Energy Security of Army Installations and Islanding Methodologies: A Multiple Criteria Decision Aid to Innovation with Emergent Conditions of the Energy Environment

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June 16, 2010

Prepared for the Environment, Energy Security and Sustainability Symposium and Exhibition

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **16 JUN 2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE **Energy Security of Army Installations and Islanding Methodologies: A Multiple Criteria Decision Aid to Innovation with Emergent Conditions of the Energy Environment**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Virginia,Center for Risk Management of Engineering Systems,151 Engineers Way, Room 112,Charlottesville,VA,22904**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Presented at the NDIA Environment, Energy Security & Sustainability (E2S2) Symposium & Exhibition held 14-17 June 2010 in Denver, CO.

14. ABSTRACT

15. SUBJECT TERMS

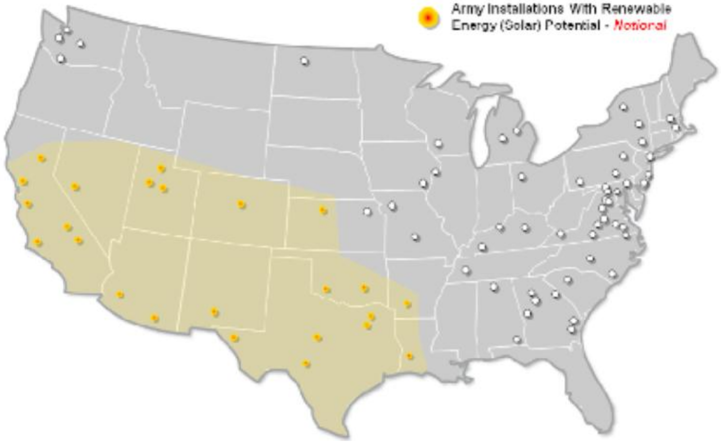
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**50**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Outline

- Motivation
- Goal and objectives
- Background
  - Overview of Army missions and goals
  - Specific missions and goals for installations
- Scenario Planning/ MCDA Methodology
  - Overview and technical considerations
  - Application to installation energy security
- Closing

Motivation



Energy security has been defined as:

"…the capacity to avoid adverse impact of energy disruptions caused either by natural, accidental, or intentional events affecting energy and utility supply and distributions systems."

Source: United States Army. The U.S. Army Energy and Water Campaign Plan for Installations 2007

"…the level of assurance that the critical missions of installations and operational units can be accomplished in the face of disruptions to electricity and/or fuel supplies."

Source: United States Army. Army Energy Security Strategic Implementation Plan (AESSIP) (draft) 2008

Motivation

- Each installation a unique set of challenges
  - Reliance on commercial utilities
  - Fragility of energy resources
  - Vulnerability of grid to deliberate attacks or natural disasters
  - Reliance on fossil-fuel back-up generators
  - Lack of guidance to installations on to perform their energy security assessments

Image Source: AESIS, 2009

- Additional cost and other tradeoffs of solutions likely due to redundancy, hardening, stockpiling

Sources: *Army Energy Security Strategic Implementation Plan (AESSIP) (draft)* and http://www.mvk.usace.army.mil/contract/docs/BAA.pdf

Goal and Objectives

Goal

Develop methodology to assist in achieving energy security with respect to critical and essential missions and operations, supporting installations to maintain operational capabilities with energy savings, increased efficiencies, reduced environmental impacts, and increased uses of renewable sources.

Objectives

- Develop scenario-informed multiple-criteria analysis to address installation energy security
- Identify scenarios of emergent conditions that warrant additional investigation and modeling resources
- Identify robust energy security alternatives across emergent conditions
  - Demonstrate the methodology in a case study
  - Provide a web-based tool to assist energy security choices for use by installations

Background

Installation Initiatives

- The *Army Energy Strategy for Installations* (2005) is based on five initiatives:
  - Eliminate energy waste
  - Increase energy efficiency in renovation and new construction
  - Reduce dependence on fossil fuels
  - Conserve water resources
  - **Improve energy security**

*Time horizon is twenty years.

Source: *The US Army Energy Strategy for Installations (2005)*

Strategic Energy Goals

- The Army established five *Strategic Energy Goals* (2009):
  - ESG 1. Reduced energy consumption
  - ESG 2. Increased energy efficiency across platforms and facilities
  - ESG 3. Increased use of renewable/alternative energy
  - ESG 4. Assured Access to sufficient energy supply
  - ESG 5. Reduced adverse impacts to the environment

Image Source: DoD Energy Security Initiatives, WSTIAC Quarterly

Source: *Army Energy Security Implementation Strategy (2009)*

Vulnerabilities of Missions and Operations

2006 Defense Science Board reported:

"…critical national security and Homeland defense missions are at an unacceptably high risk of extended outage from failure of the grid…"

- Energy infrastructure:
  - Distributed and remote
  - Aging
  - Difficult to protect
  - Cannot ensure reliability of supply
  - Subject to extreme weather, cyber attack and physical attack
  - Cascading failures from energy interdependencies

Diesel Generator Backup

- Backup diesel generators may be inadequate due to:
  - Low startup reliability
  - Can't be run continuously
  - Single point of failure
  - Fossil fuel
  - Largely imported
  - Rely on supply of diesel fuel over long periods

Incremental Adjustments to Energy Security Portfolio

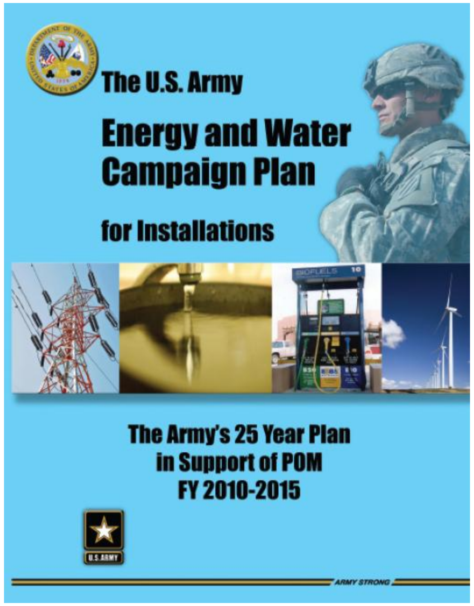
"Disparities between energy use and energy reserves underscore our need to develop alternative energy resources. The nation's demand for imported energy would be lessened by increasing coal, nuclear, and renewable energy contributions to our energy portfolio."

Image Source: AESIS, 2009

Source: *Army Energy and Water Campaign Plan for Installations*

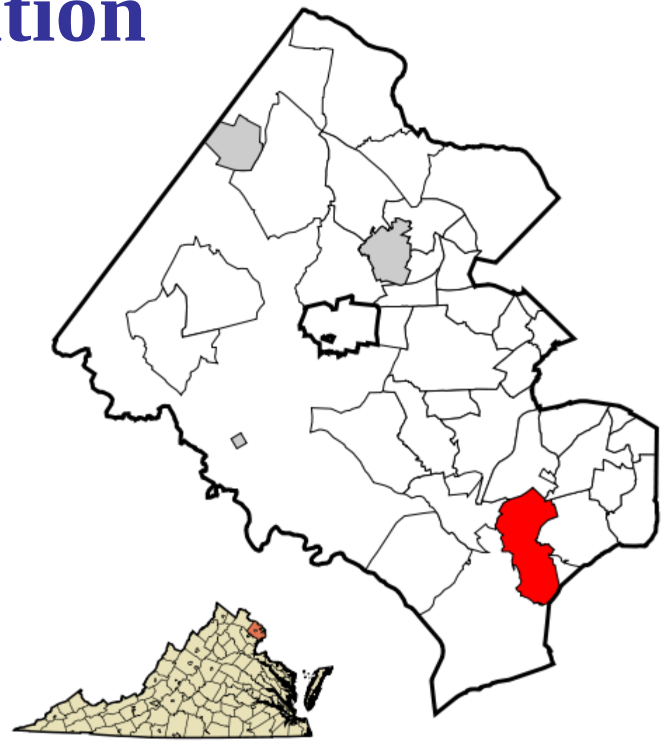
Relevant DoD and Energy Literature

- DoD Energy Security Strategic Plan (forthcoming)
- Army Energy Security Implementation Strategy (2009)
- Electricity Security of Supply from the Outside In - The Industry Perspective. Conference Presentation. Leatherman, G. (2009)
- The National Defense Industrial Association. Booz Allen Hamilton
- Kleber, D., 2009. The US Department of Defense: Valuing Energy Security. *The Journal of Energy Security*, (June 2009).
- The US Army Energy and Water Campaign Plan for Installations (2007)
- The US Army Energy Strategy for Installations (2005)
- Hightower, M. (2009). Energy Surety and Renewable Energy Approaches and Applications. Federal Utility Partnership Working Group Meeting. Sandia National Laboratories.
- Army Installation Energy Security Plans (2003)



Methodology and Application

Example: Northern VA Installation



- Located in Fairfax County, VA
- Attached to public grid
- Experiences many outages a year
- Investigating multiple diverse technologies to island key buildings during outages
- Has a new vision –

"…continue its tradition of excellent and Innovative service, but will be developed into a world-class urban federal center; a flagship installation in America's national security structure."

Source: www.belvoirnewvision.com

Other Relevant Literature

Energy Scenarios

Tonn et al. (2009); United Nations (2008); Mintzer et al. (2003); Nakićenović, N.(2000)

Scenario and impact analysis

Karvetski et al. (2010a, 2010b); Ram et al. (2010); Wright et al. (2008); Groves and Lempert (2007); Montibeller et al. (2006); Stewert (2005); Goodwin and Wright (2001)

Multiple criteria analysis

Belton and Stewart (2002); Keeney (1992); Keeney and Raiffa (1976); Clemen and Reilly (2001)

Risk analysis

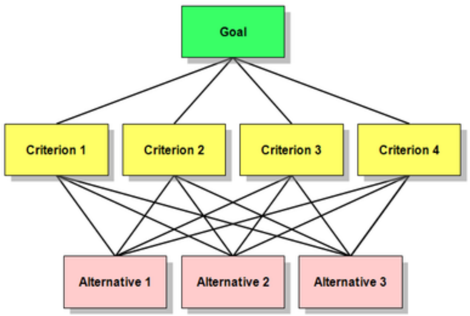
Haimes (2009); Kaplan et al. (2001): Lowrance (1976); Kaplan and Garrick (1981)

Source: *The US Army Energy Strategy for Installations (2005)*

Decision Making Under Uncertainty

- Uncertainty in decision making process from multiple sources
  - Model uncertainty
    - Internal uncertainty related to structuring problem, elicitation, and analysis
  - <u>External sources of uncertainty (emergent conditions)</u>
    - External uncertainty related to nature of decision making environment (outside control of decision maker)

Traditional Methods for Dealing with Uncertainty



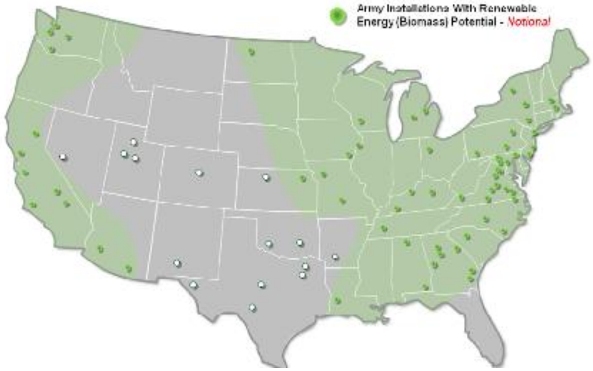
- Utility theory
  - Requires complete probabilistic description of uncertainty
  - Requires state-independent preferences
- <u>Scenario Planning (SP)</u>
  - Structures conversation and identifies relevant external factors that can affect decision making
  - Aimed at selecting a robust decision alternative, but SP is not necessarily paired with a formal evaluation model to select a preferred alternative

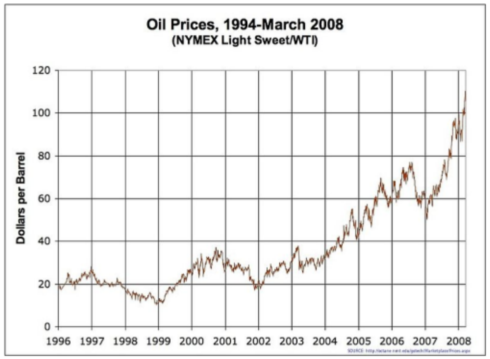
Integrating Scenario Planning with MCDA

- An integration of SP with multiple criteria decision analysis (MCDA) is complementary the following reasons:
  - SP can address external uncertainty in MCDA when probability-based utility methods fail
  - MCDA can quantify robustness of a decision across the scenarios
  - Influential scenarios can be filtered accordingly to their impact on decision making
- Multiple approaches for structuring MCDA [Stewart 2005]
- Our approach is to create a new value function for each scenario [Karvetski et al. 2010a, 2010b; Ram et al. 2010; Montibeller et al. 2006]

Elements of Methodology

- The methodology is composed of three elements:
  - **Alternatives** that represent potential options for investment or strategies to implement
  - **Performance criteria** to evaluate the alternatives
  - **Emergent conditions** that form future **scenarios** to characterize the robustness of alternatives





Related Applications of Methodology

- Multimodal transportation
- Afghanistan Sustainable Infrastructure Plan
- Erosion control in Alaska
- Climate change and infrastructure systems

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Multicriteria Decision Analysis for the Afghanistan Sustainable Infrastructure Plan

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May 2009

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Energy Security of Army Installations and Islanding Methodologies: A Multiple Criteria Decision Aid to Innovation with Emergent Conditions of the Energy Environment

University of Virginia
Center for Risk Management of Engineering Systems

Purpose:

This web based software tool will enable individual installations to conduct energy security self assessments that will quantify the impact of various energy efficiency strategies and technologies, particularly islanding, on critical missions in order to ensure the execution of those missions.

"This effort is supported by the American Recovery and Reinvestment Act and is in reponse to CERL Topic 4-1 Energy Security Assessments and Islanding Methodologies"

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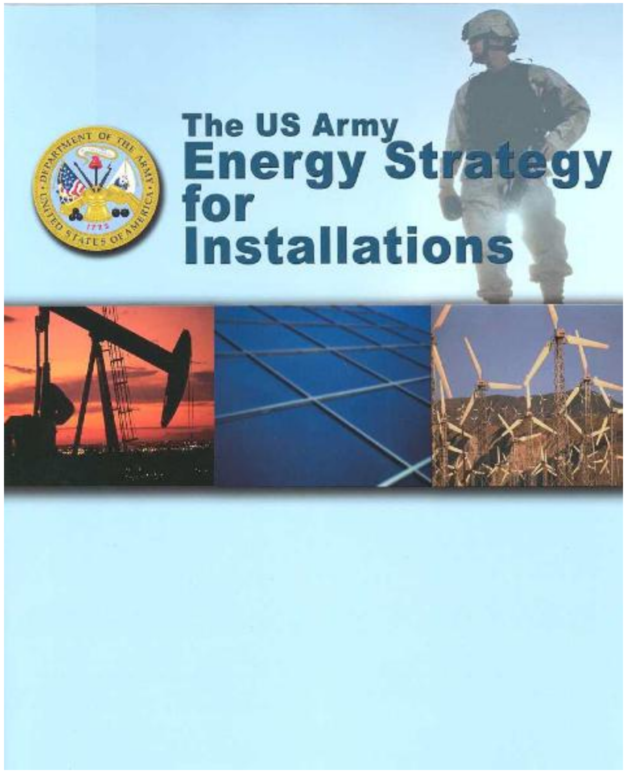
Methodology will be available in online workbook.

Baseline Assessment

Baseline Assessment

- Baseline factors and installation energy requirements
  - Serve as a benchmark
  - Define constraints for designing alternatives
  - **Identify essential/critical energy mission and operations**
  - Inventory alternatives already implemented on the installation
  - Inventory energy alternative programs that have been assessed for implementation on the installation
  - Understand the energy security impact of the above programs
  - Identify total baseline installation energy usage



Baseline Assessment (cont.)

- Identify baseline installation energy sources (*)
- Identify baseline operations energy requirements
- **<u>Identify baseline essential/critical mission energy requirements</u>**
- Identify baseline operations energy sources (*)
- Identify baseline essential/critical mission energy sources (*)
- Determine percentage of energy dedicated to operations or critical/essential missions
- Determine percentage of energy deriving from off installation sources
- Determine percent of imported resources
- Determine whether kWh production on installation site is permitted under current memorandums of understanding (MOUs)

(*) (Grid (kWh), Off Grid (kWh), Imported (kWh), Back Up (kWh))

Baseline Assessment (cont.)

- Take into account:
  - Missions (Combat support, logistics, training, etc.)
  - Operations (C4, lift, training, support, etc.)
  - Tenants
  - Deployment schedules / force flow
  - Source/generation (coal, gas, diesel, solar, geothermal, …)
  - Storage (fuel cell, battery, capacitor, fuel, kinetics, superconducting, …)
  - Transmission (grid, microgrid, fixed, moveable, …)
  - Control/management (Switches, control centers, logic/algorithms, …)
  - Demand reduction (HVAC, passive solar, electronics, high efficiency, …)
  - Time horizons (seconds/milliseconds, minutes, hours, days, weeks, months, …)
  - Facilities (buildings, floors, offices, laboratories, vehicles, equipment, …)
  - Partners/stakeholders (industry, utilities, …)
  - Regional and co-located installations
  - Other

Alternatives

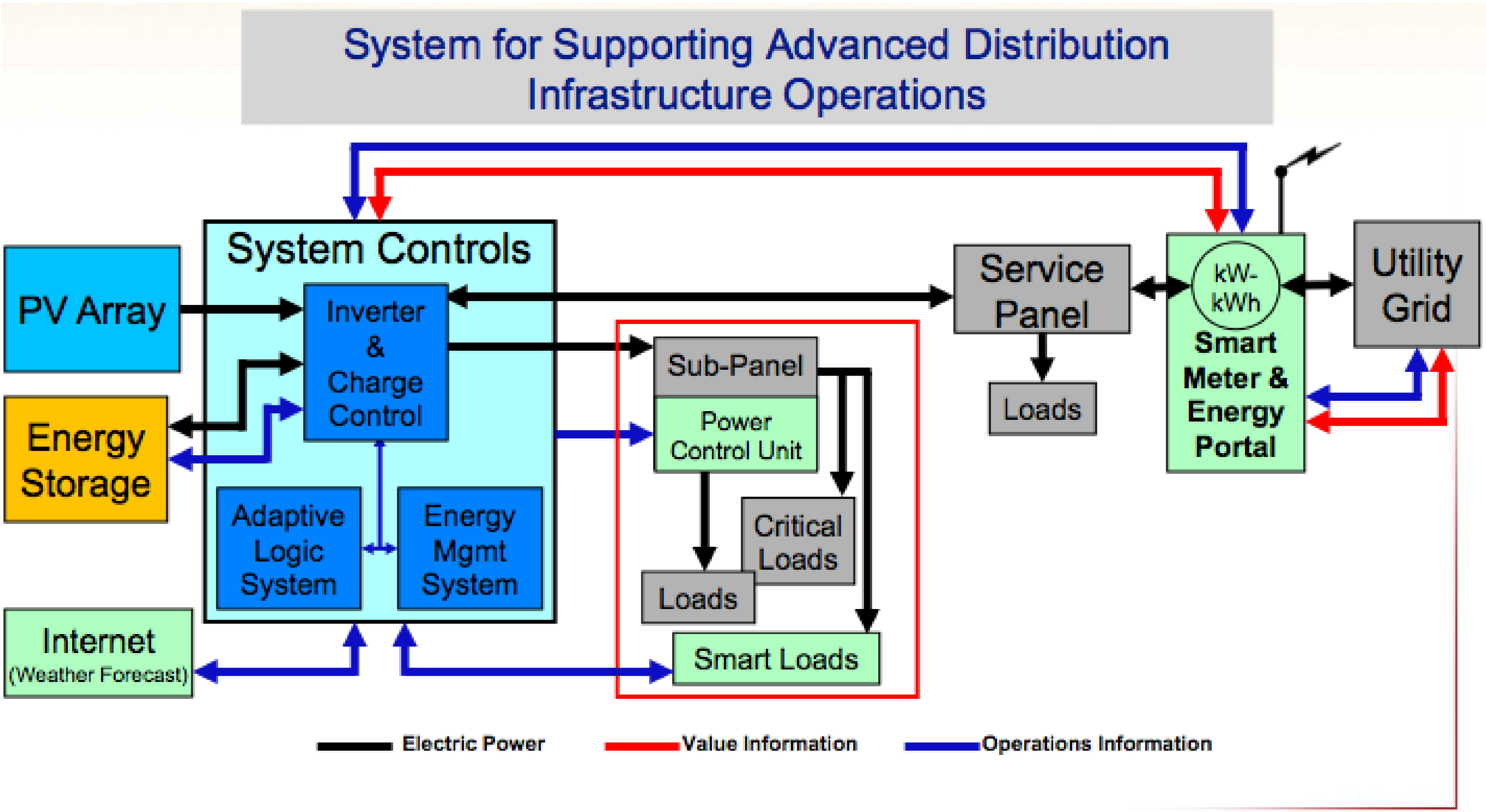
Energy Alternatives to Consider

Energy sources	Distribution/storage
Solar, biomass, wind, geothermal, ocean/hydro, coal, natural gas, diesel	Centralized generation, microgrid, fuel cells, generators
Energy technologies	**Emerging technologies**
Solar hot water, solar ventilation preheat, concentrating solar power, microturbines, HVAC ventilation	Liquid desiccant dehumidification, combined PV-solar thermal, solar powered parking lights

Energy Security Strategies

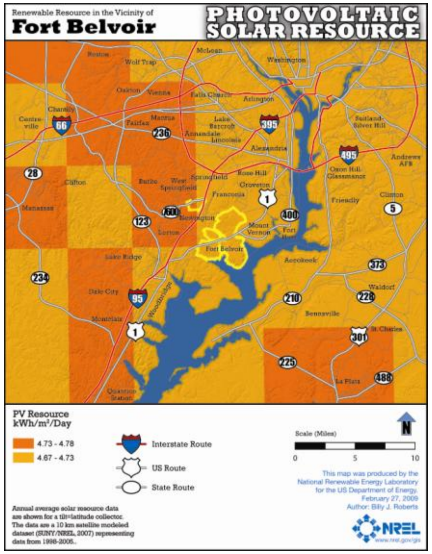
- Reduce consumption/improve efficiency
  - System monitoring and benchmarking, microgrids, green roofs, etc.
- "Islanding" critical missions from the commercial electric grid
- Alternative energy and storage
  - Microturbines, fuel cells, etc.
- Renewable energy
  - Biomass, landfill gas, municipal solid waste, geo-thermal, solar, wind, tidal, etc.

Example: Microgrid



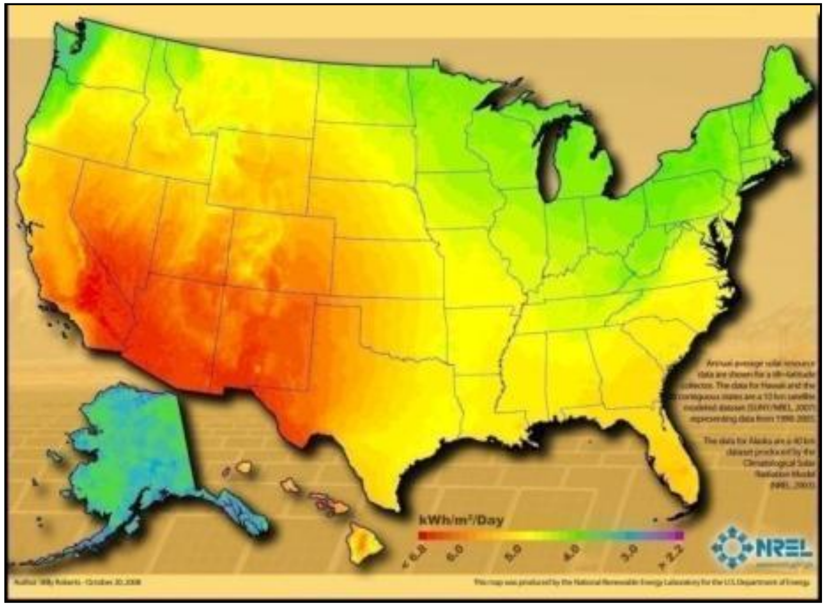
Source: Sandia National Laboratories

Example: Photovoltaics (Alternative)



Source: NREL and Ft. Belvoir

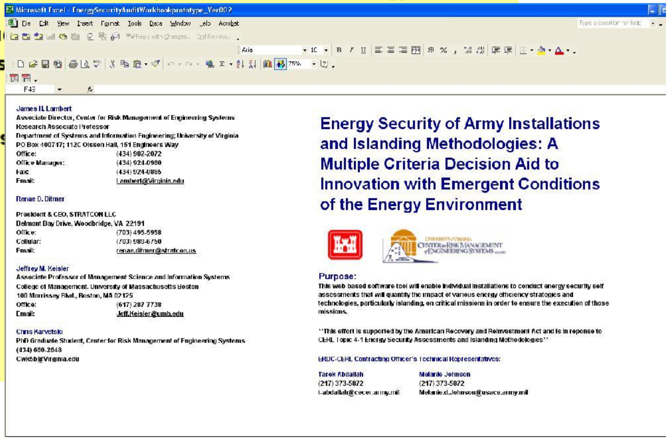
- Photovoltaic (PV) panels convert sunlight directly into electricity.
- "Fair" solar resources



US Solar Resource

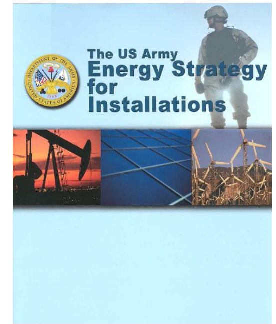
Alternatives in Software Workbook

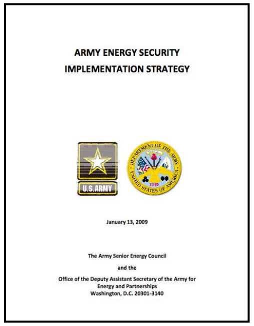
Alternative	☑	Description
ALT_01 Photovoltaic panels	☑	▪ PV panels convert sunlight directly into electricity (NREL presentation)
ALT_02 Solar hot water	☑	▪ Solar water systems use solar radiation to heat water (NREL presentation)
ALT_03 Solar ventilation preheat	☑	▪ tbd
ALT_04 Concentrating solar power	☑	▪ Mirrors are used to reflect and concentrate sunlight onto receivers that collect solar energy and convert to heat (NREL presentation)
ALT_05 Wind power	☑	▪ Wind turbines capture energy in wind and convert it into electricity (NREL presentation)
ALT_06 Biomass conversion	☑	▪ Can result in Ethanol, methane, syngas, biocrude (gasoline), and plant oil (diesel fuel) (NREL presentation)
ALT_07 Ocean/hydro power	☑	▪ Options include ocean current, ocean thermal, tidal, and wave (NREL presentation)
ALT_08 HVAC ventilation	☑	▪ Provides air purification by the use of bi-polar ionization technology and can result in energy cost redu
ALT_09 North side microgrid	☑	▪ Five subcritical bulidings
ALT_10 South side microgrid	☑	▪ Four subcritical buildings
ALT_11 Conventional hydroelectric	☑	▪ tbd
ALT_12 Microgrid	☑	▪ tbd
ALT_13 Micro-Hydro	☑	▪ tbd



Performance Criteria

Performance Criteria

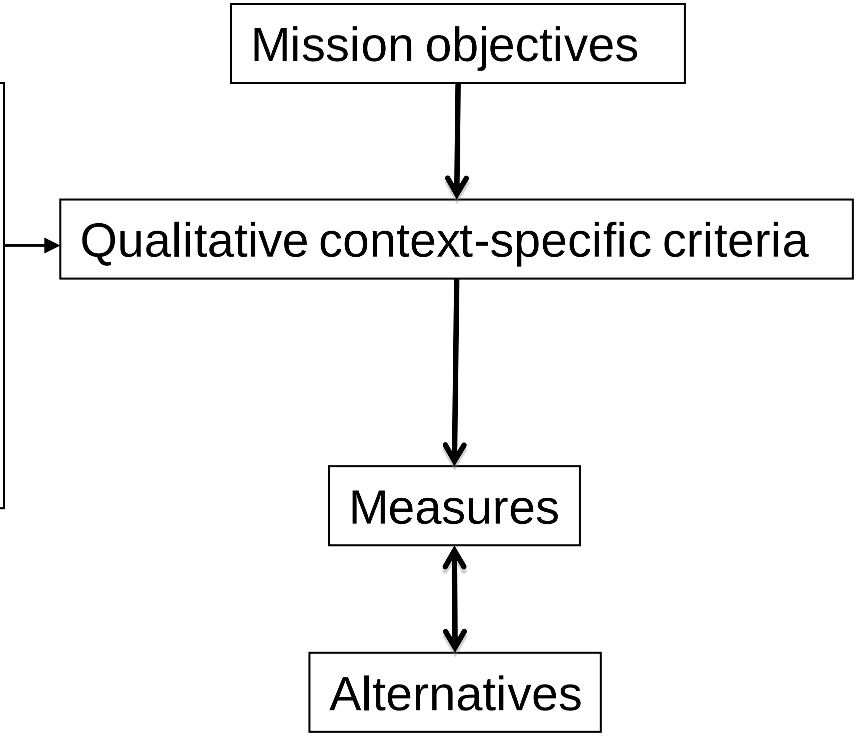



ARMY ENERGY SECURITY
IMPLEMENTATION STRATEGY

January 13, 2009

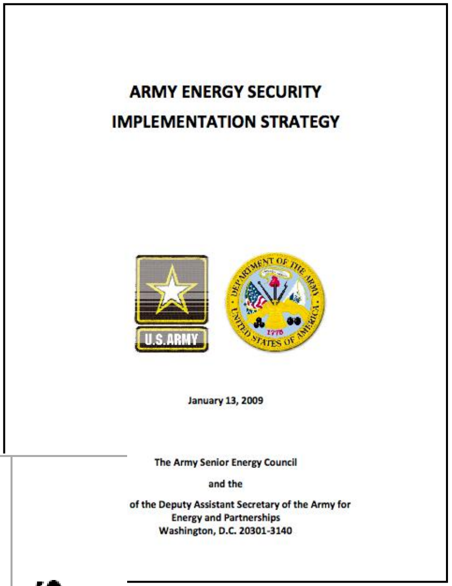
The Army Senior Energy Council
and the
Office of the Deputy Assistant Secretary of the Army for Energy and Partnerships
Washington, D.C. 20301-3140

- Maximize available energy
- Minimize frequency of shortfalls
- Maximize ease of repair
- Minimize downtime Minimize energy consumption
- Minimize environmental footprint of energy



Others will cover:
- Maintenance
- Sustainability
- Life cycle costs

Performance Criteria (cont.)


ARMY ENERGY SECURITY
IMPLEMENTATION STRATEGY

U.S. ARMY

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The Army Senior Energy Council
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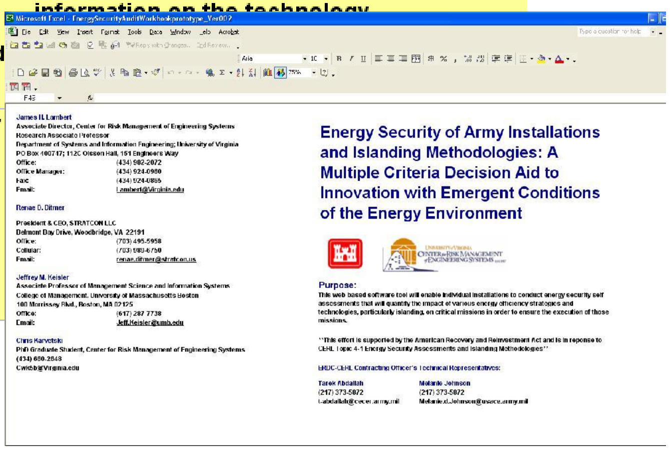
	ESG1. Reduced Energy Consumption	ESG2. Increase Energy Efficiency Across Platforms and Facilities	ESG3: Increased Use of Renewable/ Alternative Energy	ESG4: Assured Access to Sufficient Energy Supply	ESG5: Reduced Adverse Impacts on the Environment	OTHERS
C1. Increase kWh storage capacity for critical/essential missions and operations				+		
C2. Increase KWh production ability from within installation for critical/essential missions				+		
C3. Reduce variability of kWh for critical/essential missions and operations provided from renewable sources due to climatic variance				+		
C4. Reduce vulnerability of generation/storage capabilities for critical/essential missions and operations to extreme weather events				+		
C5. Reduce vulnerability of energy system for critical/essential missions and operations to malicious attack				+		
C6.Reduce likelihood of energy system for critical/essential missions and operations exploding or other catastrophe				+		

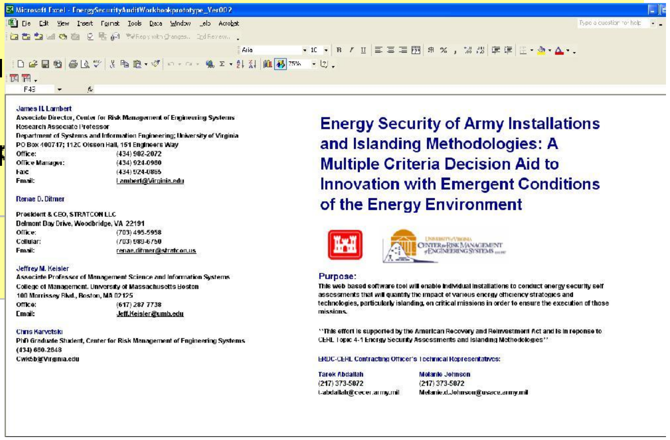
Performance Criteria (cont.)

	Performance Criteria	Notes
Maximize available energy	C1. Increase kWh storage capacity for critical/essential missions and operations	This could allow for islanding during outages
	C2. Increase KWh production ability from within installation for critical/essential missions	This could increase the surety of energy supply
Minimize frequency of shortfalls	C3. Reduce variability of kWh for critical/essential missions and operations provided from renewable sources due to climatic variance	This could increase energy surety if energy is provided by renewables
	C4. Reduce vulnerability of generation/storage capabilities for critical/essential missions and operations to extreme weather events	If weather events are deemed impactful, this could decrease energy shortfalls
	C5. Reduce vulnerability of energy system for critical/essential missions and operations to malicious attack	
	C6.Reduce likelihood of energy system for critical/essential missions and operations exploding or other catastrophe	
Maximize ease of repair	C7. Increase design maturity of technology for critical/essential missions and operations in years (is technology proven?)	This could increase the reliability information on the technology
	C8.Reduce complexity of energy system for critical/essential missions and operations	
Minimize downtime	C9.Decrease expected repair time/expected duration if energy system for critical/essential missions and operations fails	
	C10.Increase information lead-time of outage affecting critical/essential missions and operations	
	C11.Increase detectability of disruptive outage affecting critical/essential missions and operations upon occurring	



Performance Criteria (cont.)

Minimize energy consumption	C12.Reduce monthly kWh consumption of critical/essential missions and operations from domestic sources
	C13.Reduce monthly kWh consumption of critical/essential missions and operations from imported sources
	C14.Reduce monthly fuel consumption per volume unit of critical/essential missions and operations from domestic sources
	C15.Reduce monthly fuel consumption per volume unit of critical/essential missions and operations from imported sources
Minimize environmental footprint of energy	C16. Increase % buildings supporting critical/essential missions and operations using efficiency/passive technologies
	C17. Increase % of energy use supporting critical/essential missions and operations provided by renewable/alternative sources
	C18.Increase % of new/renovated building supporting critical/essential missions and operations with hot water from solar
	C19. Reduce lbs/kWh of harmful emissions and discharges generated p month from critical/essential missions and operations
	C20. tbd



Performance Criteria (cont.)

Alternatives

	ALT_01 Photovoltaic panels	ALT_02 Solar hot water	ALT_03 Solar ventilation preheat	ALT_04 Concentrating solar power	ALT_05 Wind power	ALT_06 Biomass conversion	ALT_07 Ocean/hydro power	ALT_08 HVAC ventilation	ALT_09 North side microgrid	ALT_10 South side microgrid	ALT_11 Conventional hydroelectric	ALT_12 Microgrid	ALT_13 Micro-Hydro	ALT_14 Fuel cells	ALT_15 Nucl	ALT_1
C1. Increase kWh storage capacity for critical/essential missions and operations	○	●	○	○	●	○	○	○	○	○	○	○	○		○	○
C2. Increase KWh production ability from within installation for critical/essential missions	○		○				○	●	●	○	○	○	○	●	○	
C3. Reduce variability of kWh for critical/essential missions and operations provided from renewable sources due to climatic variance	○	○	○	○	○		○	●		○	○	○	○	●	●	●
C4. Reduce vulnerability of generation/storage capabilities for critical/essential missions and operations to extreme weather events	○	●	○	○	●	●	○	●	●	○	○	○	○	●	○	○
C5. Reduce vulnerability of energy system for critical/essential missions and operations to malicious attack	○	●	●	●	●	●	○			●	●	●	●			●
C6.Reduce likelihood of energy system for critical/essential missions and operations exploding or other catastrophe	○						○	○	○					○		
C7. Increase design maturity of technology for critical/essential ... years (is technology proven?)	○	●	●		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
...gy system for critical/essential missions and operations	○	●	○	○	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Performance Criteria

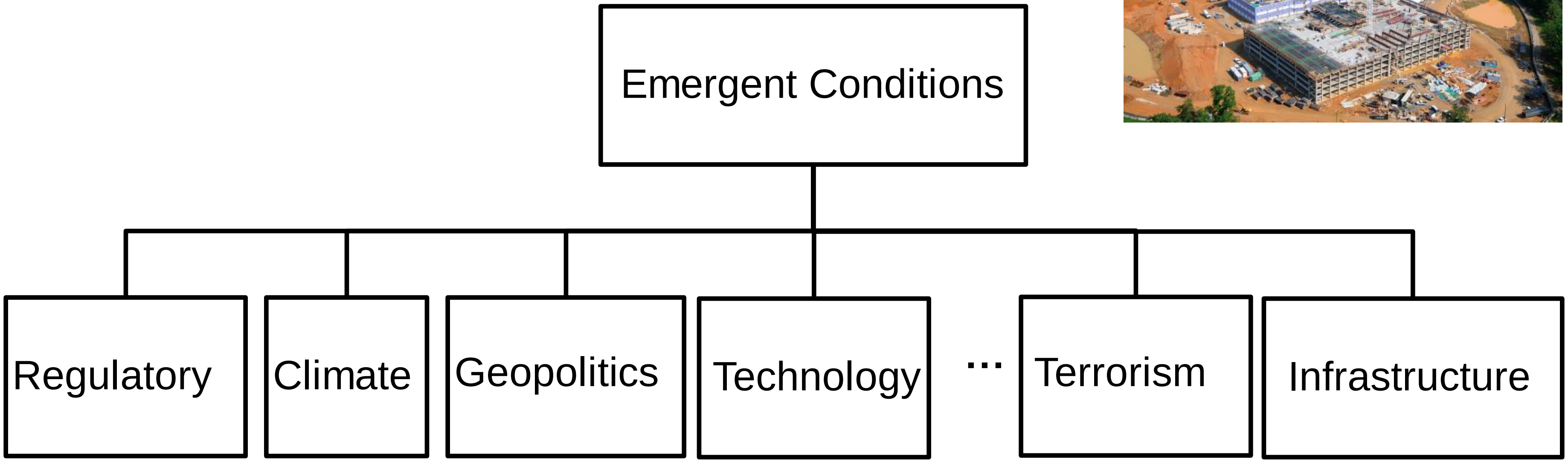
Assessments of alternatives on energy security performance criteria

Emergent Conditions

Consider **emergent conditions** of the energy environment in the evaluation of **energy-security alternatives** for installations.

The performance of energy-security alternatives will be influenced by the nature and extent of emergent conditions.

Emergent Conditions (cont.)



"In an age of terrorism, combustible and explosive fuels and weapons-grade nuclear materials create security risks. World market forces and regional geopolitical instabilities broadly threaten energy supplies. Infrastructure vulnerabilities pose further risks of disruption to Army installations."

Source: *Army Energy and Water Campaign Plan for Installations*

Emergent Conditions (cont.)

Emergent Conditions	Scenarios				
	S1	S2	S3	S4	S5
Large carbon emissions tax					
Large government subsidies for renewable energy				+	
Reemergence of nuclear technology					
Abandonment of nuclear technology					
Newly established Renewable Portfolio Standards					
Short-term national/regional energy blackout					
Long-term national/regional energy blackout					
Increased volatility in oil and gas prices and supply			+		
Oil and gas remain available and cost-effective	+				
Deterioration in geopolitics and war/peace/terrorism					+
Few changes in geopolitics and war/peace/terrorism					
Improvement in geopolitics and war/peace/terrorism					
Attack on national power grid					
Low growth in energy technology					
Moderate growth in energy technology					
High growth in energy technology		+			
Low environmental-movement impacts					
Moderate environmental-movement impacts					
High environmental-movement impacts				+	
Low national economic growth					
Moderate national economic growth					
High national economic growth		+			
Early realization of climate change					
National switch to solar energy					
Increase in National/International demand for energy security			+		
Stimulated demand for distributed energy					
Increase in demand for domestic energy sources			+		
Accelerated commercialization of renewable energy		+			
public investment in R&D in hydrogen and fuel cell technologies		+			
Prolonged drought/Inclement weather					

Scenarios are combinations of emergent conditions

Emergent Conditions (cont.)

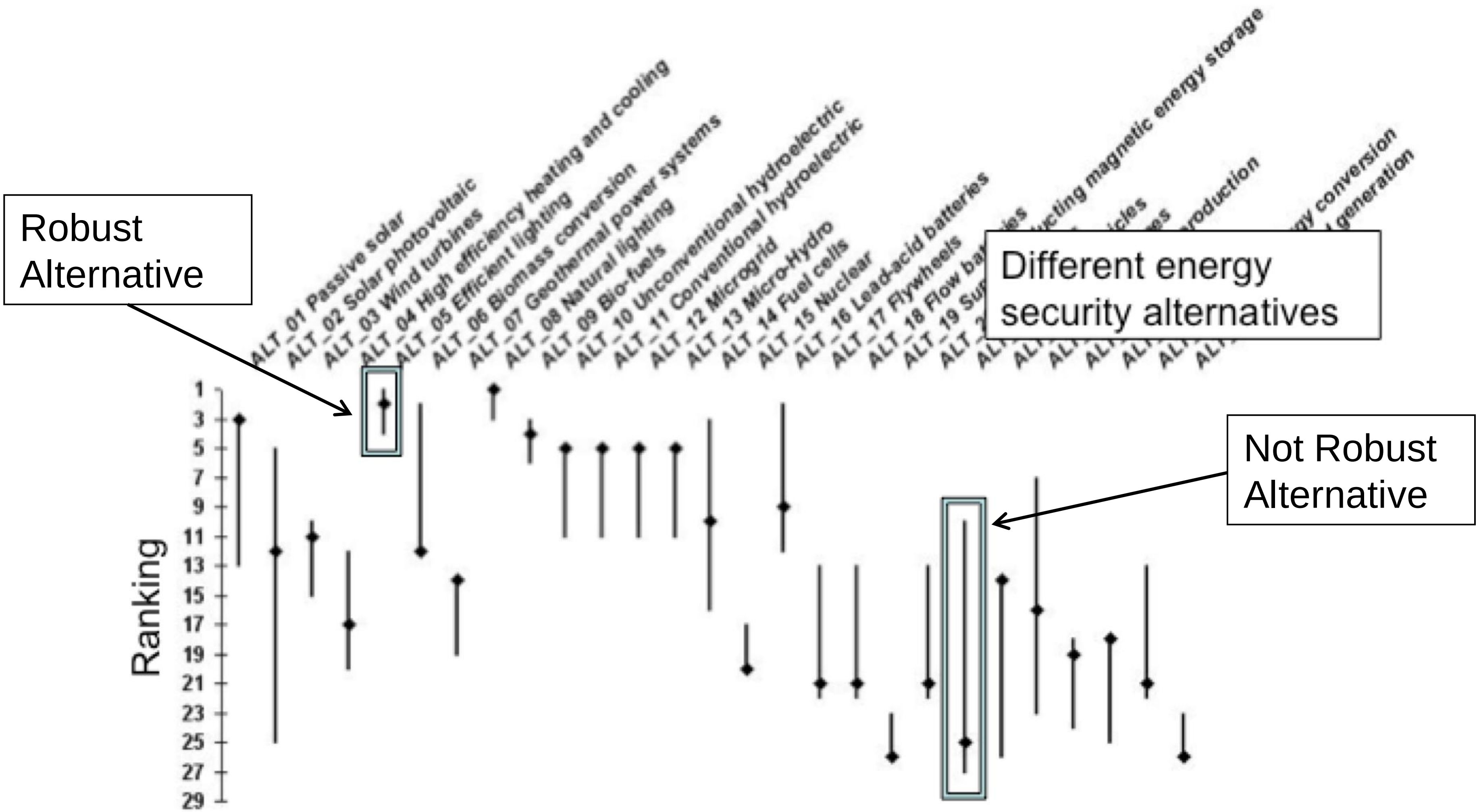
	EC_03 Reemergence of nuclear technology	EC_05 Newly established Renewable Portfolio Standards	EC_07 Long-term national/regional energy blackout	EC_12 Improvement in geopolitics an war/peace/terrorism	EC_18 Moderate environmental-movement impacts
C1. Increase kWh storage capacity for critical/essential missions and operations	Major Increase	Minor Increase	Minor Increase		
C2. Increase KWh production ability from within installation for critical/essential missions	Minor Increase				
C3. Reduce variability of kWh for critical/essential missions and operations provided from				Major Increase	
C4. Reduce vulnerability of generation/storage capabilities for critical/essential missions	Minor Increase	Major Increase	Major Increase		Major Increase
C5. Reduce vulnerability of energy system for critical/essential missions and operations to					
C6.Reduce likelihood of energy system for critical/essential missions and operations					
C7. Increase design maturity of technology for critical/essential missions and operations in					
C8.Reduce complexity of energy system for critical/essential missions and operations					
C9.Decrease expected repair time/expected duration if energy system for critical/essential					
C10.Increase information lead-time of outage affecting critical/essential missions and					
C11.Increase detectability of disruptive outage affecting critical/essential missions and		Major Increase			
C12.Reduce monthly kWh consumption of critical/essential missions and operations from		Minor Increase			
C13.Reduce monthly kWh consumption of critical/essential missions and operations from					
C14.Reduce monthly fuel consumption per volume unit of critical/essential missions and		Minor Increase			
C15.Reduce monthly fuel consumption per volume unit of critical/essential missions and					
C16. Increase % buildings supporting critical/essential missions and operations using					
C17. Increase % of energy use supporting critical/essential missions and operations					
C18.Increase % of new/renovated building supporting critical/essential missions and					
C19. Reduce lbs/kWh of harmful emissions and discharges generated per month from					

Performance Criteria

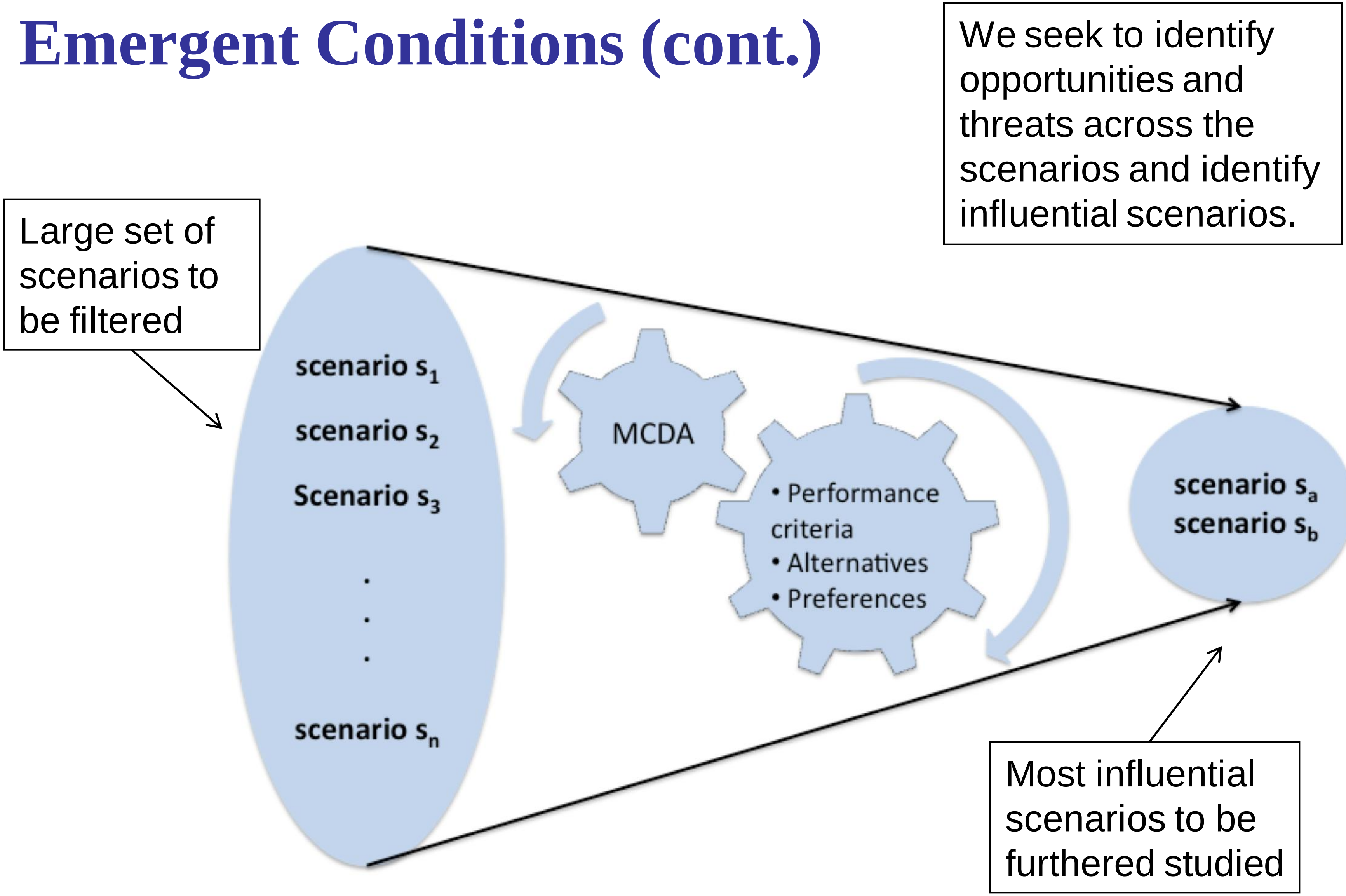
Scenarios influence of the acceptable tradeoffs across criteria

Emergent Conditions (cont.)

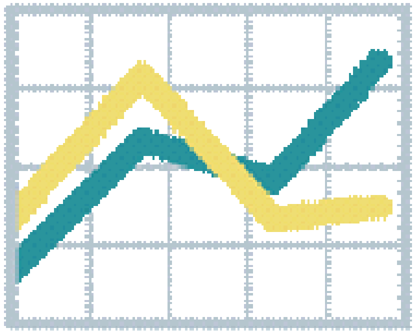
We seek to identify opportunities and threats across the scenarios and identify influential scenarios.



Emergent Conditions (cont.)



Emergent Conditions (cont.)



What scenarios are most influential or disruptive?	Scenario s_1, disrupts portfolio X_{03} from being the top prioritized portfolio.
What portfolios perform best?	X_{03} performs best under all but one considered scenario, s_1. Portfolio X_{02} ranked best under s_1.
What portfolios have upside potential to any of the additionally considered scenarios, $s_1,\ldots,s_5$?	X_{03} has upside potential to scenarios $s_2,\ldots,s_5$ and X_{05} has large upside potential to scenarios s_2 and s_4.
What portfolios have large downside potential to any of the additionally considered scenarios $s_1,\ldots,s_5$?	X_{01} has downside potential to scenarios s_2 and s_4 and X_{02} has large downside potential to the scenarios $s_2,\ldots,s_5$.

Summary of Approach

- Compares investments in energy security
- Supports analysis of off-grid energy generation and distribution networks
- Provides the opportunity, cost, and risk tradeoffs
- Supports incremental adjustments in energy security alternatives

Summary of Approach (cont.)

- Some products of this effort are expected to be useful to a related effort
  - *Strategic Choices for Energy Security of Army Installations: Implementation with Local and Regional Portfolios of Installations*
- Focus of the related ITTP effort is co-located installations and portfolios of installations

Acknowledgements

- This effort was sponsored in part by the
  - American Recovery and Reinvestment Act through Engineer Research and Development Center contract
  - Civil Works Basic Research Program by the U.S. Army Engineer Research and Development Center
  - Department of Army Installation Technology Transfer Program

End of Presentation