 – meaning that the TACS would pay-for-itself in those timeframes considering TACS dollar discounts and the TQG replacements.

Obviously, the steepness of the solid lines illustrating the GENSET is *not* due as much to GENSET replacement costs as to yearly operational and maintenance costs. Battery replacement costs for the Tactical Alternating Current System can be seen on all TACS dotted lines at the end of every 5th year.

10.8 Assumptions

TQG and Photovoltaic System Cost Comparison

Assumptions

- OPTEMPO = Deployed = 1600 hours per year
- Fuel is always available (and tested)
- 20 year life-cycle costs for TQG with replacement at years 5, 10 and 20
- 20 year life-cycle costs for PV Array (sub-element of the TACS)
- Discount PV initial cost by 40%, 50%, 60%
- Ft. Bragg Ambient Conditions
- FY02$
- Fuel cost delivered to FEBA is $13/gal[1]

[1] Fuel cost from Defense Science Board report “More Capable Warfighting Through Reduced Fuel Burden” May 2001

Figure 37. Assumptions

Let us take the discussion on GENSET operations and maintenance costs one step further. In May, 2001 the Office of the Under Secretary of Defense for Acquisition and Technology published a report entitled “More Capable Warfighting Through Reduced Fuel Burden”. This report, among other things, detailed the true cost of fuel for deployed US forces as a function of distance from the Forward Edge of the Battle Area (FEBA).

The standard price for fuel as paid by DESC represents only a fraction of the true cost of delivered fuel. The true cost of fuel from storage, delivery, re-storage and finally to the point of use, the Services incur significant additional cost. These additional costs include manpower costs, training, physical logistics assets, fuel delivery operating costs and capital expense for items such as tanker trucks, tanker aircraft, and other hardware and infrastructure necessary to deliver fuel where and when it is needed.

For example, to illustrate the difference between the visible standard price of fuel and the true cost of fuel, the Defense Science Board asked the Air Force to calculate the total embedded cost of delivering fuel in-flight. The total cost of the tanker fleet (including crew, training, maintenance, infrastructure, and other logistics costs) was added to the cost to purchase the fuel and deliver it to the tanker aircraft on the ground. This calculation did not include tanker acquisition costs. The analysis revealed that it cost the Air Force over $2.5 billion to deliver 130 million gallons of fuel in FY99. In other words, the Air Force spent 84 percent of its fuel delivery budget to deliver 6 percent of its fuel in FY99.

10.9 Cumulative Net Present Value of Cost Avoidance

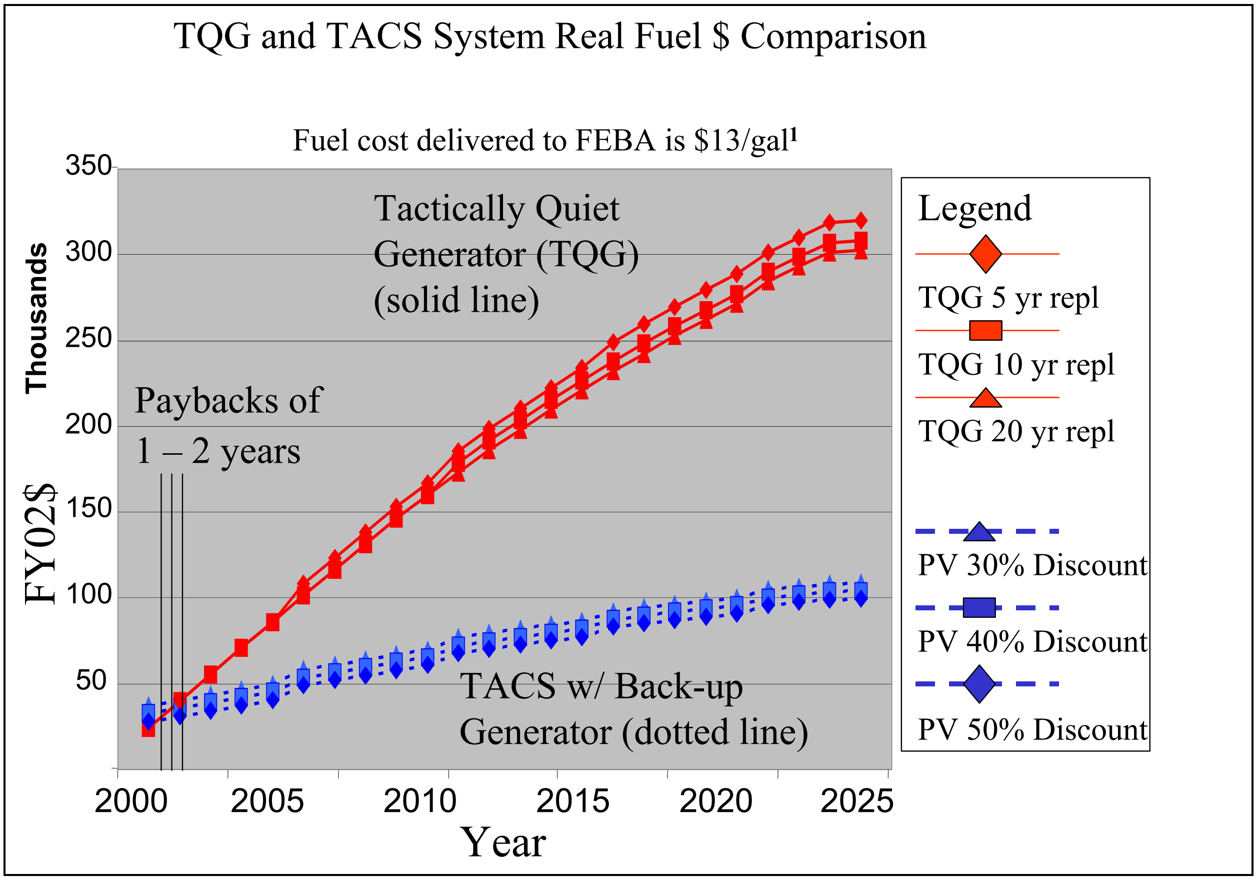


Figure 38. Cumulative Net Present Value of Cost Avoidance

The previous net present value chart illustrated that the primary life-cycle cost was the operation and maintenance of the system. It also showed a DESC cost of $.76 per gallon of JP8 fuel. However, this is a CONUS cost – and does not pertain to deployed troops using GENSETs worldwide.

The above chart carries that concept a little further in that DESC energy costs can be substantially more than the current, visible standard price of fuel. In this case, fuel cost at the FEBA for deployed troops using army GENSET power is $13 per gallon.

The Defense Science Board goes on to state in its report that the largest element of the total fuel cost in DoD is the cost of delivery. The Services pay dearly to deliver fuel to where it is needed. In-flight refueling is the most expensive way to deliver fuel. However, delivering fuel to the Forward Edge of the Battle Area (FEBA) is very costly and the further beyond the FEBA fuel is moved, the more costly it becomes. (note that according to the Defense Science Board, if fuel is delivered 100km beyond the FEBA, then the cost of delivered fuel balloons to $25 per gallon.)

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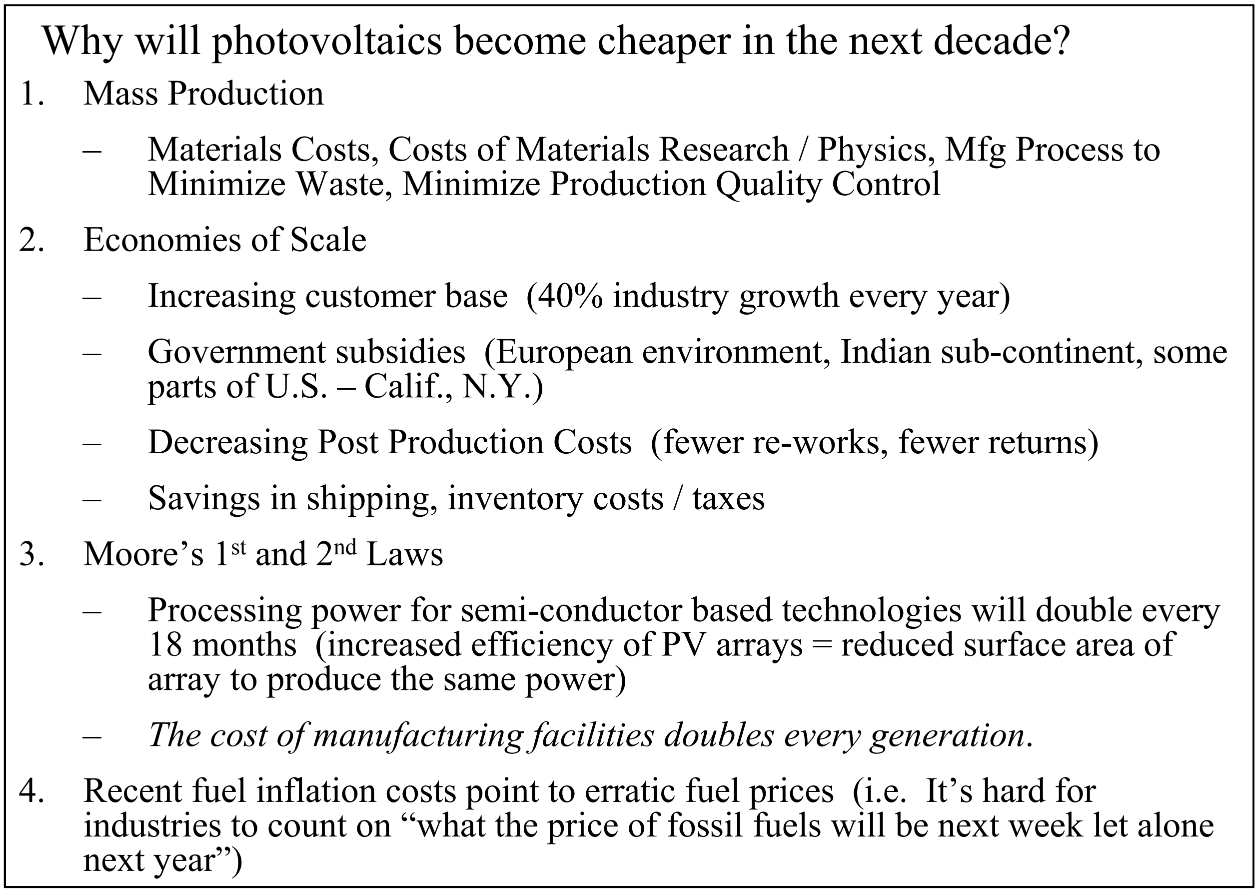
11 FUTURE ECONOMIC POTENTIAL OF HYBRID ELECTRIC GENERATORS

11.1 Future Costing Issues



Why will photovoltaics become cheaper in the next decade?

1. Mass Production
   - Materials Costs, Costs of Materials Research / Physics, Mfg Process to Minimize Waste, Minimize Production Quality Control
2. Economies of Scale
   - Increasing customer base (40% industry growth every year)
   - Government subsidies (European environment, Indian sub-continent, some parts of U.S. – Calif., N.Y.)
   - Decreasing Post Production Costs (fewer re-works, fewer returns)
   - Savings in shipping, inventory costs / taxes
3. Moore’s 1st and 2nd Laws
   - Processing power for semi-conductor based technologies will double every 18 months (increased efficiency of PV arrays = reduced surface area of array to produce the same power)
   - *The cost of manufacturing facilities doubles every generation.*
4. Recent fuel inflation costs point to erratic fuel prices (i.e. It’s hard for industries to count on “what the price of fossil fuels will be next week let alone next year”)

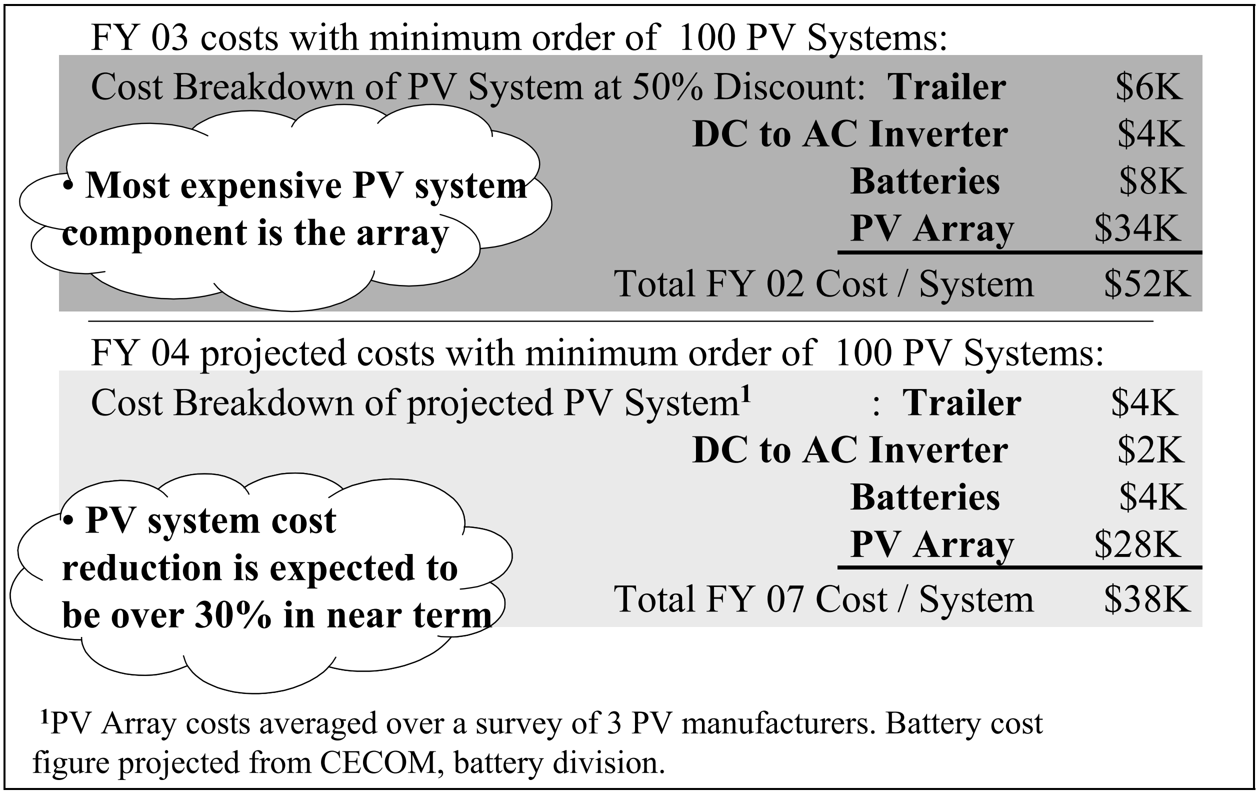
Figure 39. Future Costing Issues

Instability in any resource is not a good thing because it makes planning for the uncertainties associated with this very difficult. There are numerous examples of recent corporate failures that have been directly linked to the erratic costs of fuel. Bankruptcies in the airline industry, the collapse of ENRON, increased insurance carrier costs for fuel transportation, yearly postage increases for a struggling US Post Office - to name just a few.

Necessity is the mother of invention as the saying goes, and this continued instability in the fuels market coupled with decreasing worldwide crude oil production will continue to focus more attention on environmentally clean renewable energy resources. It’s just a matter of time.

In the long term, the market will eventually determine the true “economies of scale” for the army’s TACS system – but until that time, analysts must continue to rely on estimating the relative cost of future systems when mass production of photovoltaic materials will drive the current costs substantially down.

11.2 Current vs. Projected PV System Costs



FY 03 costs with minimum order of 100 PV Systems:

Cost Breakdown of PV System at 50% Discount:	**Trailer**	$6K
	DC to AC Inverter	$4K
	Batteries	$8K
	PV Array	$34K
	Total FY 02 Cost / System	$52K

- **Most expensive PV system component is the array**

FY 04 projected costs with minimum order of 100 PV Systems:

Cost Breakdown of projected PV System[1] :	**Trailer**	$4K
	DC to AC Inverter	$2K
	Batteries	$4K
	PV Array	$28K
	Total FY 07 Cost / System	$38K

- **PV system cost reduction is expected to be over 30% in near term**

[1] PV Array costs averaged over a survey of 3 PV manufacturers. Battery cost figure projected from CECOM, battery division.

Figure 40. Current vs. Projected PV System Costs

A sub-element of the economies of scale discussion on the previous page leads us to examine the individual parts of the army TACS system. From the above charts, the reader can clearly see that the PV array itself is the most expensive element that is incorporated into the TACS.

Therefore, if one could chose a single component to analyze how best to decrease cost, it would be the PV Array. For our currently produced TACS power generators, the PV array counts for more than 65% of the total system cost. Oddly enough, as projected through FY04, the PV array decreased in cost – but not nearly enough to make it a cheaper component to the overall cost of the TACS. Rather, it increased to a whopping 74% of the total TACS cost!

Unfortunately, PV manufacturing is a difficult process, and we can see this fact in the above array costs. Note that although we can buy cheaper batteries (by 50%) and cheaper trailers (by 33%) and cheaper inverters (by 50%), we can only purchase cheaper PV at the 18% level. (see the previous discussion of PV manufacturing under the heading “Data and Analysis”. Of all of the processes involved in the TACS systems, it will be the manufacturing of the photovoltaic arrays that will be the most challenging – and the most difficult for energy analysts to quantify and qualify associated costs for PV in any form (crystalline, thin-film, molecular, etc.)

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12 FINDINGS & INSIGHT SUMMARY

12.1 Economic Analysis Findings

TACS Paybacks Based on Net Present Value, FY02 $$$

High Payback	**Most Likely Payback**	Low Payback
8 Years	**7 Years**	6 Years

Costing Challenges:

- TQG Operations and Maintenance Costs and Initial System Costs are the primary factors in the payback analysis. (including the "increased costs" of advanced fossil-fuel power generation would decrease the paybacks shown above by 1 to 2 years)
- Military deployments pay increased costs per gallon for delivered JP8 to and beyond the FEBA. This increased cost drives the paybacks for TACS down to 1 or 2 years.
- Future Costing Issues:
  - 20 year fuel inflation costs - although updated for this particular study - fuel costs can change significantly from year-to-year. FY99 = $.87/gal, FY00 = $.62/gal, FY01 = $1.01/gal, FY02 = $1.34) This continued instability will make TACS systems more attractive to big consumers of fossil fuels in the long run
  - Determining the true economies of scale for future TACS units will in large part depend on government's commitment to make large purchases for PV power generation

Figure 41. Economic Analysis Findings

Most likely paybacks for army TACS systems given realistic estimates of field performance and use by army personnel are about 8 years. If more details are included on the actual type of fossil-fuel GENSET to be employed in the out-years, which will be quieter and use less fuel, then these GENSETs will probably be more expensive and heavier. Although this analysis did not include this level of detail for GENSETs (see the Army's Advanced Medium Sized Power Source (AMMPS) on the internet at www.pm-mep.org) it would tend to make the paybacks for TACS less – by as much as two years.

Military deployments counting on fuel to power an increasingly digitized Army will find fuel costs in places like Afghanistan, Bosnia, Indonesia, Iraq and other remote locations to be quite high, maybe even approximating the $25 / gallon figure proposed by the Defense Science Board. (see May 2001 Report "More Capable Warfighting Through Reduced Fuel Burden").

Earlier discussions centering around the vagaries of unstable fuel inflation costs and the associated detrimental effect that it has on the American consumer and industry can only hurry the increased use of hybrid power onto the American highways and business transportation.

12.2 Insights

What have we learned from REASR 2? TACS can:

1. support unit and installation applications
2. improve operational readiness
3. help to reduce logistics footprint
4. be strategically responsive thru reduced fuel requirement
5. produce tactically quiet and uninterruptible power
6. complement GENSETSs and be part of a suite of potential portable power sources – fuel cells, PV, TPV, wind . . .
7. be less effective through its PV component during inclement weather or if deployed to poor solar locations
8. reduce GENSET unscheduled maintenance through optimizing its usage profile

Figure 42. Insights

From gate guard missions at Fleigerhorst Kasern (Germany) to field training exercises at Ft. Irwin (California) – the TACS provided immediate power without waiting for additional resupply from fossil fuels. Of course, the silent-running feature of the TACS has obvious operational value. This is perhaps best understood by the troops in the field where complete generator silence (especially at night) can mean the difference between life and death.

This report has detailed the expected savings in JP8 which, depending on the system load, geographical location, weather variability and the size of the back up GENSET, can significantly reduce logistic tail both at installations (for Homeland Security missions) and for deployed forces (fighting the Global War On Terror).

These continuing TACS demonstrations OCONUS underscore the strategic transportability effectiveness of the generators. Although simple safety requirements must be followed for the transport of any energy resource, Army troops and Air Force personnel have not had any problems in 10 separate real (not simulated) exercises for TACS load plan development and execution.

Typically, in the field and on post – reliance on GENSET power alone can always be compromised when someone forgets to “fill up the gas tank”. Uninterruptible power is key to the

Army of the 21st century because of the Army's level of current digitization and future transformation goals. Operating in a suite of energy resources makes sense given the fact that current operating procedures requires "a back-up system" regardless[1].

Understandably, there are locations in the world where the TACS would not contribute much in terms of sun energy. The winter nights (that last for 6 months at a time) in the poles would not be good. Fortunately, in the last decade, there have been no deployments to either pole by any of the armed services. See chart 15 entitled "US Military Deployments" for a complete illustration of recent deployments.

Life cycle costing (LCC)

- Initial GENSET costs are lower than for TACS (hybrid)
- Operations and maintenance costs are the driving financial factors behind GENSET's long term costs
  - GENSET replacement and TACS discounting were not as important as the cost of JP8 in LCC calculations
- Sustaining Base Operations where the price of fuel is relatively low, illustrates TACS pay backs in 8 years (avg)
- Deployed Operations TACS payback in 1-2 years because of the real cost of fuel (mostly due to fuel transportation costs) to remote locations
- Expected decreases in the cost of TACS manufacturing and in photovoltaics materiel – coupled with increased PV efficiencies – will produce better future TACS paybacks

Figure 43. Insights (cont'd)

Life-cycle costing using the cumulative net present value of cost avoidance between straight GENSET and TACS applications illustrate conclusively that Army O & M costs for GENSETs drive the analysis. Although today's capitalization costs for GENSETs are lower than for the TACS – this is offset (around year 8) by the lower O&M for the TACS system. Of course, if the cost of fuel escalates or if the GENSETs / TACS are employed in remote locations OCONUS – then TACS paybacks in the "most likely class" of scenarios occur within the first two years of purchase.

---

[1] In a recent visit to a corps TOC in Germany (February of 2003), 26 GENSETS (total of 548 kW) were on-site, 11 in a "back-up" mode and not running. This means that an on-line potential of approximately 274 kW was available for use. However, a site inspection revealed that only 102 kW were actually handling the load. (Load was from 150 lap tops, 50 servers, 25 FAX machines, 5 coffee pots, 50 lights, 4 color copiers, and heating requirements)

Of course, purchasing TACS in an environment where economies of scale can also be applied to the TACS also reduces time of paybacks. Additionally, as the science of increasing the efficiencies of PV materiel matures – less PV array (both weight and cubic feet of volume) will be required to produce the same power (kW).

These economic scenarios have taken replacement of systems into account at various years within this LCC analyses. For example, replacements of GENSETs at years 5, 10 and 20 along with TACS battery replacement have been analyzed. Concerning the TACS substantial battery bank (Heavy Variant: 1,200 pounds, 750 kWh, Light Variant: 600 pounds, 375 kWh) there is the argument that the TACS is not a good system to deploy because it's too "heavy" in batteries to keep up with the pace of battle. The reader must understand that this is exactly the reason that the TACS has been demonstrated with *both* heavy and light Army units. Demonstrations of the TACS with light infantry troops and cadre reveal that the Light Variant TACS was never "air dropped" into a landing zone. Rather, it was brought to the front with other supply vehicles and materiel. Finally, it must be realized that although batteries *do represent a lot of weight of the TACS system*, at 7.5 pounds per gallon, JP8 is also very heavy and brings its own challenges regarding purchase, transport, storage and testing.

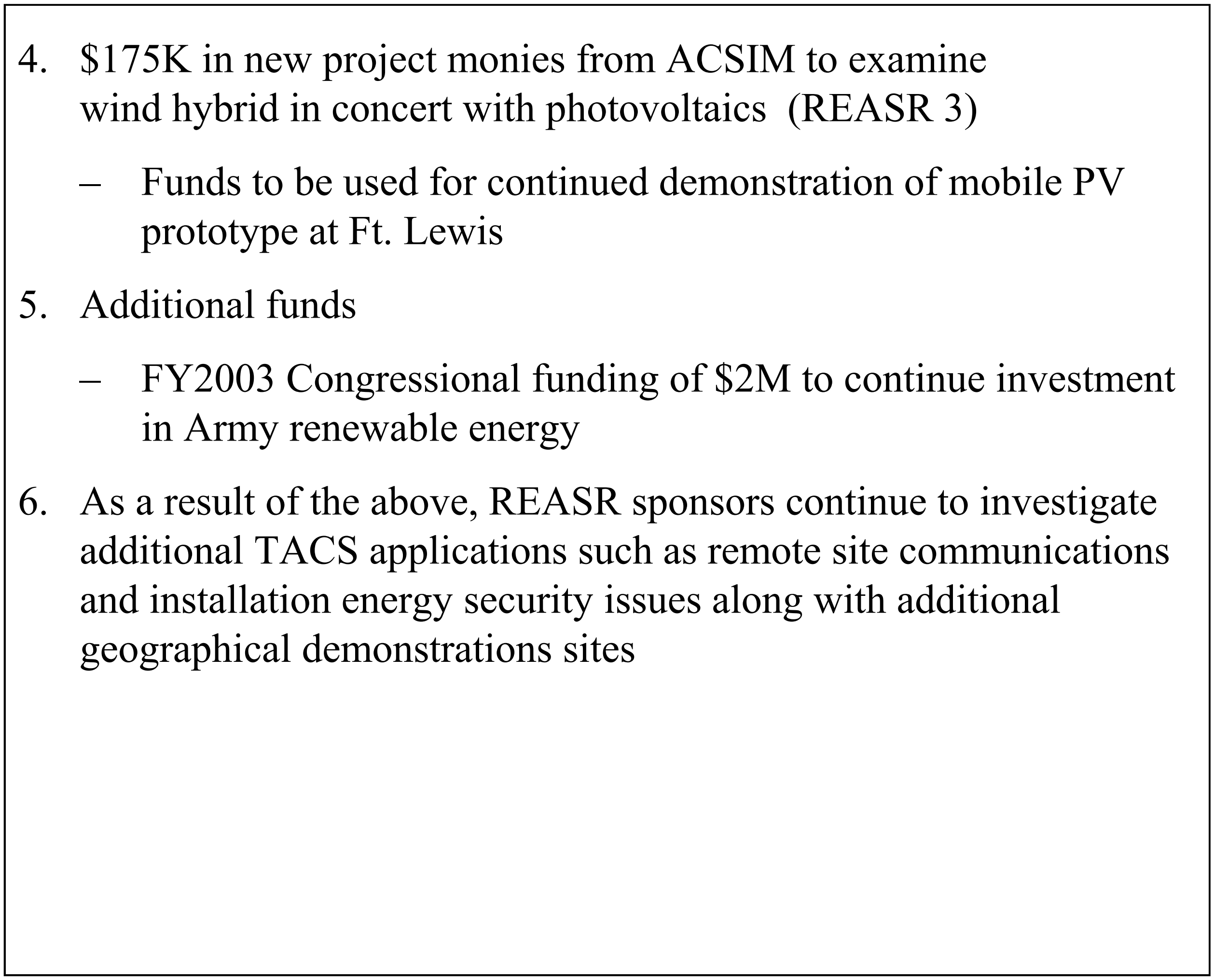
12.3 What REASR 2 Accomplished

1. Operational Effectiveness
   - Tactical PV Systems (3kW)
   - Deployment Considerations (impact of fuel costs at FEBA, maintenance costs, strategic deployment tactical load requirements)
   - Developed loading plans for strategic transport
2. Analyzed economics of thin film PV in the tactical arena
   - Mass Production (& Economies of Scale)
   - Future Costing of PV materials
3. Provided the basic analysis for future development of a TACS Operational Requirement Document and for additional GENSET requirements / procurement considerations (Ft. Lee)

Figure 44. What REASR 2 Accomplished

REASR 2 is the second in a series of demonstrations of renewable energy in the context of military applications for both units and installations. The idea behind this work is to begin to familiarize the Army with commercially available "off-the-shelf" technologies to add value to Army missions. *It is not the intent of this work to do away with the Army's legacy component of GENSET capability* – but rather to enhance this legacy capability by leveraging complementing technologies such that the sum of the parts is greater in terms of value-added army missions, than could be accomplished by any single, individual technology.

One such private sector example of this concept can be found in Toyota Motor Car Corporation's Prius and Honda's Insight automobiles. These new cars – introduced last year – increase the gas mileage of their respective engines by optimizing their employment within the context of two energy sources working together: gasoline and battery energy. The only difference between this private sector philosophy and the Army's is that the Army is suggesting a third energy source be employed to reduce even further the dependence on fossil fuel: photovoltaics.



4. $175K in new project monies from ACSIM to examine wind hybrid in concert with photovoltaics (REASR 3)
    – Funds to be used for continued demonstration of mobile PV prototype at Ft. Lewis
5. Additional funds
    – FY2003 Congressional funding of $2M to continue investment in Army renewable energy
6. As a result of the above, REASR sponsors continue to investigate additional TACS applications such as remote site communications and installation energy security issues along with additional geographical demonstrations sites

Figure 45. (continued) What REASR 2 Accomplished

Under the auspices of the ACSIM, hybrid based, TACS systems are being built to provide a hedge against terrorism for Ft. Lewis, WA. These two new TACS will employ a wind option along with PV, the battery bank and back-up GENSET to provide power for gate-guard security at Ft. Lewis (Tacoma) and at Ft. Lewis (Yakima) locations.

Congress is also interested in leveraging this work and has included the Army in its Tri-Service Renewable Energy Forum. This group's mission is to leverage renewable energy technologies in order to lessen the Armed Services' dependence on traditional power-grid energy, and most important – to come up with demonstration programs (to include TACS) for various CONUS-based military posts, camps and installations.

12.4 What Next

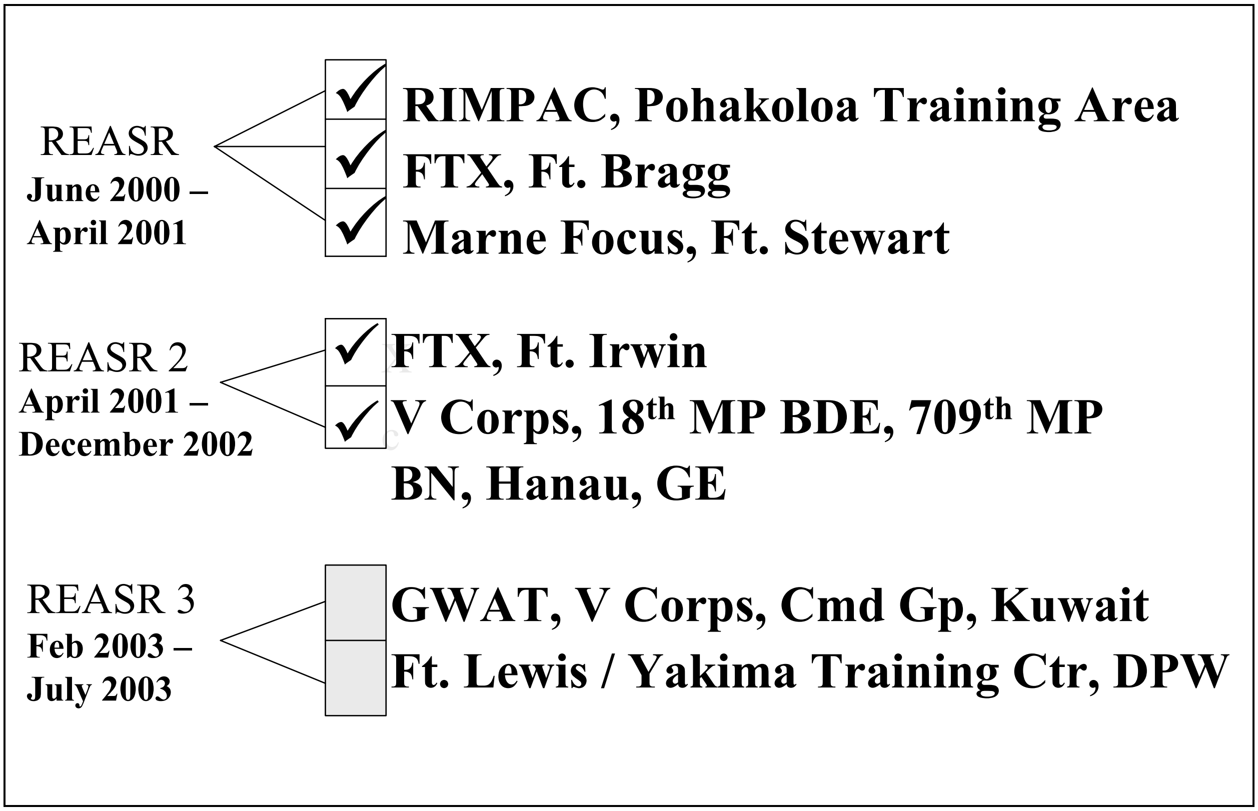


Figure 46. What Next

REASR 3 is in process with 2 new wind / PV / battery bank / GENSET hybrid systems being produced near West Point, NY. This study report should be available in the late summer of 2004.

Two additional demonstration sites are planning to utilize these two new TACS systems. The first is at Ft. Lewis, WA while the second site is in Kuwait. The two new TACS (mentioned above) will be going to the DPW (Plans Division) at Ft. Lewis (Tacoma) and Ft. Lewis (Yakima). Missions of remote gate-guard duty, recreation power, emergency preparedness and renewable energy training are expected. The second demonstration of TACS is also ongoing with elements of V Corps – now deployed to the Persian Gulf Region (February 2003).

Both of these demonstrations of tactical renewable energy applications will help to push the analysis to the next level of understanding. In that regard, we will continue to address costing as well as the other renewable, wind. In the Ft. Lewis environment, wind is expected to provide an additional 12% of energy to the TACS battery bank – further reducing our dependence on fossil fuels.

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12.5 Glossary

AAR	after-action report
AC	alternating current
ACSIM	Assistant Chief of Staff for Installation Management
amp	ampere
bde	brigade
CAA	Center for Army Analysis
CASCOM	Combined Arms Support Command
CECOM	Communications - Electronics Command
CERL	Construction Engineering Research Laboraatory
CONUS	continental United States
DC	direct current
DCSLOG	Deputy Chief of Staff for Logistics
DESC	Defense Energy Support Center
DOD	Department of Defense
DSB	Defense Science Board
FTX	Field Training Exercise
gal	gallon
GWOT	Global War On Terrorism
km	kilometer
kW	kilowatt
lb	pound
LTA	Logistics Transformation Agency
Marne Focus	Field Exercise with 82nd Airborne Division, Ft. Stewart, GA
MEP	mobile electric power
MILSPEC	Military Specification
MTW	major theater war
NTC	National Training Center
OPTEMPO	operating tempo
ORD	Operational Requirements Document
photovoltaics	from photo, meaning "light," and volta, meaning "energy"
PM	project manager
PV	photovoltaics
RIMPAC	Pacific Rim United Nations sponsored, US Military support humanitarian assistance exercise
SOF	Special Operations Forces
SSC	smaller-scale contingency
TACS	Tactical Alternating Current System
TOC	tactical operations center
TPV	thermal photovoltaics
TQG	Tactically Quiet Generator
V	volt

Figure 47. Glossary

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APPENDIX A PROJECT CONTRIBUTORS

1. PROJECT TEAM

a. Project Director:

Hugh W. Jones

b. Team Members:

James Keller, Steve Siegel

c. Other Contributors:

Soldiers and Command from 1/504 Parachute Infantry Regiment, XVIII AB Corps, Ft. Bragg, NC
Soldiers and Command from 127/709 MP Company, 18th MP Brigade, V Corps, Hanau, GE
Project Manager's Office for Mobile Electric Power (PM-MEP) (COL Mark Jones, Dr. James Cross)
Mr. Jeff Hager and Mr. Bruce Murphy (LTA, 54M Avenue, New Cumberland, PA 17070)

2. PRODUCT REVIEWERS

Dr. Ralph E. Johnson, Quality Assurance

3. EXTERNAL CONTRIBUTORS (If any)

Scot Albright (Global Solar Energy), Jim Chaney (Consultant)

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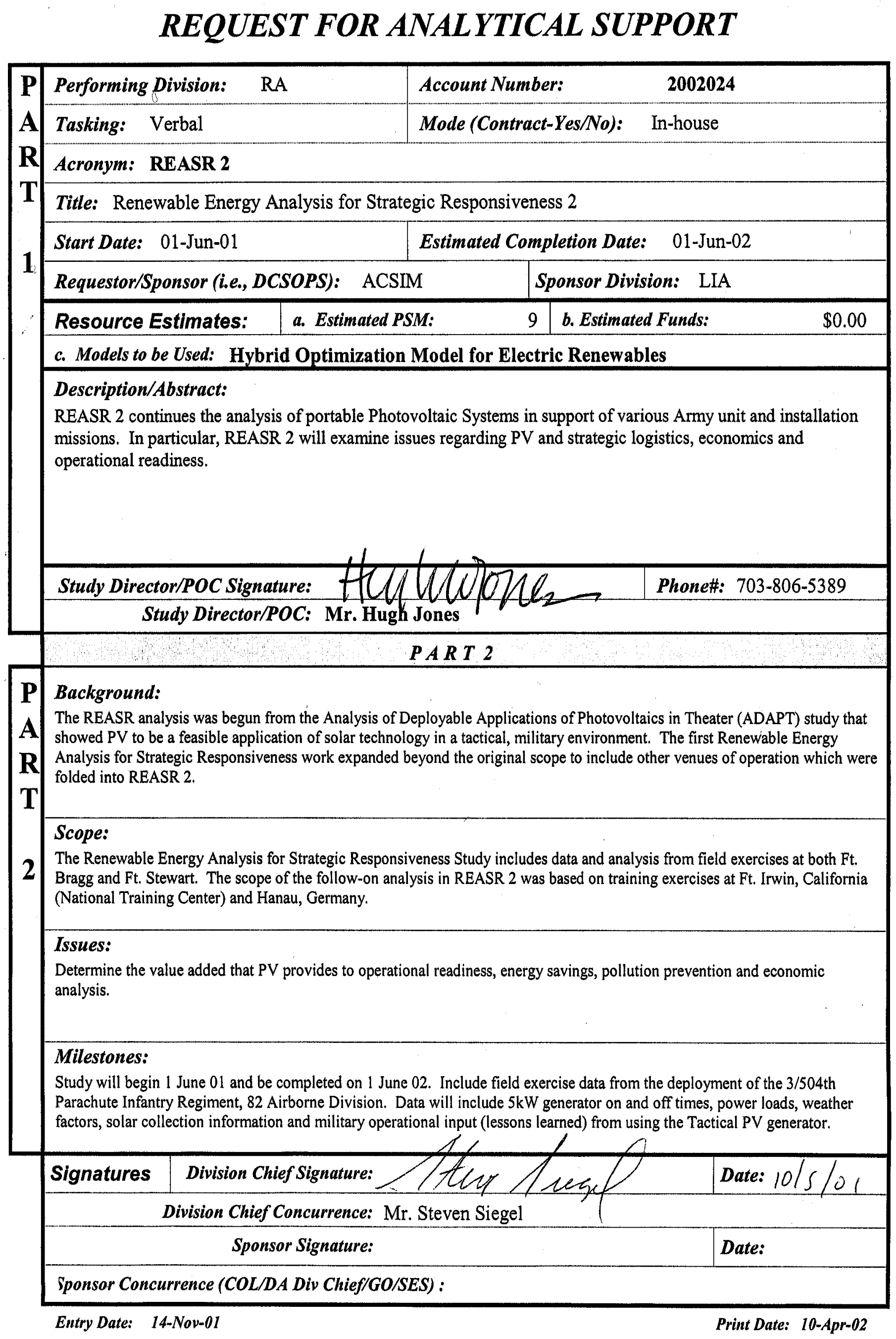
APPENDIX B REQUEST FOR ANALYTICAL SUPPORT



REQUEST FOR ANALYTICAL SUPPORT

PART 1

Performing Division: RA

Account Number: 2002024

Tasking: Verbal

Mode (Contract-Yes/No): In-house

Acronym: **REASR 2**

Title: Renewable Energy Analysis for Strategic Responsiveness 2

Start Date: 01-Jun-01

Estimated Completion Date: 01-Jun-02

Requestor/Sponsor (i.e., DCSOPS): ACSIM

Sponsor Division: LIA

Resource Estimates: ***a. Estimated PSM:*** 9 ***b. Estimated Funds:*** $0.00

c. Models to be Used: **Hybrid Optimization Model for Electric Renewables**

Description/Abstract:

REASR 2 continues the analysis of portable Photovoltaic Systems in support of various Army unit and installation missions. In particular, REASR 2 will examine issues regarding PV and strategic logistics, economics and operational readiness.

Study Director/POC Signature:

Phone#: 703-806-5389

Study Director/POC: **Mr. Hugh Jones**

PART 2

Background:

The REASR analysis was begun from the Analysis of Deployable Applications of Photovoltaics in Theater (ADAPT) study that showed PV to be a feasible application of solar technology in a tactical, military environment. The first Renewable Energy Analysis for Strategic Responsiveness work expanded beyond the original scope to include other venues of operation which were folded into REASR 2.

Scope:

The Renewable Energy Analysis for Strategic Responsiveness Study includes data and analysis from field exercises at both Ft. Bragg and Ft. Stewart. The scope of the follow-on analysis in REASR 2 was based on training exercises at Ft. Irwin, California (National Training Center) and Hanau, Germany.

Issues:

Determine the value added that PV provides to operational readiness, energy savings, pollution prevention and economic analysis.

Milestones:

Study will begin 1 June 01 and be completed on 1 June 02. Include field exercise data from the deployment of the 3/504th Parachute Infantry Regiment, 82 Airborne Division. Data will include 5kW generator on and off times, power loads, weather factors, solar collection information and military operational input (lessons learned) from using the Tactical PV generator.

Signatures ***Division Chief Signature:*** ***Date:*** 10/5/01

Division Chief Concurrence: Mr. Steven Siegel

Sponsor Signature: ***Date:***

Sponsor Concurrence (COL/DA Div Chief/GO/SES) :

Entry Date: 14-Nov-01 ***Print Date: 10-Apr-02***

Figure 48. CAA Form 233: REASR 2

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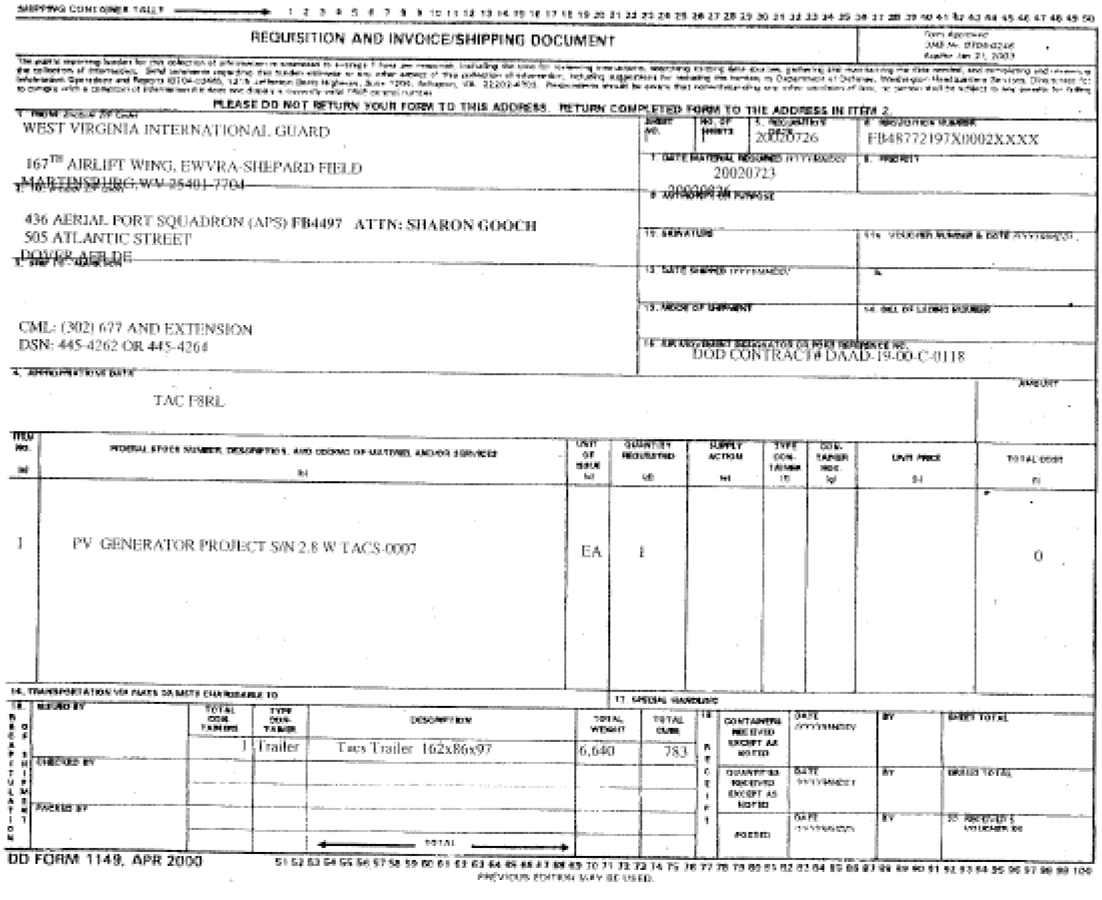
APPENDIX C STRATEGIC SHIPPING DOCUMENT (AIRCRAFT LOAD PLAN)

The following document was prepared for strategic shipment of the hybrid electric, trailer mounted generator. The aircraft loadmaster required that all cables be disconnected from the battery bank along with emptying the fuel tank on the diesel GENSET. He also required that the crankcase also be emptied (of oil). Questions on this appendix can be addressed to Ms. Sharon C- Gooch at Dover Air Force Base, Dover, Delaware. Her phone is 302-677-4262 / 4264.



SHIPPING CONTAINER TALLY → 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

REQUISITION AND INVOICE/SHIPPING DOCUMENT

PLEASE DO NOT RETURN YOUR FORM TO THIS ADDRESS. RETURN COMPLETED FORM TO THE ADDRESS IN ITEM 2.

WEST VIRGINIA INTERNATIONAL GUARD

167TH AIRLIFT WING, EWVRA-SHEPARD FIELD
MARTINSBURG, WV 25401-7704

436 AERIAL PORT SQUADRON (APS) FB4497 ATTN: SHARON GOOCH
505 ATLANTIC STREET
DOVER AFB DE

CML: (302) 677 AND EXTENSION
DSN: 445-4262 OR 445-4264

1
1
20020726
FB48772197X0002XXXX

20020723
20020826

DOD CONTRACT# DAAD-19-00-C-0118

TAC F8RL

AMOUNT

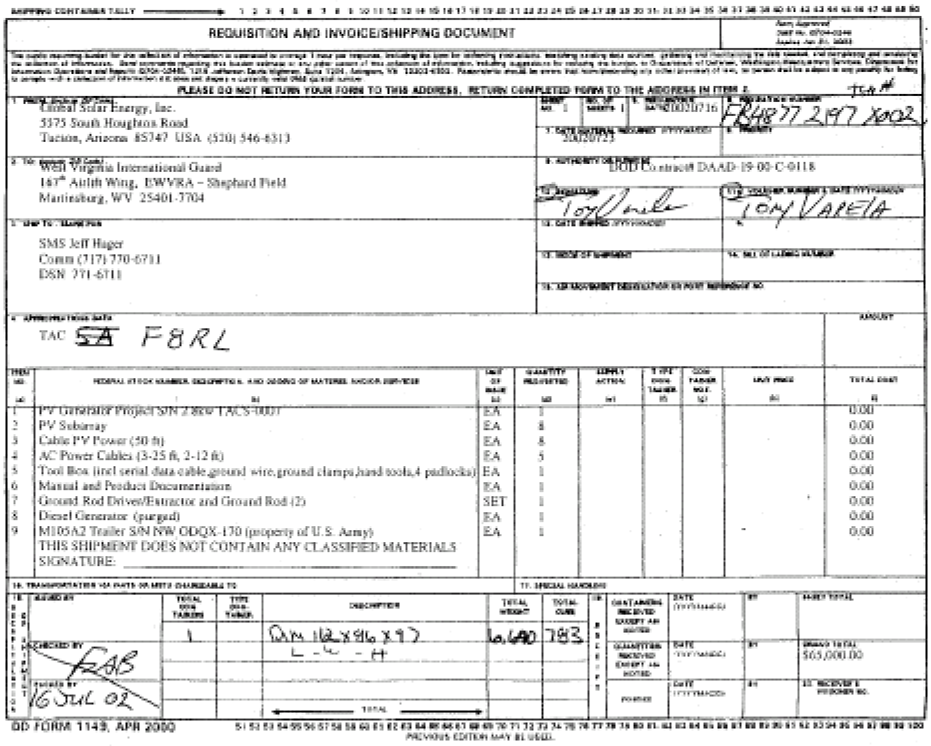
1	PV GENERATOR PROJECT S/N 2.8 W TACS-0007	EA	1					0

1	Trailer	Tacs Trailer 162x86x97	6,640	783

DD FORM 1149, APR 2000

51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

PREVIOUS EDITION MAY BE USED.



REQUISITION AND INVOICE/SHIPPING DOCUMENT

PLEASE DO NOT RETURN YOUR FORM TO THIS ADDRESS. RETURN COMPLETED FORM TO THE ADDRESS IN ITEM 2.

TCA #

1. FROM
Global Solar Energy, Inc.
5575 South Houghton Road
Tucson, Arizona 85747 USA (520) 546-6313

SHEET NO. 1 NO. OF SHEETS 1

5. REQUISITION DATE 20020716

6. REQUISITION NUMBER FB4877 2197 X002

7. DATE MATERIAL REQUIRED (YYYYMMDD) 20020723

2. TO
West Virginia International Guard
167th Airlift Wing, EWVRA – Shephard Field
Martinsburg, WV 25401-7704

9. AUTHORITY OR PURPOSE DOD Contract# DAAD-19-00-C-0118

10. SIGNATURE Tony Varela

11. TONY VARELA

3. SHIP TO - MARK FOR
SMS Jeff Hager
Comm (717) 770-6711
DSN 771-6711

4. APPROPRIATIONS DATA
TAC ~~5A~~ F8RL

ITEM NO.	FEDERAL STOCK NUMBER, DESCRIPTION, AND CODING OF MATERIEL AND/OR SERVICES	UNIT OF ISSUE	QUANTITY REQUESTED	SUPPLY ACTION	TYPE CONTAINER	CONTAINER NOS.	UNIT PRICE	TOTAL COST
1	PV Generator Project S/N 2 new TACS-0001	EA	1					0.00
2	PV Subarray	EA	8					0.00
3	Cable PV Power (50 ft)	EA	8					0.00
4	AC Power Cables (3-25 ft, 2-12 ft)	EA	5					0.00
5	Tool Box (incl serial data cable,ground wire,ground clamps,hand tools,4 padlocks)	EA	1					0.00
6	Manual and Product Documentation	EA	1					0.00
7	Ground Rod Driver/Extractor and Ground Rod (2)	SET	1					0.00
8	Diesel Generator (purged)	EA	1					0.00
9	M105A2 Trailer S/N NW ODQX-170 (property of U.S. Army)	EA	1					0.00
	THIS SHIPMENT DOES NOT CONTAIN ANY CLASSIFIED MATERIALS SIGNATURE: ______							

TOTAL CONTAINERS	TYPE CONTAINER	DESCRIPTION	TOTAL WEIGHT	TOTAL CUBE
1		Dm 12x96x97 L-4-H	6,640	783

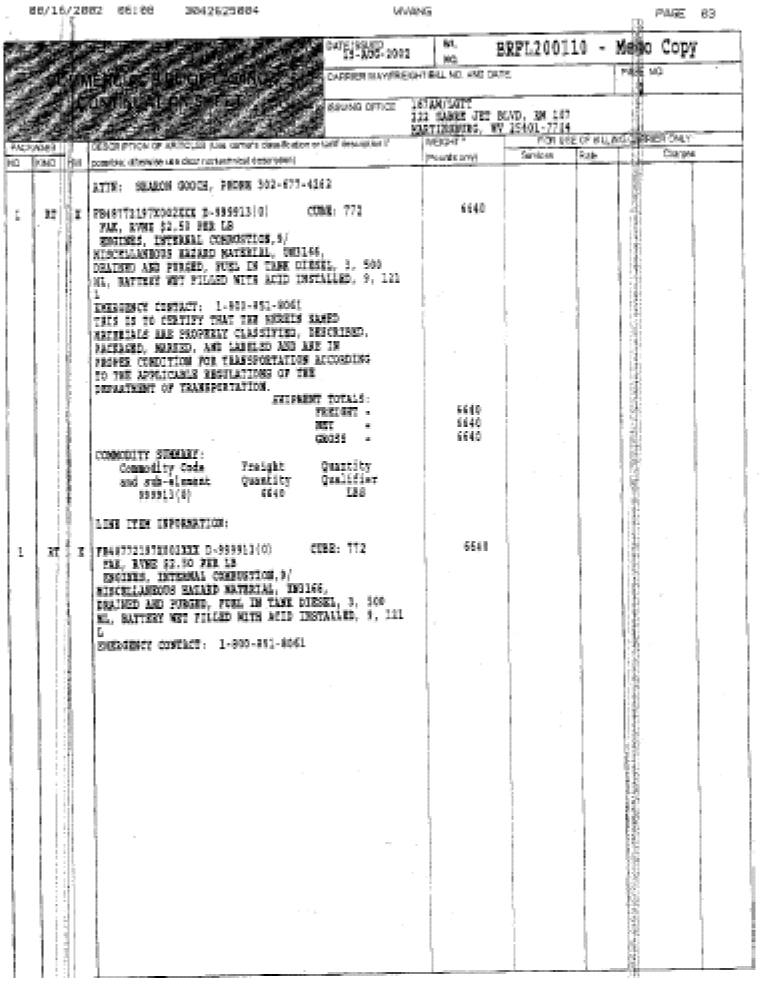
CHECKED BY RAB

PACKED BY 16 JUL 02

GRAND TOTAL $65,000.00

DD FORM 1149, APR 2000

PREVIOUS EDITION MAY BE USED.



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DATE ISSUED 13-AUG-2002

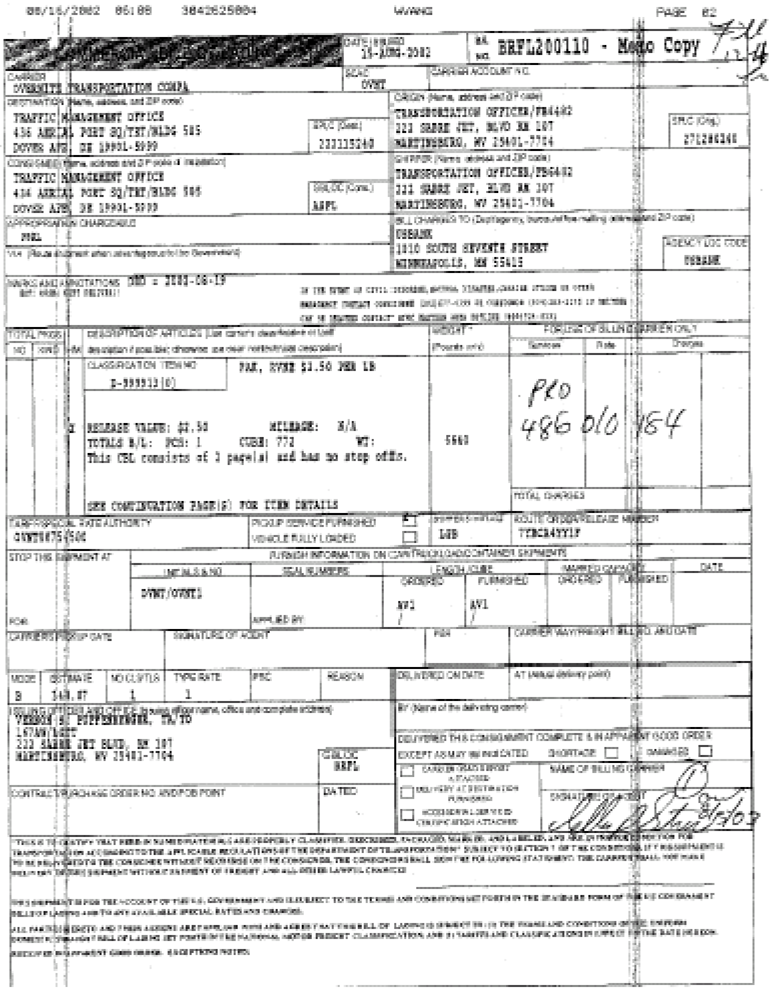
B/L NO. BRFL200110 - Memo Copy

CARRIER WAYBILL/FREIGHT BILL NO. AND DATE

PAGE NO. 3

ISSUING OFFICE
167AW/LGTT
222 SABRE JET BLVD, RM 107
MARTINSBURG, WV 25401-7704

PACKAGES NO	PACKAGES KIND	HM	DESCRIPTION OF ARTICLES (use carrier's classification or tariff description if possible, otherwise use a clear nontechnical description)	WEIGHT* (Pounds only)	FOR USE OF BILLING CARRIER ONLY Services	Rate	Charges
			ATTN: SHARON GOOCH, PHONE 302-677-4262				
1	RT	X	FB4877219TX002XXX D-999913(0) CUBE: 772 FAK, RYMS $2.50 PER LB ENGINES, INTERNAL COMBUSTION,9/ MISCELLANEOUS HAZARD MATERIAL, UN3166, DRAINED AND PURGED, FUEL IN TANK DIESEL, 3, 500 ML, BATTERY WET FILLED WITH ACID INSTALLED, 9, 121 L EMERGENCY CONTACT: 1-800-851-8061 THIS IS TO CERTIFY THAT THE HEREIN NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED, AND LABELED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO THE APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION.	6640			
			SHIPMENT TOTALS: FREIGHT = NET = GROSS =	 6640 6640 6640			
			COMMODITY SUMMARY: Commodity Code and sub-element: 999913(0) Freight Quantity: 6640 Quantity Qualifier: LBS				
			LINE ITEM INFORMATION:				
1	RT	X	FB4877219TX002XXX D-999913(0) CUBE: 772 FAK, RYMS $2.50 PER LB ENGINES, INTERNAL COMBUSTION,9/ MISCELLANEOUS HAZARD MATERIAL, UN3166, DRAINED AND PURGED, FUEL IN TANK DIESEL, 3, 500 ML, BATTERY WET FILLED WITH ACID INSTALLED, 9, 121 L EMERGENCY CONTACT: 1-800-851-8061	6640			



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DATE ISSUED 19-AUG-2002

B/L NO. BRFL200110 - Memo Copy

7-11-4

CARRIER
OVERNITE TRANSPORTATION COMPA

SCAC
OVNT

CARRIER ACCOUNT NO.

DESTINATION (Name, address, and ZIP code)
TRAFFIC MANAGEMENT OFFICE
436 AERIAL PORT SQ/TRT/BLDG 505
DOVER AFB, DE 19901-5909

SPLC (Dest.)
223115240

ORIGIN (Name, address and ZIP code)
TRANSPORTATION OFFICER/FB4482
222 SABRE JET, BLVD RM 107
MARTINSBURG, WV 25401-7704

SPLC (Orig.)
271286240

CONSIGNEE (Name, address and ZIP code of installation)
TRAFFIC MANAGEMENT OFFICE
436 AERIAL PORT SQ/TRT/BLDG 505
DOVER AFB, DE 19901-5909

GBL/OC (Cons.)
AAPL

SHIPPER (Name, address and ZIP code)
TRANSPORTATION OFFICER/FB4482
222 SABRE JET, BLVD RM 107
MARTINSBURG, WV 25401-7704

APPROPRIATION CHARGEABLE
FREL

BILL CHARGES TO (Dept/agency, bureau/office mailing address and ZIP code)
USBANK
1010 SOUTH SEVENTH STREET
MINNEAPOLIS, MN 55415

AGENCY LOC CODE
USBANK

VIA (Route shipment when advantageous to the Government)

MARKS AND ANNOTATIONS RDD : 2002-08-19

TOTAL PKGS NO	KIND	HM	DESCRIPTION OF ARTICLES (Use carrier's classification or tariff description if possible; otherwise use clear nontechnical description)	WEIGHT (Pounds only)	FOR USE OF BILLING CARRIER ONLY: Services	Rate	Charges
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		1	RELEASE VALUE: $2.50 MILEAGE: N/A TOTALS B/L: PCS: 1 CUBE: 772 WT: This CBL consists of 3 page(s) and has no stop offs.	5660			
			SEE CONTINUATION PAGE(S) FOR ITEM DETAILS		TOTAL CHARGES		

TARIFF/SPECIAL RATE AUTHORITY
OVNT0875/500

PICKUP SERVICE FURNISHED ☐
VEHICLE FULLY LOADED ☐

SHIPPER'S WEIGHT
LDB

ROUTE ORDER/RELEASE NUMBER
TYBCA4YY1F

STOP THIS SHIPMENT AT

FOR

FURNISH INFORMATION ON CAR/TRUCKLOAD/CONTAINER SHIPMENTS

INITIALS & NO	SEAL NUMBERS	LENGTH/CUBE ORDERED	LENGTH/CUBE FURNISHED	MARKED CAPACITY ORDERED	MARKED CAPACITY FURNISHED	DATE
OVNT/OVNT1	APPLIED BY	AV1	AV1			

CARRIER'S PICKUP DATE

SIGNATURE OF AGENT

PBN

CARRIER WAY/FREIGHT BILL NO. AND DATE

MODE	ESTIMATE	NO CUSTLS	TYPE RATE	PRC	REASON
B	348.87	1	1		

ISSUING OFFICER AND OFFICE (Issuing officer name, office and complete address)
VERNON S. PUFFENBERGER, TA/TO
167AW/LGRT
222 SABRE JET BLVD, RM 107
MARTINSBURG, WV 25401-7704

GBLOC
BRFL

CONTRACT/PURCHASE ORDER NO AND/OR FOB POINT

DATED

DELIVERED ON DATE

AT (Actual delivery point)

BY (Name of the delivering carrier)

DELIVERED THIS CONSIGNMENT COMPLETE & IN APPARENT GOOD ORDER EXCEPT AS MAY BE INDICATED SHORTAGE ☐ DAMAGED ☐

☐ CARRIER INSPECTION REPORT ATTACHED

☐ DELIVERY AT DESTINATION FURNISHED

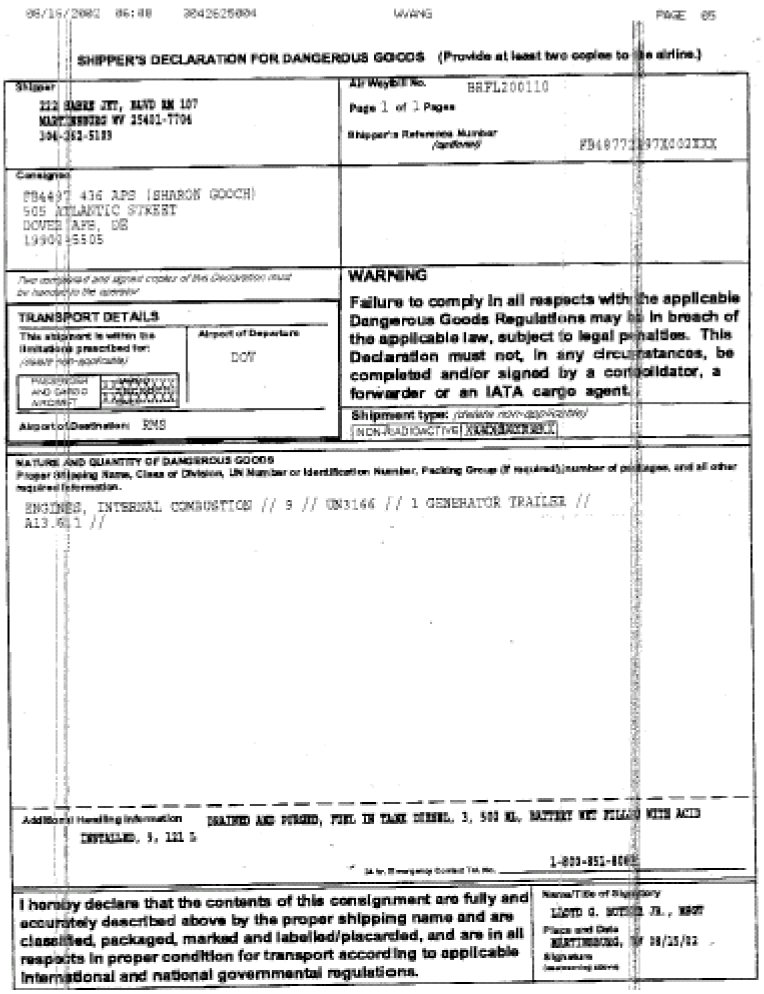
☐ ACCESSORIAL SERVICES CERTIFICATION ATTACHED

NAME OF BILLING CARRIER

SIGNATURE OF AGENT

8/7/03

RECEIVED IN APPARENT GOOD ORDER, EXCEPTING NOTED:



08/16/2002 06:48 3042625004 WVANG PAGE 05

SHIPPER'S DECLARATION FOR DANGEROUS GOODS (Provide at least two copies to the airline.)

Shipper

222 [illegible] JCT, BLVD RM 107
MARTINSBURG WV 25401-7704
304-262-5183

Air Waybill No. BRFL200110

Page 1 **of** 1 **Pages**

Shipper's Reference Number *(optional)* FB4077[illegible]97X002XXX

Consignee

FB4497 436 APS (SHARON GOOCH)
505 ATLANTIC STREET
DOVER AFB, DE
19902-5505

Two completed and signed copies of this Declaration must be handed to the operator

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: *(delete non-applicable)*

PASSENGER AND CARGO AIRCRAFT ~~CARGO AIRCRAFT ONLY~~

Airport of Departure: DOV

Airport of Destination: RMS

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

Shipment type: *(delete non-applicable)*

NON-RADIOACTIVE ~~RADIOACTIVE~~

NATURE AND QUANTITY OF DANGEROUS GOODS

Proper Shipping Name, Class or Division, UN Number or Identification Number, Packing Group (if required), number of packages, and all other required information.

ENGINES, INTERNAL COMBUSTION // 9 // UN3166 // 1 GENERATOR TRAILER //
A13.6L1 //

Additional Handling Information DRAINED AND PURGED, FUEL IN TANK DIESEL, 3, 500 ML, BATTERY WET FILLED WITH ACID INSTALLED, 3, 121 L

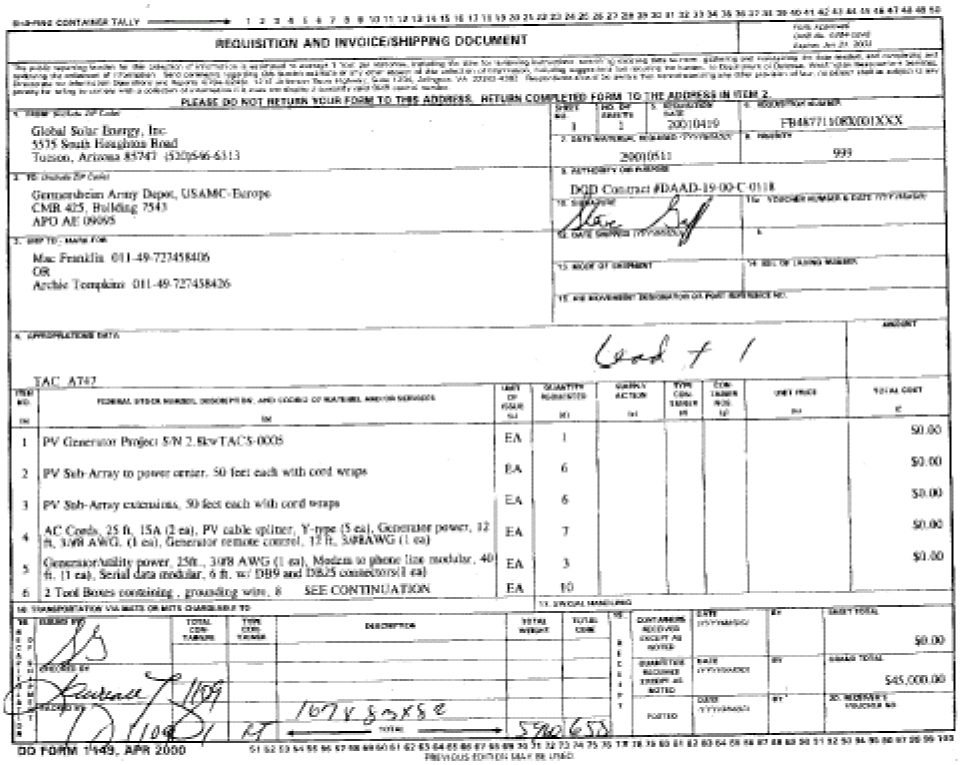
24 hr. Emergency Contact Tel. No. 1-800-851-8061

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations.

Name/Title of Signatory LLOYD G. BUTLER JR., MSGT

Place and Date MARTINSBURG, WV 08/15/02

Signature (see warning above)



SHIPPING CONTAINER TALLY 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

REQUISITION AND INVOICE/SHIPPING DOCUMENT

PLEASE DO NOT RETURN YOUR FORM TO THIS ADDRESS. RETURN COMPLETED FORM TO THE ADDRESS IN ITEM 2.

1. FROM:
Global Solar Energy, Inc
5575 South Houghton Road
Tucson, Arizona 85747 (520)546-6313

2. TO:
Germersheim Army Depot, USAMC-Europe
CMR 425, Building 7543
APO AE 09095

3. SHIP TO - MARK FOR
Mac Franklin 011-49-727458406
OR
Archie Tompkins 011-49-727458426

SHEET NO	1
NO. OF SHEETS	2
5. REQUISITION DATE	20010419
6. REQUISITION NUMBER	FB4877108X001XXX
7. DATE MATERIAL REQUIRED	20010511
8. PRIORITY	999
9. AUTHORITY OR PURPOSE	DOD Contract #DAAD-19-00-C-0118
10. SIGNATURE	Stan Goff

4. APPROPRIATIONS DATA
TAC AT47

Lead + 1

ITEM NO. (a)	FEDERAL STOCK NUMBER, DESCRIPTION, AND CODING OF MATERIEL AND/OR SERVICES (b)	UNIT OF ISSUE (c)	QUANTITY REQUESTED (d)	SUPPLY ACTION (e)	TYPE CONTAINER (f)	CONTAINER NOS. (g)	UNIT PRICE (h)	TOTAL COST (i)
1	PV Generator Project S/N 2.8kwTACS-0005	EA	1					$0.00
2	PV Sub-Array to power center. 50 feet each with cord wraps	EA	6					$0.00
3	PV Sub-Array extensions, 50 feet each with cord wraps	EA	6					$0.00
4	AC Cords, 25 ft, 15A (2 ea), PV cable splitter, Y-type (5 ea), Generator power, 12 ft, 3/08 AWG, (1 ea), Generator remote control, 12 ft, 5#8AWG (1 ea)	EA	7					$0.00
5	Generator/utility power, 25ft., 3/08 AWG (1 ea), Modem to phone line modular, 40 ft. (1 ea), Serial data modular, 6 ft. w/ DB9 and DB25 connectors(1 ea)	EA	3					$0.00
6	2 Tool Boxes containing , grounding wire, 8 SEE CONTINUATION	EA	10					

16. TRANSPORTATION VIA MATS OR MSTS CHARGEABLE TO

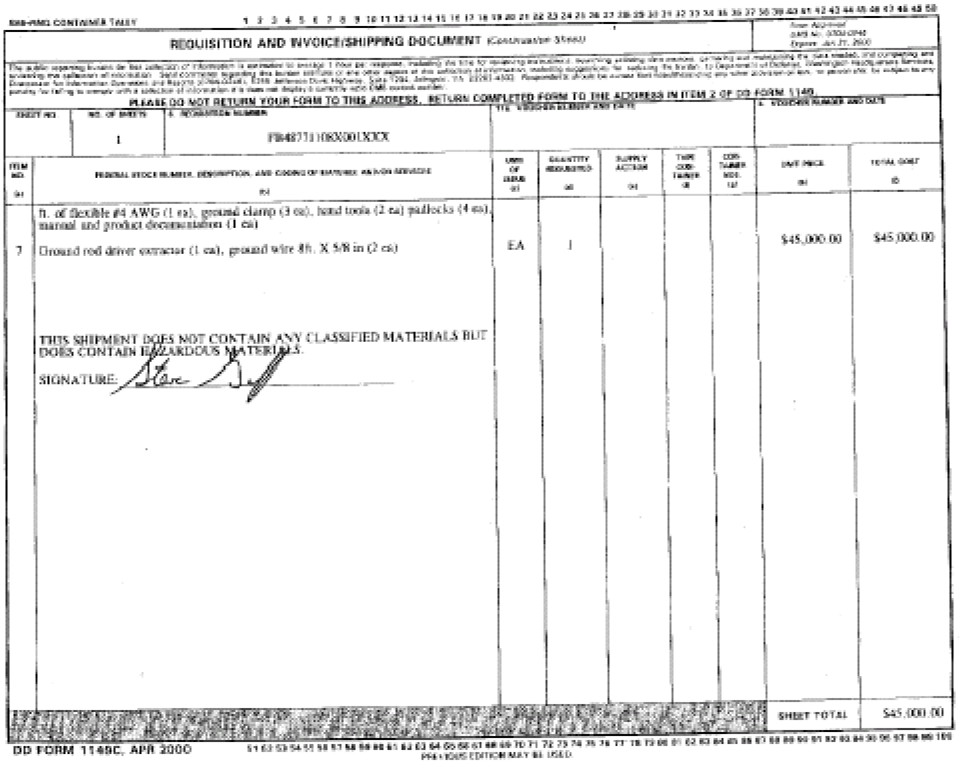
17. SPECIAL HANDLING

ISSUED BY SG
CHECKED BY Laurence 1109
PACKED BY 1109
RT 107 x 83 x 82 TOTAL 580 653

SHEET TOTAL $0.00
GRAND TOTAL $45,000.00

DD FORM 1149, APR 2000 PREVIOUS EDITION MAY BE USED.

FROM : THE DAVIS-MONTHAN AFB,AFB AZ FAX NO. : Apr. 26 2001 10:25AM P2



SHIPPING CONTAINER TALLY 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

REQUISITION AND INVOICE/SHIPPING DOCUMENT (Continuation Sheet)

PLEASE DO NOT RETURN YOUR FORM TO THIS ADDRESS. RETURN COMPLETED FORM TO THE ADDRESS IN ITEM 2 OF DD FORM 1149.

SHEET NO	
NO. OF SHEETS	1
3. REQUISITION NUMBER	FB4877108X001XXX

ITEM NO. (a)	FEDERAL STOCK NUMBER, DESCRIPTION, AND CODING OF MATERIEL AND/OR SERVICES (b)	UNIT OF ISSUE (c)	QUANTITY REQUESTED (d)	SUPPLY ACTION (e)	TYPE CONTAINER (f)	CONTAINER NOS. (g)	UNIT PRICE (h)	TOTAL COST (i)
	ft. of flexible #4 AWG (1 ea), ground clamp (3 ea), hand tools (2 ea) padlocks (4 ea), manual and product documentation (1 ea)							
7	Ground rod driver extractor (1 ea), ground wire 8ft. X 5/8 in (2 ea)	EA	1				$45,000.00	$45,000.00

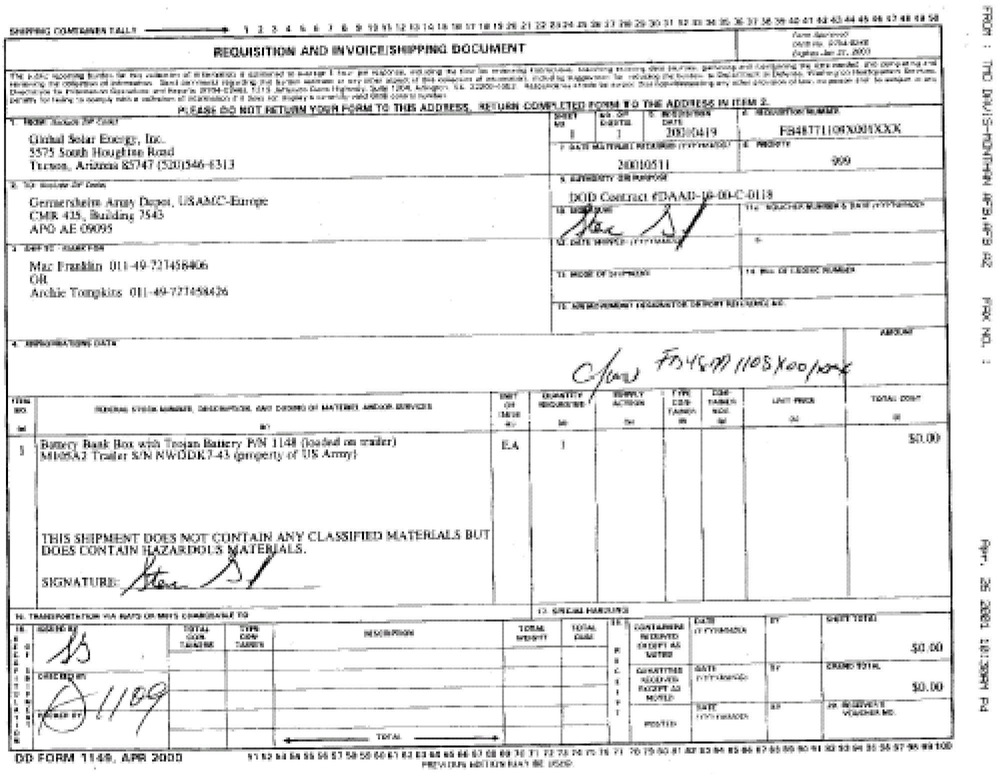
THIS SHIPMENT DOES NOT CONTAIN ANY CLASSIFIED MATERIALS BUT DOES CONTAIN HAZARDOUS MATERIALS.

SIGNATURE: Stan Goff

SHEET TOTAL $45,000.00

DD FORM 1149C, APR 2000 PREVIOUS EDITION MAY BE USED.

FROM : THE DAVIS-MONTHAN AFB,AFB AZ FAX NO. : Apr. 26 2001 10:38AM P3



FROM : TMD DAVIS-MONTHAN AFB,AFB AZ FAX NO. : Apr. 25 2001 10:30AM P4

SHIPPING CONTAINER TALLY → 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

REQUISITION AND INVOICE/SHIPPING DOCUMENT

Form Approved
OMB No. 0704-0246
Expires Jan 31, 2003

PLEASE DO NOT RETURN YOUR FORM TO THIS ADDRESS. RETURN COMPLETED FORM TO THE ADDRESS IN ITEM 2.

1. FROM (Include ZIP Code)

Global Solar Energy, Inc.
5575 South Houghton Road
Tucson, Arizona 85747 (520)546-6313

2. TO (Include ZIP Code)

Germersheim Army Depot, USAMC-Europe
CMR 435, Building 7543
APO AE 09095

3. SHIP TO - MARK FOR

Mac Franklin 011-49-727458406
OR
Archie Tompkins 011-49-727458426

SHEET NO. 1	NO. OF SHEETS 1	5. REQUISITION DATE 20010419	6. REQUISITION NUMBER FB48771109X001XXX
7. DATE MATERIEL REQUIRED (YYYYMMDD) 20010511			8. PRIORITY 999

9. AUTHORITY OR PURPOSE
DOD Contract #DAAD-10-00-C-0118

10. SIGNATURE

11a. VOUCHER NUMBER & DATE (YYYYMMDD)

12. DATE SHIPPED (YYYYMMDD)

13. MODE OF SHIPMENT

14. BILL OF LADING NUMBER

15. AIR MOVEMENT DESIGNATOR OR PORT REFERENCE NO.

4. APPROPRIATIONS DATA

C/[illegible] FB4877 1108X001XXX

AMOUNT

ITEM NO. (a)	FEDERAL STOCK NUMBER, DESCRIPTION, AND CODING OF MATERIEL AND/OR SERVICES (b)	UNIT OF ISSUE (c)	QUANTITY REQUESTED (d)	SUPPLY ACTION (e)	TYPE CONTAINER (f)	CONTAINER NOS. (g)	UNIT PRICE (h)	TOTAL COST (i)
1	Battery Bank Box with Trojan Battery P/N 1148 (loaded on trailer) M105A2 Trailer S/N NWDDK7-43 (property of US Army)	EA	1					$0.00
	THIS SHIPMENT DOES NOT CONTAIN ANY CLASSIFIED MATERIALS BUT DOES CONTAIN HAZARDOUS MATERIALS. SIGNATURE:							

16. TRANSPORTATION VIA MATS OR MSTS CHARGEABLE TO

17. SPECIAL HANDLING

18. RECAPITULATION OF SHIPMENT

ISSUED BY

CHECKED BY 1109

PACKED BY

TOTAL CONTAINERS | TYPE CONTAINER | DESCRIPTION | TOTAL WEIGHT | TOTAL CUBE

← TOTAL →

19. RECEIPT

CONTAINERS RECEIVED EXCEPT AS NOTED | DATE (YYYYMMDD) | BY

QUANTITIES RECEIVED EXCEPT AS NOTED | DATE (YYYYMMDD) | BY

POSTED | DATE (YYYYMMDD) | BY

SHEET TOTAL $0.00

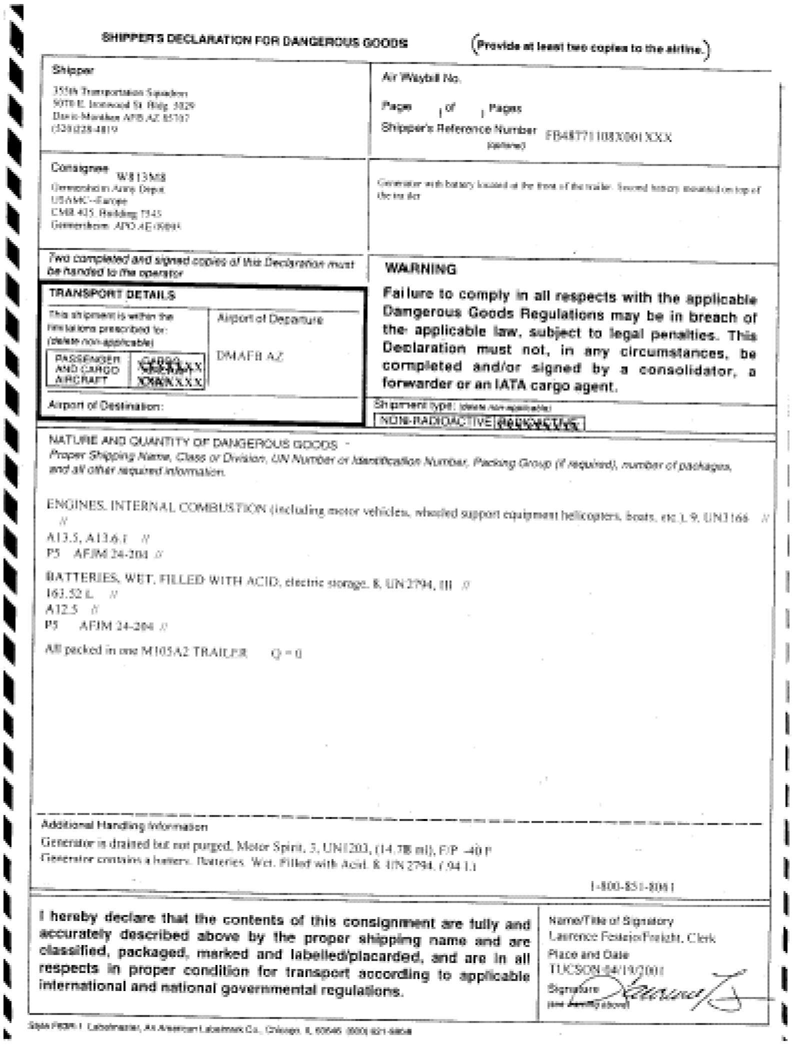
GRAND TOTAL $0.00

20. RECEIVER'S VOUCHER NO.

DD FORM 1149, APR 2000

51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

PREVIOUS EDITION MAY BE USED.



SHIPPER'S DECLARATION FOR DANGEROUS GOODS (Provide at least two copies to the airline.)

Shipper

355th Transportation Squadron
5070 E. Ironwood St. Bldg. 3029
Davis-Monthan AFB AZ 85707
(520)228-4819

Air Waybill No.

Page | of | Pages

Shipper's Reference Number (optional) FB48T71108X001XXX

Consignee W813M8

Germersheim Army Depot
USAMC--Europe
CMR 435, Building 7545
Germersheim, APO AE 09095

Generator with battery located at the front of the trailer. Second battery mounted on top of the trailer

Two completed and signed copies of this Declaration must be handed to the operator

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: (delete non-applicable)

PASSENGER AND CARGO AIRCRAFT	~~CARGO AIRCRAFT~~ XXXXXXX XXXXXXX

Airport of Departure DMAFB AZ

Airport of Destination:

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

Shipment type: (delete non-applicable)

NON-RADIOACTIVE	~~RADIOACTIVE~~ XXXXXXXXX

NATURE AND QUANTITY OF DANGEROUS GOODS

Proper Shipping Name, Class or Division, UN Number or Identification Number, Packing Group (if required), number of packages, and all other required information.

ENGINES, INTERNAL COMBUSTION (including motor vehicles, wheeled support equipment helicopters, boats, etc.), 9, UN3166 //
//
A13.5, A13.6.1 //
P5 AFJM 24-204 //

BATTERIES, WET, FILLED WITH ACID, electric storage, 8, UN 2794, III //
163.52 L //
A12.5 //
P5 AFJM 24-204 //

All packed in one M105A2 TRAILER Q = 0

Additional Handling Information

Generator is drained but not purged, Motor Spirit, 3, UN1203, (14.78 ml), F/P -40 F
Generator contains a battery. Batteries, Wet, Filled with Acid, 8, UN 2794, (.94 L)

1-800-851-8061

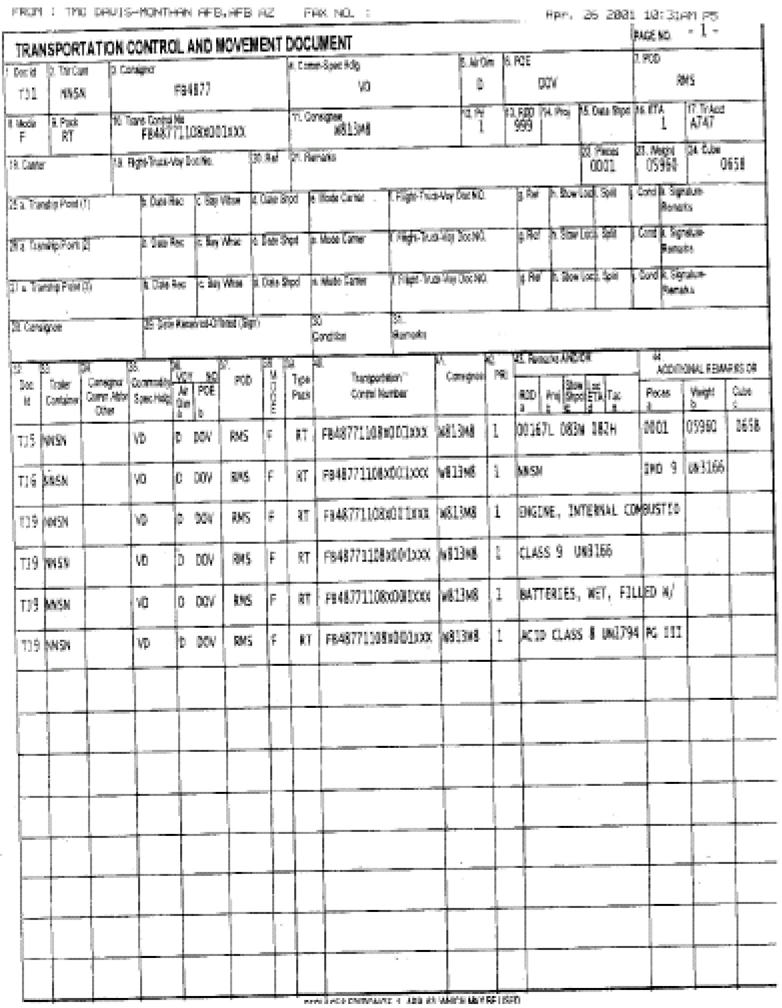
I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations.

Name/Title of Signatory
Laurence Festejo/Freight, Clerk

Place and Date
TUCSON 04/19/2001

Signature (see ~~warning~~ above)

Style FSDR-1 Labelmaster, An American Labelmark Co., Chicago, IL 60646 (800) 621-5808



FROM : TMO DAVIS-MONTHAN AFB,AFB AZ FAX NO. : Apr. 26 2001 10:31AM P5

PAGE NO. - 1 -

TRANSPORTATION CONTROL AND MOVEMENT DOCUMENT

1. Doc Id: TJ1
2. Trlr Cont: NNSN
3. Consignor: FB4877
4. Comm-Spec Hdlg: VD
5. Air Dim: D
6. POE: DOV
7. POD: RMS
8. Mode: F
9. Pack: RT
10. Trans Control No: FB48771108X001XXX
11. Consignee: W813M8
12. Pri: 1
13. RDD: 999
14. Proj:
15. Date Shpd:
16. ETA: 1
17. Tr Acct: A747
18. Carrier:
19. Flight-Truck-Voy Doc No.:
20. Ref:
21. Remarks:
22. Pieces: 0001
23. Weight: 05960
24. Cube: 0658

25 a. Transhp Point (1) | b. Date Rec | c. Bay Whse | d. Date Shpd | e. Mode Carrier | f. Flight-Truck-Voy Doc NO. | g. Ref | h. Stow Loc | i. Split | j. Cond | k. Signature-Remarks

26 a. Transhp Point (2) | b. Date Rec | c. Bay Whse | d. Date Shpd | e. Mode Carrier | f. Flight-Truck-Voy Doc NO. | g. Ref | h. Stow Loc | i. Split | j. Cond | k. Signature-Remarks

27 a. Transhp Point (3) | b. Date Rec | c. Bay Whse | d. Date Shpd | e. Mode Carrier | f. Flight-Truck-Voy Doc NO. | g. Ref | h. Stow Loc | i. Split | j. Cond | k. Signature-Remarks

28. Consignee | 29. Date Received-Ultimate (Sign) | 30. Condition | 31. Remarks

32. Doc Id	33. Trailer Container	34. Consignor Comm Abbr Other	35. Commodity Spec Hdlg	36. VOY NO a Air Dim	36. b POE	37. POD	38. MODE	39. Type Pack	40. Transportation Control Number	41. Consignee	42. PRI	43. Remarks AND/OR a ROD b Proj c Stow Shpd d Loc ETA e Tac	44. ADDITIONAL REMARKS OR a Pieces	b Weight	c Cube
TJ5	NNSN		VD	D	DOV	RMS	F	RT	FB48771108X001XXX	W813M8	1	00167L 083N 082H	0001	05960	0658
TJ6	NNSN		VD	D	DOV	RMS	F	RT	FB48771108X001XXX	W813M8	1	NNSN	IMD 9	UN3166	
TJ9	NNSN		VD	D	DOV	RMS	F	RT	FB48771108X001XXX	W813M8	1	ENGINE, INTERNAL COMBUSTIO			
TJ9	NNSN		VD	D	DOV	RMS	F	RT	FB48771108X001XXX	W813M8	1	CLASS 9 UN3166			
TJ9	NNSN		VD	D	DOV	RMS	F	RT	FB48771108X001XXX	W813M8	1	BATTERIES, WET, FILLED W/			
TJ9	NNSN		VD	D	DOV	RMS	F	RT	FB48771108X001XXX	W813M8	1	ACID CLASS 8 UN1794	PG III		

[illegible] 1 APR 83 WHICH MAY BE USED

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