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RENEWABLE ENERGY ANALYSIS FOR STRATEGIC RESPONSIVENESS 3

(REASR 3)

June 2005

UNITED STATES ARMY
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13. ABSTRACT *(Maximum 200 Words)*

Army installations require electric power to perform the missions assigned to them whether or not the power is used at the main post or at remote locations at the installation. Providing electric power to the main post is accomplished through the local electric company. However, for remote locations the usual source of electric power is diesel generated 1.5 kW to 200 kW power – from generators using diesel fuel as the fuel stock. This report details the missions that different kinds of Army installations have to support in remote locations along with their associated electric peak power requirements. Installation energy managers at five different locations participated in a power and energy survey designed to examine alternative power source options to current and emerging mission demands. A cost-benefit analysis provided the economic underpinning to evaluate the best of four power source alternatives and to examine cost drivers.

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RENEWABLE ENERGY ANALYSIS FOR STRATEGIC RESPONSIVENESS 3

(REASR 3)

SUMMARY

THE PROJECT PURPOSE was to survey the need for remote mission power.
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THE PROJECT SPONSOR was the Assistant Chief of Staff for Installation Management.

THE PROJECT OBJECTIVES were to:

(1) Conduct cost - benefit analyses of power alternatives in remote applications
(2) Analyze alternative power sources (to the status quo)
(3) Analyze air pollution emissions from selected power source alternatives

THE SCOPE OF THE PROJECT was to develop 3 economic case studies (one for each surveyed installation) for peak power source alternatives of 10kW, 40kW and 150kW given a 20 year timeframe: FY 2005 - 2025

THE MAIN ASSUMPTIONS were:

(1) Assume three levels of notional, operational runtime hours for each Case Study:
- 500 operational hours (suggested by EPA)
- 1600 operational hours (training OPTEMPO)
- 5840 operational hours (per year maximum)

(2) No privatization of remote mission grid connected capital investment
(3) Use peak power ratings of status quo power generation sources for purposes of life-cycle costing.

THE PRINCIPAL FINDINGS are**:**

(1) Solar-Hybrid power source options for remote power generation can be economically viable given the right conditions. These conditions include but are not limited to:
- Good natural resource
- Remote location
- Well defined peak power profile
- Installations open to alternative power source alternatives to include renewable energy

(2) Surveyed information illustrates over 3,000 remote location missions requiring electric power
(3) Each analysis for remote power station alternatives must be evaluated on a case-by-case basis (i.e. no "rule-of-thumb" exists that generalizes a specific solution set)

(4) Pollution emissions from small, back-up fossil-fueled generators are mitigated somewhat by being used less frequently than larger, fossil fueled prime power generation.

THE PROJECT EFFORT was conducted by Mr. Hugh W. Jones, Center for Army Analysis, Resource Analysis Division.

COMMENTS AND QUESTIONS may be sent to the Director, Center for Army Analysis, ATTN: CSCA- RA, 6001 Goethals Road, Suite 102, Fort Belvoir, VA 22060-5230

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This report was requested by the Assistant Chief of Staff for Installation Management (ACSIM), Facilities and Housing Directorate to examine renewable energy alternatives to fossil fuel generators currently used at Army installations. The original ACSIM sponsor, Mr. Satish Sharma (see CAA form 233 at appendix) retired in October 2004 during the finalization of this effort. Mr. Don Juhasz replaced Mr. Sharma in February 2005 and was briefed on this effort during that same month.

This effort also analyzes the cost benefit between grid-electric and hybrid-electric renewables for a remote mission applications at Ft. Irwin, California, Yuma Proving Ground, Arizona and the White Sands Missile Range, New Mexico. This report also documents the life-cycle pollution abatement achieved for each of these three case studies.

The analysis contained within this report was performed by the author, Mr. Hugh Jones. However, the author would like to recognize the insights, experiences and general contributions of Dr. Charles Leake; friend and co-worker in whose memory this report is dedicated.

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Problem Statement

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Problem Statement. To conduct case study, cost-benefit analyses of power alternatives for installation energy missions in remote areas.

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Army installations require electric power to perform the missions assigned to them whether or not the power is used at the main post or at remote locations at the installation. Providing electric power to the main post is accomplished through the local electric company and either overhead or underground power lines.

However, for remote locations the usual source of electric power is diesel generated 1.5 kW to 200 kW power – from generators using diesel fuel as the fuel stock. To be sure, other sources of power exist such as generators using propane as the fuel stock or even gasoline powered generators. Some installations such as Yakima Training Center (Washington State) and the Pohakoloa Training Center (Hawaii) utilize photovoltaic energy with back-up diesel generators as an alternative power source. But diesel generation represents significant – if not the majority of remote power used at Army installations. This finding comes from surveys and conversations with Department of Army energy managers at Ft. Lewis, Yakima, Fort Irwin, Yuma Proving Ground, White Sands Missile Range and other installations.

For example, White Sands Missile Range (New Mexico) maintains a fleet of 600 diesel generators of which 25% are at fixed remote sites, 25% are skid mounted at remote sites and 50% are trailer mounted for use at remote sites.

Background

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The need for clean, competitively priced electric power at remote facilities on installations such as Yuma Proving Ground, Fort Irwin, White Sands Missile Range, Yakima Training Center and Pohakoloa Training Center continues to grow as new ranges are added, new missions are undertaken and state and local pollution standards tighten.

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Operation Enduring Freedom and Operation Iraqi Freedom have underscored the need for continued soldier training in a variety of environments to include built-up areas like those found in Fallujah, Iraq. Indeed CONUS based army installations are investing in new training facilities which provide training in built-up areas called Military Operations on Urban Terrain (MOUT).

As new ranges are proposed and built, each host installation must consider a number of important issues which include:

range safety

required land area

range location

environmental impact statements

pollution abatement and power options

Although all of these criteria for new ranges are important, this paper will focus on the last two criteria; pollution abatement and power options. Today's installations must comply with federal Environmental Protection Agency pollution standards but more importantly with state and local environmental pollution restrictions – which are usually more stringent than Federally mandated clean air standards. (note: noise, dust, water and ground pollution are also important factors but this paper's focus is on air pollution). Power options are those employed where no grid power is available and usually include renewable sources such as photovoltaic, wind, geothermal and hydroelectric power for these remote ranges. This analysis will explore the costs associated with employing renewables versus more conventional power sources such as grid power and fossil fuel engines.

The study sponsor was interested in exploring remote site missions at a number of Army installations to determine the need for remote power. Three of these installations (1) Ft. Irwin, California, (2) White Sands Missile Range (WSMR), New Mexico, and (3) Yuma Proving Ground, Arizona were selected by the sponsor as case study locations.

The objective of this report is to conduct a cost-benefit analyses of power alternatives looking at renewable power and energy as compared with grid power or portable power from fossil-fuel sources depending on the scenario.

Activities Since Last Analysis Review Board

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- Developed and distributed survey to help better understand installation remote power challenges and issues:
  - CONUS installations (White Sands Missile Range, Ft. Irwin, Yuma Proving Ground, Yakima Training Center, Pohakoloa Training Center)
- ACSIM surveys covered missions, power demand, power types, power quality, power mobility, power flexibility, power maintainability, power reliability, environmental impact, reuse, and other emerging issues
- Analyzed September 2004 DoD Installation Solar Energy spreadsheet as part of the Report to Congress on Renewable Energy
- Reviewed July 2004 USMA report entitled “Army Hybrid Power Systems”
- Continue to provide “on-call” renewable energy analysis to OEF and OIF (212th MASH of the 30th MED BDE , 173rd SETAF (18th Engineer BN))

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Army installations and deployed forces have brought into focus the need for a review of power and energy alternatives in a cost-benefit setting. The Assistant Chief of Staff for Installation Management intends to use this report as analytical underpinning for strategic decision making as regards power and energy for remote mission sites.

Operation Iraqi Freedom and the battle for Fallujah pointed to in increased need to train American soldiers in built-up areas. As a result, several MOUT troop training centers have been built or are in the planning stages to be built in remote site areas at Fort Irwin, Yakima Training Center, and Fort Lewis.

Alternative energy sources for deployed forces are also being investigated on many fronts. Although the focus of this paper is on installation remote energy needs at CONUS installations, parallels may be made to Operation Iraqi Freedom (OIF) and Operation

Enduring Freedom (OEF) needs for remote power at Forward Operating Bases (FOBs) as well. 7th Army and USAREUR are investigating photovoltaic energy from deployable trailer 10kW power stations while 173rd SETAF engineers are analyzing photovoltaics and wind energies for remote outposts in Afghanistan. This interest is a carry-over from the fact that transported fuel costs are expensive and a dangerous operation while being convoyed. (See Defense Science Board; July 2003 white paper entitled "The True Cost of Fuel to the Battlefield")

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Essential Elements of Analysis

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1. What are the peak power requirements for the mission(s) at the studied remote locations? Best power alternatives?
2. What are the costs to provide electric power to the remote facilities in the 3 case studies?
3. What are the benefits of each system to the installation?
4. What is the cost/benefit for the two top remote power alternatives?
5. How will the "best" system(s) affect environmental stewardship?

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These are the essential elements of analysis. These questions form the basis of our search for the best systems that are cost effective and environmentally friendly from the three case studies that we will examine: (1) Yuma Proving Ground, (2) Ft. Irwin, and (3) White Sands Missile Range. These are three of many potential remote power cases studies that could be studied from over 70 army installations located in CONUS plus Alaska and Hawaii. These same questions could be posed for each of the deployed force locations in OEF and OIF as well.

Approach

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- Survey FORSCOM, TRADOC, ATEC installations to
  - determine a list of installation <u>missions</u> conducted in remote post areas which require electricity
  - determine feasible **<u>alternative power sources</u>**
- Conduct ACSIM survey to understand installation "point-of-view" as to remote power needs
- Analyze surveys to obtain best power alternatives
- *Develop 3 Case Studies* cost and benefit analysis
- Analyze air pollution emissions from best power alternatives
- Include all surveys and survey notes in final report

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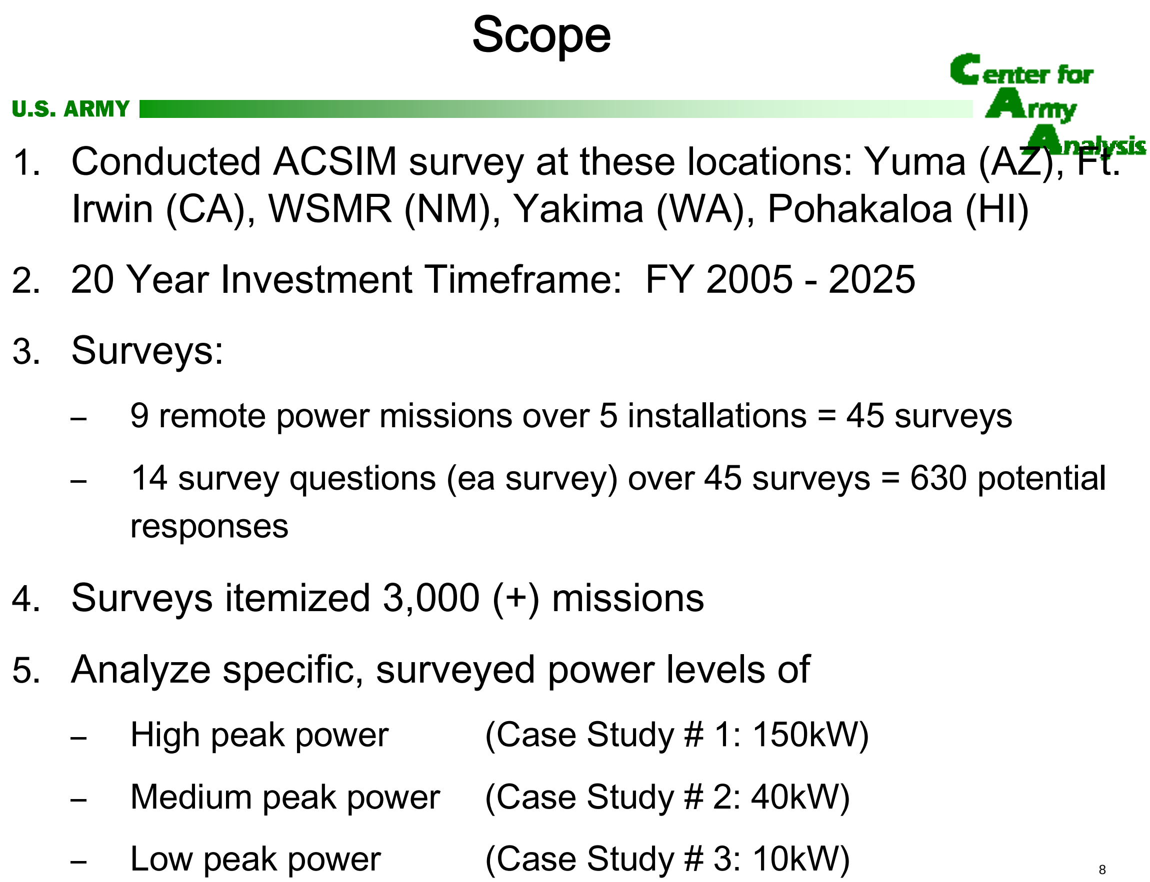
Every Army installation has certain missions that are important yet different from missions at other installations. Some installations are for troop training and billeting while others are for weapon testing. Some installations are marshalling centers in preparation for troop deployment while others are headquarters. Some installations are research installations while others are arsenals. Each of these types of installations may be categorized as force installations (FORSCOM), training installations (TRADOC) or test and evaluation installations (ATEC). Likewise, each has certain missions that are performed on post but at remote locations – away from access to the power grid.

The analytical approach used to capture these remote post missions at each of the case study installations was to first develop a survey – in concert with the sponsor – and to provide these surveys to the case study installations. This process was administered and completed during the summer and fall of 2004.

Each installation energy manager was contacted and participated in the survey process. These individuals were Mr. Jack Nixon at Yuma Proving Ground (YPG), Mr. Rene Quinones at the National Training Center (NTC) and Mr. Julian Delgado at the White Sands Missile Range (WSMR). They provided insights into environmental, power and energy and other scoping issues that helped in the surveying process.



Although a number of different surveys were taken, only 3 are illustrated in this work as supporting the case study analyses at YPG, NTC and WSMR. The 3 missions chosen by the sponsor to evaluate were (1) communications, (2) test and instrumentation and (3) military operations on urban terrain. These 3 missions were not prioritized, but were rated by the installations as having peak power requirements of 10kW for communications, 40kW for test and instrumentation and 150kW for MOUT facilities respectively.

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Assumptions

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- Assume three levels of notional, operational runtime hours for each Case Study:
  - 500* operational hours (suggested by EPA)
  - 1600* operational hours (training OPTEMPO)
  - 5840* operational hours (per year maximum)
- No privatization of remote mission grid connected capital investment
- Used peak power ratings of status quo power generation sources for purposes of life-cycle costing.

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* power required 16 of 24 hours per day; 0700 - 2300

Because there were no records of current (status quo) power profiles, this study assumed 3 different sets of operational hours, chosen so as to bookcase low case, medium case and high case usage. EPA requires minimum operational hours for all generators – regardless of usage profiles. Medium operational levels were chosen because of typical army unit training cycle hours. High end operational hours were scaled to incorporate maximum known usage as suggested by energy managers at the case study installations. Privatization is occurring at many army facilities nationwide and although this method of upgrading installation facilities is being used for main post and cantonment areas, it is not being used for remote post missions.

Limitation

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- ❑ No power profile data exists for the studied missions (i.e. kW over time).

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As previously stated, no power profiles existed for the case study missions of communication, test and instrumentation and MOUT. This is primarily the reason why EPA requires a minimum emission calculation from an installation's fleet of fossil-fueled generators to include a power profile that includes at least 500 operational hours per year.

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Methodology

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1. Analyze feedback from Army remote power surveys by analyzing the numerical ranking to surveyed responses.
2. Determine surveyed peak power levels for status quo remote missions
3. Determine best power alternative to status quo by calculating highest scored response by power category to determine best ranked power alternatives
4. Calculate estimated kilowatt hours for each of the 3 notional operational hours; 500, 1600, 5840.
5. Utilize Department of Army Economic Analysis standards (DASA(CE)) for economic analysis
6. Employ the Army Environmental Center's (RDECOM) spreadsheet analysis tool to compute pollution emissions for nitrogen dioxides (NO_2), sulfur dioxides (SO_2), particulate matter (PM), volatile organic compounds (VOC), and carbon monoxide (CO).

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Once the survey was developed, exercised and returned for analysis a numerical ranking was provided, from best to worst based on the survey's ranking criteria: 1-3 (negative ranking); 4-6 (neutral ranking) and 8-10 (positive ranking). The ranking occurred over 4 different categories that had the potential to provide enough power for the missions; communication, test and instrumentation and MOUT.

The installation energy managers coordinated the final survey responses from their respective facilities. Sometimes, the energy manager provided all the primary responses. Other times, the installations preferred to use their respective staffs to provided feedback that the energy managers themselves compiled and edited. Regardless, each survey contained one and only one response to the surveyed questions. No one knew better than the energy manager or their installation staff as to the peak power level required of remote post missions. Therefore the surveys contained information provided by the installations outlining which power sources were capable of providing the peak power and which power sources were not capable of providing peak power.

The power sources were divided into four categories of power: (1) hard-stand photovoltaics with generator back-up, (2) mobile photovoltaics with generator back-up, (3) grid-tied power and (4) remote pad site fossil-fuel generator.

Once the survey responses were tallied, it then became obvious which of the two (of the four) potential power sources would be compared within the cost-benefit framework using 500, 1600 and 5840 hours of operation to gather usage statistics (e.g. fuel consumption, solar panel sizing, generator maintenance, etc.) These statistics were used as inputs into DASA(CE)'s model for computing the required economic parameters for the cost benefit analysis.

Finally, the US Army Research and Development Command's spreadsheet analysis tool was employed to calculate projected emissions for the two power source candidates.

Methodology Task 1: Analyze Survey Feedback

Survey Questions for Installation Remote Power
(by mission; 1 = no, through 10 = yes)

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Benefits (unranked)

1. Delivery of Required Power. Do we receive the necessary power when we need it?
2. Power Quality. Is the power conditioned properly for the mission?
3. Impact on Mission. Does the power source supply the required power?
4. Mobility. Is the ability to move the power source to another site important?
5. Flexibility. Can the power source be used for multiple missions or tasks?
6. Supportability. Is the power system adequately supported so that it's always operational?
7. Maintainability. Is the power system adequately maintained so that it's always operational?
8. Reliability. Is the power system reliable enough so that it's always operational?
9. Environmental Impact. Does the power system meet or exceed local, state and federal environmental requirements?

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Each perceived benefit by the installation was graded by the installation. There were 14 questions each of which were scored by the installations for each of 4 previously discussed power source categories. No one knows better than the installation energy managers themselves the pros and cons of certain power source capabilities to meet various remote mission need. From this graded list of perceived critical power source questions would come the ranked list (1 through 4) of the two best power source alternatives which would then be subjected to the economic analysis.

Delivery of required power talks to the availability of the power to be delivered, in a timely manner to the mission. Sometimes mechanical failures of fossil-fuel generators prevent the required power for the mission while some photovoltaic systems may be underpowered for others. This is why the first question "Do we receive the necessary power when we need it?" is important for the case study missions of (1) communication, (2) test and instrumentation and (3) MOUT. For if the requisite power would not be enough from any of the four power sources, then no economic analysis would need to be done as none of the power source candidates would not be viable. However, during the analysis of the case studies, this was not the case. There were always two or more viable candidates obtained from the ranking of the survey questions.

Methodology Task 1: Survey Feedback (cont'd)

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10. Reuse at Other Sites. If a mission change were to occur, can the power sources now in place be easily moved to support a mission at another site?
11. Emerging Benefits. Are there any new power challenges that another remote power source could better meet over the status quo or those evaluated here?
12. Emerging Issues or Challenges. Are there any issues or challenges not envisioned within this questionnaire that our DPW or installation has specific knowledge of that would prohibit or limit the effectiveness or operation of any named alternative power system?
13. Tertiary Issues. Are there any other issues not addressed in this survey that should be considered?
14. Remote Power Assets and Power. Provide by type and number the peak remote demand (by mission) in kW, the number of generators that supply this demand (by LIN or other identifier) and the energy supply in kWh available (or any other power sources)

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The survey questions as posed to the energy managers were well understood by each of the installations. Extreme care was taken by the survey providers to insure that equal understanding of the survey questions was with each of the survey respondents. To accomplish this, significant time was taken by the survey providers to answer questions by installation personnel, to talk with energy managers about realistic COTs power solutions, potential impact of the survey and other issues. This does not mean however, that installations could not answer the questions with pertinent responses due their localities.

For example, the responses provided to the survey question number 12: "Emerging Issues or Challenges. Are there any issues or challenges not envisioned within this questionnaire that our DPW or installation has specific knowledge of that would prohibit or limit the effectiveness or operation of any named alternative power system?" Some installations answered this question as biased by any of the following "boots-on-the-ground" understanding of the local situations:

o Some installations had to deal with local Indian neighbors whose reservation bordered on the army installation in question. No power source in remote areas could be considered without communicating this to local tribal leaders.

o Installations within states having strict emissions limits on remote power source generation (more strict than EPA standards) answered survey questions with a different intent than did other surveyed installations.

o Some installations shared common borders with sister services. There is significant interest for a sharing of remote power between Army, Navy, Marine Corps and other government entities sharing common borders and potentially a cost sharing as well.

Methodology Task 2: Determine Peak Power Levels

Identify Installation Remote Missions by # of msns & power levels

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Installation Remote Mission Categories (provided by 5 Army installations)	# of msns	Power Range
1. range / installation safety	120	100w – 10kW
2. communication	70	3 – 10kW
3. test and instrumentation	300	5 – 40kW
4. weather monitoring stations	210	3 – 10kW
5. environmental monitoring	420	3 – 10kW
6. water pumping	85	1 – 5kW
7. target operations and control	2200	100w – 100kW
8. military operations on urban terrain (MOUT)	30	60kW – 150kW
9. security	95	100w – 10kW
Total Number of Missions over 9 Categories	**3,530**	

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Color key: Shaded area represents 3 "Case Studies" chosen to examine different power levels

Five of eighty army installations registered a grand total of 3,530 missions for remote power. This is the first comprehensive look undertaken by the army to better understand its missions and how they relate to other installations and the peak power requirements. The chart above illustrates the chosen missions for the 3 case studies (in yellow hi-lite) undertaken by this analysis. Communication, test and instrumentation and MOUT missions were not the most prolific numbers of missions out there, nor were they common to all three army installations. For example, NTC is developing the MOUT facilities but YPG and WSMR are not. On the other hand, all three installations had similar experiences with remote power for both communication and test and instrumentation.

The bottom line here is the peak power as seen from the “Power Range” column as being a maximum 10kW for the communication missions, 40kW for the test and instrumentation mission and 150kW for the MOUT mission. These maximum power requirements would have significant impacts on the economics because larger power requirements are more expensive in terms of ground footprint and requisite equipment.

Methodology Task 3 : Determine Best Power Alternatives

List Power Alternatives from Surveys

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	Power Alternatives:	Negative	Positive
 1	120kW photovoltaic platform (30kW diesel generator and battery bank not in photo)	High capital cost ($7 / watt installed) Dependent on sun & wind Night use may require deep-cycle batteries	Low fuel use Low maintenance Low emissions High efficiency Non interruptible power
 2	10kW mobile photovoltaic, wind, & fossil fuel generator with 30 kWh battery bank. (photovoltaic array – not shown in photo - is 30'x30')	High capital cost ($10 / watt installed) Dependent on sun & wind Night use requires deep-cycle batteries Cost for trailer	Low fuel use Low maintenance Low emissions Mobile power High efficiency Non interruptible power
 3	Power from the electric grid (cost per kWh varies widely depending on location)	High usage cost ($.12 - .20 / kwh) Market price fluctuations Complex user fees High installation costs Not mobile Power interruptibility	Low fuel use Moderate maintenance Low to moderate emissions Power quality
 4	10kW-40kW diesel fuel generator with fuel tank (also mobile application)	High fuel use Low efficiency High maintenance High emissions Fuel delivery costs Power interruptibility	Sized generator for mission 1/5 the cost of PV No batteries Mobile power

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These are the four power source categories. Positives and negatives of each source are discussed above. All of the case study installations have at least some experience in all of the power sources seen here, but some have more experience and more equipment than others.

The completed surveys, when the responses were tallied pointed to two of these potential power sources. These two finalists were then adjudicated by an economic analysis looking at a 20 year life-cycle window.

Methodology Task 4 : Calculate Estimated kilowatt hours (kWh)

Calculate annual, notional estimates of kilowatt hours for each mission

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Case Study	Mission \ Annual Op Hours	500 hrs	1600 hrs	5840 hrs
1.	Village MOUT (150kW)	75,000	240,000	876,000
2.	Test & Instrument (40kW)	20,000	64,000	233,600
3.	Communication (10kW)	5,000	16,000	58,400

key: Shaded area is kWh per year

Cost of Electricity ($ / kWh) from the Power Grid =

(Capital & Installation Costs) + (Operations & Maintenance Costs) + Line Charges

Cost of grid electricity by location (FY 05 annualized with demand charges included)

Location	Pohakoloa	Ft. Irwin	White Sands MR	Yuma Proving Ground	Yakima Trng Ctr
$ / kWh	$.148	$.145	$.104	$.079	$.055 [16]

In order to compare costs, a good understanding of the kWh involved is important. Recall that because no power profile existed for any of the status quo power sources, an estimated usage matrix had to be built. The yearly values of 500 hours, 1600 hours and 5840 hours were previously addressed as low, medium and high range parameters. Calculating the kWh required to meet the power demands of 10kW, 40kW and 150kW is calculated and shown in the above matrix.

Although Ft. Irwin, White Sands Missile Range and Yuma Proving Ground are the case studies chosen for this study, it is interesting to note other costs for grid power such as Pohakoloa, Hawaii and Yakima Training Center in Washington (state). Note that the highest costs for electric power exist in California and Hawaii while the lowest is at Yakima, WA. The high costs for electricity in southern California will have a negative impact on the cost-benefit analysis for remote grid-tied power for the MOUT facility at Ft. Irwin and will favor remote, renewable energy alternatives. Conversely, the cheap cost of electricity at Yakima (primarily due to the economical cost of hydroelectric power from Grand Coulee and 18 other dams on the Columbia River basin) would make Yakima an ideal place for a MOUT facility using grid power.

Methodology Tasks 5 & 6 : Cost-Benefit Analysis

Measures of Effectiveness (MOE)

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1. Life Cycle Costs; discounted *net present value* (in constant $) of cost avoidance (answers EEA # 2, 4)

2. Savings to Investment Ratio; *present value* of cost savings over the lifetime of the project divided by the *present value* of investments minus the *present value* of investment terminal value, if any. (answers EEA # 4)

3. Installation Operational Benefits (to installation)
   - Survey responses (survey feedback answers EEA # 1, 3)
   - energy saved (tons) (answers EEA # 3)
   - pollution prevention (lbs) (answers EEA # 5)

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The cost benefit analysis will answer the Essential Elements of Analysis (EEA) in terms of these economic outcomes: Total life cycle costs as discounted net present value (NPV), savings to investment ratios and installation operational benefits to each studied installation.

Cost Benefit Case Studies

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1. **Ft. Irwin; Village MOUT** (~ 42 target buildings, 1 control bldg)
   (High Peak Power Case; 150kW)
   a. Notional operational hours; 500, 1600, 5840
   b. Status Quo; (none, but Ft. Irwin survey selected grid and hybrid photovoltaics power generation as best alternatives)
   c. Power used for fluorescent lighting, cameras, sound equipment, digital equipment, target control, meeting room, and small a/c (for computers)

2. **White Sands Missile Range; Instrumentation Site**
   (Medium Peak Power Case; 40kW)
   a. Notional operational hours; 500, 1600, 5840
   b. Status Quo; 40kW fossil-fueled, diesel generator
   c. Power used for single-site data collection, test monitoring, communications

3. **Yuma Proving Ground; Communication Retransmission Site**
   (Low Peak Power Case; 10kW)
   a. Notional operational hours; 500, 1600, 5840
   b. Status Quo; 10kW fossil-fueled, diesel generator
   c. Power used for communications retransmission

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Case study information that forms the basis for comparative analysis is shown here. Ft. Irwin will be evaluated for two competing remote power solutions obtained from the power survey. Both solutions will be evaluated against 500, 1600 and 5840 operational hours of use. The peak power for each mission is well defined and well understood by the installation energy mangers.

For example, the MOUT training facility at Ft. Irwin requires enough power for fluorescent lighting, cameras, sound equipment, digital equipment, target control, meeting room and a small a/c for computers. Energy managers computed this total as requiring a peak power of 150kW – but steady state power requirement is much less. (In lay terms, this means that for the person making a pot of coffee in a 15 amp coffee pot, for the first three minutes when water is being boiled the peak power of 15 amps is required, however once the coffee is made, the steady state power to keep the coffee hot is reduced to 3 amps. This analogy is true for computers, air compressors and many other electrical devices needing an initial peak power to function properly.)

Ft. Irwin Case Study; Village MOUT Survey

Evaluate Ft. Irwin survey for "MOUT village mission" best alternatives

U.S. ARMY

Center for Army Analysis

Case Study # 1

4 Categories of Power Generation

Benefits	Category 1 PV & GENSET	Category 2 Mobile Renew	Category 3 Grid Tied	Category 4 GENSET
Approximate kW Rating	150kW	150kW	150kW	150kW
1. Delivery of Required Power	10	1	10	9
2. Power quality	10	n/a	10	10
3. Impact on Mission	10	n/a	5	4
4. Mobility	5	n/a	1	7
5. Flexibility	2	n/a	1	4
6. Supportability	10	n/a	6	4
7. Maintainability	10	n/a	5	2
8. Reliability	9	n/a	5	4
9. Environmental Impact	5	n/a	2	1
10. Reuse at other sites	5	n/a	1	7
11. Emerging Benefits	8	n/a	8	2
12. Emerging Issues or Challenges	10	n/a	10	1
13. Tertiary Issues	n/a	n/a	n/a	n/a
Survey Totals	94	1	64	55

Select categories 1 and 3 for cost and pollution analysis

The higher the number, the higher the estimated benefits by Irwin post engineers
The lower the number, the more negative the response
Key issues to post personnel: (8-10 positive) (4-7 neutral) (1-3 negative) Selected Options

19

This is the survey response chart from the Ft. Irwin, MOUT village to determine the top two power source alternatives. Survey totals from the survey illustrate that the top two alternatives are:

Category 1; Photovoltaics with back-up generator and

Category 3; Grid Tied Power

These two alternatives will now be analyzed for life cycle cost effectiveness.

Ft. Irwin Case Study; Cost Benefit Analysis

Grid Electric Capital & Investment & O & M Costs (FY05 $)

U.S. ARMY

Center for Army Analysis

Power Grid Capital and Installation Costs for 150kW Village MOUT (So. Calif. Edison = SCE)						
Item		**Distance (mi)**	**# of Items**	**$ / mi (or unit)**		**Total**
Underground lines		10		$225,901		$2,259,010
Armored cable		10		$278,401		$2,784,010
Transformers			2	$100,000		$200,000
Environmental Impact			1	$10,000		$10,000
Survey / Clear / Demolition (route)			1	$5,440		$5,440
Earthwork / Drainage			1	$62,720		$62,720
Electrical Dsn / Grounding / Lighting			1	$148,480		$148,480
Sub Total Cost (FY05 $)						$5,469,660
Power Grid Operation and Maintenance Costs (So. Calif. Ediso				$10,939		$10,939
Annual kWh cost given	876,000	kWh usage @	$0.145	per kWh		$127,020
Annual kWh cost given	233,000	kWh usage @	$0.145	per kWh		$33,785
Annual kWh cost given	58,400	kWh usage @	$0.145	per kWh		$8,468
		5840 hour	Grand Totals			$5,607,619
		1600 hour	Grand Totals			$5,514,384
		500 hour	Grand Totals			$5,489,067

- Annual highest O & M is 2.4 percent of total capital installation cost
- Primary cost driver is power distribution costs over 10 miles to remote MOUT village
- Secondary cost driver is the (high) kWh rate

Inputs into the DASA(CE) economic analysis model are seen here. Initial costs of the grid-tied alternative (Provided by Southern California Edison) are quite high and are drivers for this case study. These high costs arise from the reality of running a single one-phase electric line 10 miles into the California desert. As previously discussed, once installed, the grid-tied ongoing cost of $.145 cents per kilowatt hour is in itself high over 20 years and is seen by the model as not being economically feasible.

Ft. Irwin Case Study; Cost Benefit Analysis

Hybrid Photovoltaic Capital & Investment & O & M Costs (FY05 $)

U.S. ARMY

Center for Army Analysis

Ground Mounted Hybrid Photovoltaic Capital and Installation Costs for 150kW for Village MOUT						
Item			**ea**	**Ea Cost**	**DESC Cost**	**Total**
120kW Photovoltaic Array			120000	$7		$840,000
30kW Diesel Internal Combustion Engine			1	$18,000		$18,000
Energy Storage (36 batteries @ 48VDC)			36	$5,000		$5,000
Environmental Impact			1	$10,000		$10,000
Survey / Clear / Demolition			1	$5,440		$5,440
Earthwork / Drainage			1	$62,720		$62,720
Paving (aggregate only)			1	$11,755		$11,755
Structure Cost			1	$7,500		$7,500
Electrical Dsn / Grounding / Lighting			1	$148,480		$148,480
Design Contingency			1	$10,000		$10,000
Sub Total Cost (FY05 $)						$1,118,895
Operation and Maintenance Costs (Shell Solar)				$2,198		$2,198
Energy Storage (432 batteries @ 48VDC)			432	$150		$12,960
Annual hour usage	5,840	0.20	% on time	1168	1.27	$1,483
Annual hour usage	1,600	0.20	% on time	320	1.27	$406
Annual hour usage	500	0.20	% on time	100	1.27	$127

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- 80% lower 1st year capital costs and O & M costs than grid alternative

This alternative is approximately 1/5th the initial 1st year capital costs as compared to the grid-tied alternative. After the 1st year, the photovoltaic option also offers lower operations and maintenance costs. If the back-up diesel usage profile provides unacceptable levels of hydrocarbon emissions, then a propane fueled generator may be substituted.

Ft. Irwin Case Study; Cost Benefit Analysis

Life Cycle; Discounted Net Present Value

U.S. ARMY

Center for Army Analysis

As of	Ending in	Net Present Value (NPV) 5840 operational hours	Savings to Investment Ratio	Break Even Year (discounted)	Discount Rate
FY05	FY25	$5.978 (M) ($4.161 (M))	5.45 (4.10)	FY05	5.05%
FY05	FY25	$4.755 (M) 1600 op hours	4.58	FY05	5.05%
FY05	FY25	$4.438 (M) 500 op hours	4.35	FY05	5.05%

- Solar hybrid option is life-cycle cost effective / break-even point is in the first year (all cases)
- Savings to Investment Ratio is positive over life-cycle (compare with 1.00)
- Solar option saves maximum of 876,000 kWh coming from grid
- 500 hour and 1600 hour cases exhibit higher NPV and higher SIR (fewer savings)

Surveyed Benefits of Solar Option over Electric Grid Option (from installation point-of-view)

- IMPACT ON MISSION: Ft. Irwin experiences annual earthquakes that cause widespread power disruptions. Solar point source power generation without distribution lines enhances power reliability
- MAINTAINABILITY: Less dependence on Southern California Edison for power and line maintenance. Solar option weak link is the 30kW diesel generator. However, reduced run times mean less generator maintenance.
- SUPPORTABILITY: When accidents occur and grid power goes out, supportability is a problem with power grid.
- RELIABILITY: Reduced maintenance for generators with reduced run-time

22

This chart illustrates the economics in terms of net present value, savings to investment ratio and break-even year of the two systems in question. The across the board winner in this case study is the hard-stand photovoltaics with back-up generator.

To determine how much the initial capital costs of the grid-tied system affected the outcome, a separate analysis was performed by arbitrarily halving the highest two cost factors for the grid-tied system; (1) underground line costs and (2) armored cable costs. If this is done and the economic figures are recalculated with these lower costs for the 5,840 operational hour usage rate, the values in parentheses ($4.161 M net present value) and (4.10 savings to investment ratio) makes grid-tied energy more attractive, but the winner by a wide margin is still the photovoltaic alternative.

Ft. Irwin Case Study; Cost Benefit Analysis

Air Pollution Analysis for 30kW Diesel Generator

U.S. ARMY — Center for Army Analysis

20 Year Cumulative Emission Totals (tons) from 30kW Diesel Generator

pollutant / hrs / yr	NOx	CO	PM	VOC	SOx
500 * .20 = 100	1.2	.2	.0	.2	.0
1600 * .20 = 320	4.0	.8	.2	.4	.2
5840 * .20 = 1168	14.4	3.2	1.0	1.2	1.0

20 year Grid estimate from small, boiler using diesel fuel oil #2 (with .5 sulfur content)

20 * 5840 hours (boiler)	7.6	2.2	0.4	0.2	30.2
20 * 1168 hours (30kW)	14.4	3.2	1.0	1.2	1.0

20 year pollution difference (tons) between 30kW and Grid Estimate

△ (boiler – 30kW)	-6.8	-1.0	- 0.6	-1.0	+29.2

- Net 20 tons of pollutant over a twenty year period is abated with solar hybrid

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This chart compares the pollutant output between the photovoltaics with back-up 30kW generator and a typical Southern California Edison boiler using fuel oil as the feed stock and compares the highest pollutant case for the photovoltaics unit (1168 operational hrs / year) with the grid tied system.

Over a twenty year period, the photovoltaic alternative with the highest 30kW diesel generator on-times will still save approximately 20 tons of pollutants over the grid-electric alternative. All of the savings are in the form of abated SO_2.

WSMR Case Study; Instrumentation Site

Evaluate WSMR survey for test & instrumentation best alternatives

U.S. ARMY Center for Army Analysis

Case Study # 2

4 Categories of Power Generation

Benefits	Category 1 PV & Genset	Category 2 Mobile DG	Category 3 Grid Tied	Category 4 GENSET
Approximate kW Rating	40 kilowatts	40 kilowatts	40 kilowatts	40 kilowatts
1. Delivery of Required Power	10	1	1	10
2. Power quality	9	n/a	10	10
3. Impact on Mission	9	n/a	8	8
4. Mobility	2	n/a	n/a	8
5. Flexibility	9	n/a	1	4
6. Supportability	9	n/a	5	4
7. Maintainability	9	n/a	4	2
8. Reliability	7	n/a	6	4
9. Environmental Impact	10	n/a	4	1
10. Reuse at other sites	7	n/a	1	9
11. Emerging Benefits	9	n/a	9	2
12. Emerging Issues or Challenges	1	n/a	1	1
13. Tertiary Issues	1	n/a	1	n/a
Survey Totals	92	n/a	51	63

Select Categories 1 and 4 for Cost Analysis

(Option 4 is status quo)

The higher the number, the higher the estimated benefits by Irwin post engineers
The lower the number, the more negative the response
Key issues to post personnel: (8-10 positive) (4-7 neutral) (1-3 negative) Selected Options

24

This is the survey response chart from the White Sands Missile Range, test and instrumentation mission to determine the top two power source alternatives. Survey totals from the survey illustrate that the top two alternatives are:

Category 1; Photovoltaics with back-up generator and

Category 4; Stand Alone 40kW fossil-fuel generator

These two alternatives will now be analyzed for life cycle cost effectiveness.

WSMR Case Study; Cost Benefit Analysis

40kW Genset Capital & Investment & O & M Costs (FY05 $)

U.S. ARMY — Center for Army Analysis

Power from Status Quo 40kW Genset						
Item			**# of Items**	**$ / mi (or unit)**	DESC Cost	**Total**
40kW Diesel Generator			1	$26,500		$26,500
Survey / Clear / Concrete Pad			1	$1,440		$1,440
Fencing			1	$1,200		$1,200
Electrical Dsn / Grounding / Lighting			1	$3,850		$3,850
Sub Total Cost (FY05 $)						$31,490
Generator Operation and Maintenance Costs				$110		$1,320
Annual fuel cost	5,840	genset hours @	6	gal per hour	1.27	$44,501
Annual fuel cost	1,600	genset hours @	6	gal per hour	1.27	$12,192
Annual fuel cost	500	genset hours @	6	gal per hour	1.27	$3,810

- 5,840 hours X 6 gal per hour X 20 years = 700,800 gallons of diesel for the 40 kW generator
- Significant yearly fuel costs

25

This represents the FY05 costs for the White Sands Missile Range current capability for providing electric power for test and instrumentation missions. The driver in this case is the significant yearly fuel costs. Because this alternative already exists, no *permitting cost* for an environmental impact statement is required.

WSMR Case Study; Cost Benefit Analysis

30kW Hybrid Photovoltaic Investment & O & M Costs (FY05 $)

Ground Mounted Hybrid Photovoltaic Capital and Installation Costs for 40kW Instrumentation Site						
Item			ea	Ea Cost	DESC Cost	Total
30kW Photovoltaic Array			30000	$7		$210,000
10kW Diesel Internal Combustion Engine			1	$12,000		$12,000
Energy Storage (72 batteries @ 48VDC)			72	$150		$10,800
Environmental Impact			1	$2,000		$2,000
Survey / Clear / Demolition			1	$5,440		$5,440
Earthwork / Drainage			1	$2,100		$2,100
Paving (aggregate only)			1	$3,500		$3,500
Structure Cost			1	$2,200		$2,200
Electrical Dsn / Grounding / Lighting			1	$3,850		$3,850
Design Contingency			1	$1,500		$1,500
Sub Total Cost (FY05 $)						$253,390
Operation and Maintenance Costs (Shell Solar)				$798		$798
Energy Storage (72 batteries @ 48VDC)			72	$150		$2,160
Annual hour usage	5,840	0.15	% on time	876	1.27	$1,213
Annual hour usage	1,600	0.15	% on time	240	1.27	$332
Annual hour usage	500	0.15	% on time	75	1.27	$104
10kW Consumption (gals / hr)		1.09				

- 5,840 hours X .15 usage rate X 1.09 gal per hour X 20 years = 19,097 gallons of diesel for the 10 kW generator 26

The hard-stand photovoltaics power station with 10kW back-up generator has significantly higher first year costs than the status quo. However, lower yearly operation and maintenance costs may prove to be more economically feasible over the status quo in the long run.

WSMR Case Study; Cost Benefit Analysis

Life Cycle; Discounted Net Present Value

U.S. ARMY

Center for Army Analysis

As of	Ending in	Net Present Value (NPV)	Savings to Investment Ratio	Break Even Year (discounted)	Discount Rate
FY05	FY25	$0.335 (M) 5840 op hours	2.08	FY10	5.05%
FY05	FY25	($0.086) (M) 1600 op hours	0.71	-	5.05%
FY05	FY25	($0.196) (M) 500 op hours	0.34	-	5.05%

- Solar hybrid option is life-cycle cost effective at 5840 op hours/ break-even point is yr 5
- 2.08 Savings to Investment Ratio is positive over life-cycle (compare with 1.00)
- Solar option saves 681,703 gallons of fuel over 20 years
- 500 hour and 1600 hour cases are not cost effective over the status quo

Surveyed Benefits of 40kW Genset Option over Solar Hybrid (from installation point-of-view)

- MOBILITY: WSMR notes that a ground-mounted solar hybrid is not a mobile asset (as is a single, point generator)

Surveyed Benefits of Solar Hybrid over 40kW Genset Option (from installation point-of-view)

- FLEXIBILITY: Can utilize solar array for sensitive air-quality sensing (instrumentation).
- SUPPORTABILITY: Fewer readiness problems with solar hybrid for mission support
- MAINTAINABILITY: Generators running less will require less maintenance
- ENVIRONMENTAL IMPACT: Fewer emissions from solar hybrid
- EMERGING BENEFIT: Easier to meet EPA, state and local emissions requirements

27

In this case, the solar hybrid showed a positive net present value only if the system was used at the maximum operational hour level; 5,840 hours per year. The high initial systems cost for the photovoltaic system took until year five of the 20 year operational window to pay for itself.

If the system is not to be used at the maximum of 5,840 hours per year – it may not be the most economical system to chose. Let us now evaluate the pollution and emissions analysis.

WSMR Case Study; Cost Benefit Analysis

Air Pollution Analysis for 40kW & 10kW Diesel Generator

U.S. ARMY Center for Army Analysis

20 Year Cumulative Emission Totals (tons) from 10kW Diesel Generator

hrs / yr \ pollutant	NOx	CO	PM	VOC	SOx
500 * .15 = 75	.4	.0	.0	.0	.0
1600 * .15 = 320	1.2	.2	.0	.2	.0
5840 * .15 = 876	3.6	.8	.2	.2	.2

20 year estimate from 40kW diesel generator versus the 10kW hybrid diesel

20 * 5840 hours (40kW)	97.8	21.0	7.0	8.0	6.4
20 * 876 hours (10kW)	3.6	.8	.2	.2	.2

20 year pollution difference (tons) between 10kW and 40kW

△ (40kW – 10kW)	94.2	20.2	6.8	7.8	6.2

- Net 135 tons of pollutant over a twenty year period is abated with solar hybrid

28

Common sense tells us that if there are no pollutants coming from the photovoltaic panels themselves, then the comparison comes down to the pollutants generated from the 40kW diesel versus the 10kW diesel.

Generally speaking, the lay person would be surprised to find that larger fossil fuel generators are usually less polluting than smaller ones. However, in our case study, the smaller back-up generator was on much less than the status quo 40kW and this made the pollution difference tilt in favor of the smaller generator.

Without this analysis, it would have been difficult at best to determine that the smaller generator (run less often) would provide a net 135 tons decrease in pollutants over a 20 year period over its larger 40kW brother.

Yuma Proving Ground Case Study; Cost Benefit Analysis

Evaluate Yuma survey for commo retransmission best alternatives

U.S. ARMY

Center for Army Analysis

Case Study # 3

4 Categories of Power Generation

	Category 1	Category 2	Category 3	Category 4
Benefits	PV & Genset	Mobile DG	Grid Tied	Other
Approximate kW Rating	10 kilowatts	10 kilowatts	10 kilowatts	10 kilowatts
1. Delivery of Required Power	8	7	1	8
2. Power quality	8	8	n/a	8
3. Impact on Mission	2	10	n/a	9
4. Mobility	1	9	n/a	9
5. Flexibility	1	9	n/a	9
6. Supportability	10	10	n/a	5
7. Maintainability	6	6	n/a	3
8. Reliability	10	9	n/a	4
9. Environmental Impact	8	10	n/a	1
10. Reuse at other sites	2	10	n/a	9
11. Emerging Benefits	8	10	n/a	5
12. Emerging Issues or Challenges	6	5	n/a	2
13. Tertiary Issues	n/a	5	n/a	6
Survey Totals	70	108		78

Select Categories **2** and **4** for Cost Analysis

(Option **4** is status quo)

The higher the number, the higher the estimated benefits by Irwin post engineers

The lower the number, the more negative the response

Key issues to post personnel: (8-10 positive) (4-7 neutral) (1-3 negative) Selected Options

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This is the survey response chart from the Yuma Proving Ground, communication mission to determine the top two power source alternatives. Survey totals from the survey illustrate that the top two alternatives are:

Category 2; Mobile Distributed Generation (Photovoltaics with back-up generator) and

Category 4; Stand Alone 40kW fossil-fuel generator

These two alternatives will now be analyzed for life cycle cost effectiveness.

Yuma Case Study; Cost Benefit Analysis

10kW Genset Capital & Investment & O & M Costs (FY05 $)

U.S. ARMY — Center for Army Analysis

Power from Status Quo 10kW Genset

Item		# of Items	$ / mi (or unit)	DESC Cost	Total
10kW Diesel Generator		1	$12,000		$12,000
M105 (5T Trailer)		1	$5,000		$5,000
Sub Total Cost (FY05 $)					$17,000
Generator Operation and Maintenance Costs			$50		$600
Annual fuel cost	5,840 genset hours @		0.57 per hour	1.27	$4,228
Annual fuel cost	1,600 genset hours @		0.57 per hour	1.27	$1,158
Annual fuel cost	500 genset hours @		0.57 per hour	1.27	$362

- 5,840 hours X .57 gal per hour X 20 years = 66,576 gallons of diesel for the 10 kW generator

30

The data for the 10kW mobile power station is illustrated above. Note that the highest operational run time for this generator requires over 66,000 gallons of fuel over twenty years. However, low capitalization costs could make this option more economically feasible over the solar hybrid case.

Yuma Case Study; Cost Benefit Analysis

10kW Hybrid Photovoltaic Investment & O & M Costs (FY05 $)

U.S. ARMY Center for Army Analysis

Mobile Hybrid Photovoltaic Capital and Integration Costs for 10kW Commo Retrans Site

Item			ea	Ea Cost	DESC Cost	Total
5kW Photovoltaic Array (A-si or CIGS)			5000	$8		$40,000
5kW Diesel Internal Combustion Engine			1	$8,000		$8,000
Energy Storage (36 batteries @ 48VDC)			36	$150		$5,400
M105 (5T Trailer)			1	$5,000		$5,000
Sub Total Cost (FY05 $)						$58,400
Operation and Maintenance Costs (Shell Solar)				$399		$399
Energy Storage (36 batteries @ 48VDC)			36	$150		$1,080
Annual hour usage	5,840	0.10 % on time		584	1.27	$423
Annual hour usage	1,600	0.10 % on time		160	1.27	$116
Annual hour usage	500	0.10 % on time		50	1.27	$36
5kW Consumption (gals / hr)		0.57				

- 5,840 hours X .10 usage rate X .57 gal per hour X 20 years = 6,658 gallons of diesel for the 10 kW generator

31

Given that it is not possible to put cheaper crystalline solar arrays on a M105, 5 ton trailer, this option explores using thin-film photovoltiacs to do the job. This type of solar panel has approximately the same efficiency as that of crystalline PV (~ 13%) but is much lighter. For example, a single solar panel from crystalline to generate 100 watts could way upwards of 30 – 40 pounds (depending on manufacturer) whereas thin-film only weighs about 2.5 pounds. Maximum gross vehicle trailer weight consideration is the primary reason why thin-film PV has to be used in this case study analysis. Unfortunately, thin-film is very expensive coming in at around $8 / watt (average FY05 cost between copper-indium-gallium-diselenide and amorphous silicon thin-film alternatives). Incidentally, the heavier, crystalline can be purchased at around $3 - $4 per watt, depending on the manufacturer.

Yuma Case Study; Cost Benefit Analysis

Life Cycle; Discounted Net Present Value

U.S. ARMY

Center for Army Analysis

As of	Ending in	Net Present Value (NPV) 5840 op hours	Savings to Investment Ratio	Break Even Year (discounted)	Discount Rate
FY05	FY25	($0.002) (M) $0.550 (M)	0.97 6.83	-	5.05%
FY05	FY25	($0.039) (M) 1600 op hours	0.51	-	5.05%
FY05	FY25	($0.049) (M) 500 op hours	0.38	-	5.05%

- Solar hybrid option is not life-cycle cost effective at any scenario unless thin-film photovoltaics cost is reduced by "half". (note: thin-film is used because 1/10th weight and is foldable)
- Solar option saves 59,918 gallons of fuel over 20 years

Surveyed Benefits of 10kW Genset Option over Solar Hybrid
(from installation point-of-view)

- DELIVERY of REQUIRED POWER: Yuma has had only limited solar experience

Surveyed Benefits of Solar Hybrid over 40kW Genset Option
(from installation point-of-view)

- FLEXIBILITY: Can utilize solar array for sensitive air-quality sensing (instrumentation).
- SUPPORTABILITY: Fewer readiness problems with solar hybrid for mission support
- MAINTAINABILITY: Generators running less will require less maintenance
- ENVIRONMENTAL IMPACT: Fewer emissions from solar hybrid
- EMERGING BENEFIT: Easier to meet EPA, state and local emissions requirements

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The solar hybrid option for the 10kW communications case study is not economically feasible because of the expense of the thin-film photovoltaics necessary for less weight. Examining this $/watt driving cost factor, a decrease of ½ the cost would be necessary before this alternative would become economically viable (see above NPV figure of $0.550 M with corresponding savings to investment ratio of 6.83).

Yuma Case Study; Cost Benefit Analysis

Air Pollution Analysis for 10kW hybrid & 10kW Diesel generator

U.S. ARMY Center for Army Analysis

20 Year Cumulative Emission Totals (tons) from 10kW Diesel Generator

pollutant / hrs / yr	NOx	CO	PM	VOC	SOx
500 * .10 = 50	.2	.0	.0	.0	.0
1600 * .10 = 160	.6	.2	.0	0	.0
5840 * .10 = 584	2.4	.6	.2	.2	.2

20 year estimate from 10kW status quo diesel generator and 5kW hybrid diesel

20 * 5840 hours (10kW)	23.6	5.0	1.6	2.0	1.6
20 * 584 hours (5kW)	2.4	.6	.2	.2	.2

20 year pollution difference (tons) between 10kW and 5kW

△ (10kW – 5kW)	21.2	49.4	1.4	1.8	1.4

- Net 75 tons of pollutant over a twenty year period is abated with solar hybrid

33

Again, as in the WSMR case study, two fossil fuel generators are compared for purposes of understanding the emissions and pollution abatement picture. The first, rated at 10kW running for 5,840 hours per year and the second, a 5kW back-up generator running at 584 hrs/year provides the above estimates for pollution. The 5kW solar hybrid diesel running for 1/10th the time of the 10kW abates 75 tons of pollutants over a twenty year period.

Review of Case Study Findings

U.S. ARMY

Center for Army Analysis

1. **Ft. Irwin; Village MOUT (150kW peak power)**
   a. Hybrid Solar option is life-cycle cost effective with positive Benefit Cost Ratio for all operational hour scenarios
   b. Survey noted benefits to mission (positive impact), maintainability, supportability, and reliability
   c. Solar hybrid option saves 876,000 kWh annually from grid
   d. Emissions abated with reduced use of 30kW genset

2. **White Sands Missile Range; Instrumentation Site (40kW peak power)**
   a. Hybrid solar option is life-cycle cost effective for 5,840 operational hour case but not for 1600 and 500 hour cases.
   b. Survey noted expected value added from solar maintainability, flexibility, sustainability and environmental impact
   c. Hybrid solar option saves 600,000(+) gallons of fuel over 20 years and abates 135 tons of pollutants

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It is important for the reader to understand that each analysis depicting each case study is different such that no "rules of thumb" except for individual analyses applying to each individual case. In other words, separate analysis for each case study has to be performed in order to obtain a true picture of the final alternative power options.

Review of Case Study Findings (cont'd)

U.S. ARMY — Center for Army Analysis

3. **Yuma Proving Ground; Communication Retransmission Site (10kW peak power)**
   a. Solar hybrid option is not life-cycle cost effective for any scenario unless thin-film photovoltaic cost is reduced by "half". (note: thin-film is used on trailers because it's 1/10th weight and is foldable)
   b. Solar option saves 59,918 gallons of fuel over 20 years
   c. Solar option abates 75 tons of pollutants over 20 years

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The states of California, Arizona and New Mexico have some of the strictest pollution standards in the country. Any military installation within these states placing a high value on clean energy should consider hybrid solar options as these case studies all reduce pollution over the status quo across the board. Even in the cases where the economics are not favorable, the solar hybrid option still abates more pollution than the non-solar power source alternative.

What this Study Accomplished

U.S. ARMY

Center for Army Analysis

- Surveyed 5 installations and determined 9 categories of remote location missions requiring a range of power from watts to kilowatts
- Provided a cost - benefit analyses of 3 Case Studies illustrating remote power energy alternatives and installation feedback
- Examined pollution levels at various levels of operational use
- Established an analytical approach and methodology "roadmap" for similar future studies

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As the US Army continues to follow the recommendations of the Base Realignment and Closure (BRAC) commission and stricter laws governing pollution are enacted, it is important to know that certain power and energy solutions are available to help when missions are combined into single installations and sister services have to share the same facilities as Army components. Never before has an Army study been undertaken to determine both remote energy needs for corresponding remote power missions nor have surveys been taken to better understand the power and energy story from the point of view of the installation energy manager.

This document explores the problem of remote power and energy and the many considerations required to understand the issues. As we have seen, individual analysis for each case study has to be completed because of the complex, dynamic interaction between comparative solutions. It is this overall complexity of each case that defies simple intuition.

More importantly however, this work provides viable solutions that have the potential of being more cost effective to the Army and the American taxpayer and to reduce pollution emissions as well.

Recommendations

U.S. ARMY — Center for Army Analysis

- For areas outside the southwest IMA Region, detailed engineering studies need to be done in order to verify that sufficient renewable energy exists at the surveyed installations
- Power profiles (kW over time) need to be determined to correctly size the appropriate power generation assets
- Economies of scale and other market factors continue to reduce the cost of renewable energy. Periodic cost-benefit analysis in this area can serve to keep HQDA up-to-date for purposes of policy revision and new policy development.

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Further installation surveys are warranted if works like this are to continue shedding analytical light on additional remote energy missions and locations. The reader is cautioned that although solar energy was a focus for installations such as White Sands, Yuma and Ft. Irwin, sufficient solar energy exists at these locations to make hybrid solar options viable. However in northern climates, additional research would need to be done to verify that sufficient solar energy levels exist to support a solar or hybrid solar solution.

Installations are encouraged to sample existing power profiles (kW over time) for existing and emerging missions powered by any kind of power platform. The REASR 3 analysis could have been done much easier if it were not for the variability involved in analyzing 3 different levels of projected power profiles.

Additional analyses of this type will need to be done on a frequent basis as renewable options such as fuel cells, bio-gasifiers, wind, solar, geothermal and hydro become more viable and available. As these alternative power sources make their way into the American power mainstream in significant numbers, their purchase costs will decrease and economies of scale will help to decrease long term ownership costs as well.

APPENDIX A PROJECT CONTRIBUTORS

1. PROJECT TEAM

a. Project Director:

Hugh W. Jones, Resource Analysis Division

b. Team Member:

Dr. Charles Leake

c. Other Contributors:

Mr. Julian Delgado

Mr. Rene Quinones

Mr. Jack Nixon

2. PRODUCT REVIEWERS

Dr. Ralph E. Johnson, Quality Assurance

3. EXTERNAL CONTRIBUTORS

Mr. Steve Siegel, Energy Security Group

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APPENDIX B REQUEST FOR ANALYTICAL SUPPORT

P A R T 1

Performing Division: RA ***Account Number:*** **2003038**

Tasking: ***Method (Contract-Yes/No):*** In-house

Acronym: **REASR 3**

Title: Renewable Energy Analysis for Strategic Responsiveness

Start Date: 01-Feb-03 ***Estimated Completion Date:*** 01-Jun-04

Requestor/Sponsor (i.e., DCSOPS): ACSIM ***Sponsor Division:*** FDF-UE

Resource Estimates: ***a. Estimated PSM:*** 3 ***b. Estimated Funds:*** $0.00

c. Models to be Used:

Description/Abstract: REASR 3 continues the analysis of hybrid solar and wind systems in support of various Army installation missions. In particular, REASR 3 will examine issues regarding remote energy capabilities for installations selected by the study sponsor.

Study Director/POC Signature: (signed) ***Phone#:*** 703-806-5389

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

If this Request is for an External Project expected to consume 6 PSM or more, Part 2 Information is Not Required. See Chap 3 of the Project Directors' Guide for preparation of a Formal Project Directive.

Background: The REASR 3 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 to include economies of scale and mass production. REASR 3 builds on army renewable energy analysis by adding installation applications.

P A R T 2

Scope: The Renewable Energy Analysis for Strategic Responsiveness 2 Study includes data from field exercises. REASR 3 builds upon this knowledge base via surveys conducted at Ft. Irwin, Yuma Proving Ground and White Sands Missile Range.

Issues: Determine the value added that solar hybrid provides to installation readiness, energy savings, pollution prevention and economic analysis.

Milestones: yProvide review analysis for the ongoing effort to obtain surveys by December '04. Provide briefings in June '04

Signatures

Division Chief Signature: Original Signed and Dated ***Date:2Jan 03***

Division Chief Concurrence: Original Signed and Dated

Sponsor Signature: Original Signed and Dated ***Date:1Jan 03***

Sponsor Concurrence (Div Chief; DAIM-FDF-UE): Original Signed and Dated

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APPENDIX C BIBLIOGRAPHY

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GLOSSARY (U)

1. ABBREVIATIONS, ACRONYMS, AND SHORT TERMS

CERL	U. S. Army Construction Engineering Research Laboratory
CO	carbon monoxide
CO2	carbon dioxide
DG	distributed generation
IC	internal combustion
kW	kilowatt(s)
kWh	kilowatt hour(s)
lbs.	pounds
MW	megawatt(s)
MWh	megawatt hour(s)
NG	natural gas
NGIC	natural gas internal combustion
NOX	nitrogen oxide
PART	particulates
PV	photovoltaic(s)
SOX	sulfur oxide