Power Technology and Alternative Energy Branch
US Army RDECOM CERDEC C2D Army Power Division
Aberdeen Proving Ground, MD

PTAE - TR – 09 – 01

CERDEC Co-generation and Absorption System Targets and Enabling Technologies

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
06 MAY 2009	**Presentation**	**06-05-2009 to 06-05-2009**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
CERDEC Co-generation and Absorption System Targets and Enabling Technologies Presentation to IAPG Mechanical Work Group	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Jonathan Cristiani	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
U.S. ARMY COMMUNICATIONS-ELECTRONICS RESEARCH DEVELOPMENT AND ENGINEERING CENTER,5100 Magazine Rd.,Aberdeen Proving Ground,MD,21005-1852	**; PTAE - TR - 09 - 01**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
U.S. ARMY COMMUNICATIONS-ELECTRONICS RESEARCH DEVELOPMENT AND ENGINEERING CENTER, 5100 Magazine Rd., Aberdeen Proving Ground, MD, 21005-1852	**RDER-CCA-PS**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)
	PTAE - TR - 09 - 01

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

An introduction to CERDEC's American Recovery and Reinvestment Act of 2009 program for smaller, lighter cogeneration and absorption environmental control systems is presented.

15. SUBJECT TERMS

absorption; cogeneration; waste heat utilization

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**22**	

CERDEC Co-generation and Absorption System Targets and Enabling Technologies

IAPG Mechanical Working Group Meeting, Philadelphia, PA

06 May 2009 08:30 AM

CERDEC
US ARMY – RDECOM

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Jonathan M. Cristiani, Renewable Energy Team Leader
Communications-Electronics Research Development Engineering Center
Command and Control Directorate Army Power Division
Power Technology and Alternative Energy (PTAE) Branch
Aberdeen Proving Ground, Maryland

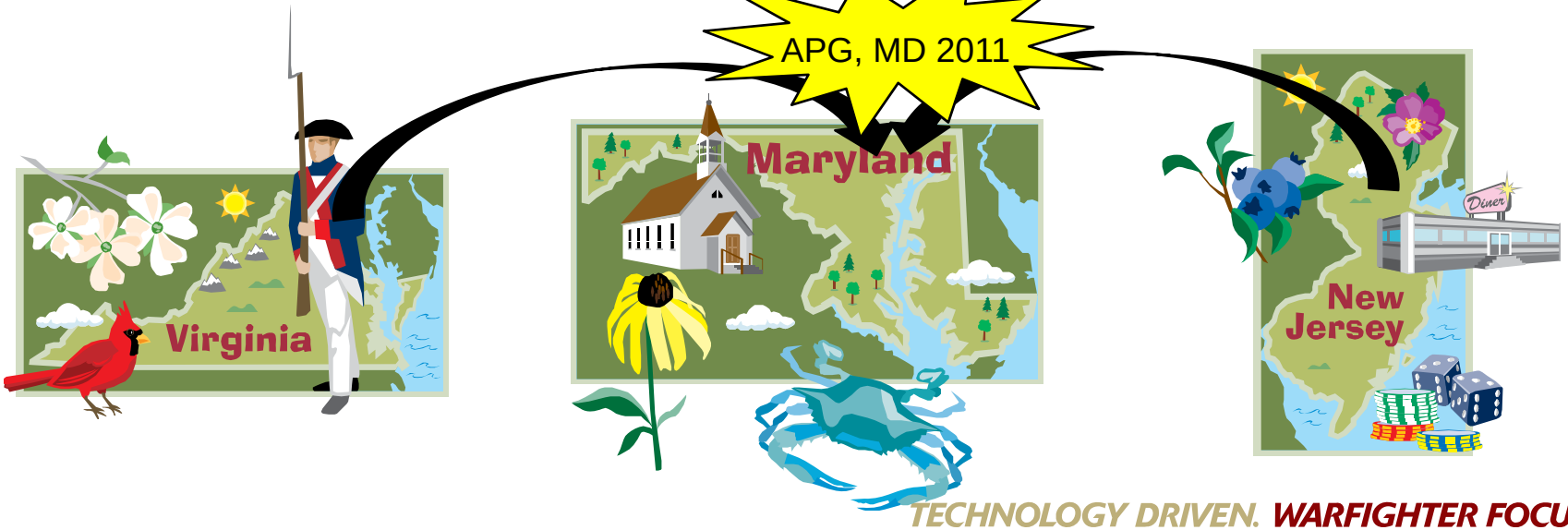
Agenda: 08:30 - 09:00

- Introduction
- Combined Cooling, Heating, and Power (CCHP) Technologies
- CCHP Applications
- CCHP Opportunities
- Closing

Army Power Division

- Engineering Support Branch
- Power Sources Branch
- Experimentation and Simulation Branch
- Power Technology and Alternative Energy Branch
  - Renewable Energy Team
  - Electromechanical Team
  - Special Projects Office

APG, MD 2011



Mission Summary
CERDEC Renewable Energy Team

Enabling Technologies

- Photovoltaic and Solar Concentrators
- Wind Turbines
- Fuel Processing, Waste-to-Energy, and Synthesis Gas to Liquids
- Thermoelectric
- Heat-actuated Cooling & Co-generation

Applications

- Tactical Mobile Power
- Vehicle-mounted Auxiliary Power and Environmental Control
- Portable Renewable and Fueled Power Sources
- Energy Security for Installation Operations
- Waste abatement

Objectives

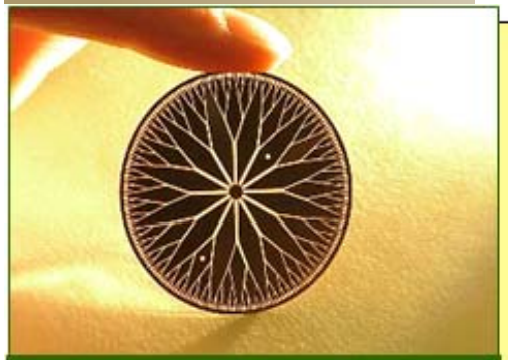
- Fuel Efficiency
- Force Protection
- Improved Mobility
- Reduced Signatures
- Reduced Logistics

CCHP Technologies

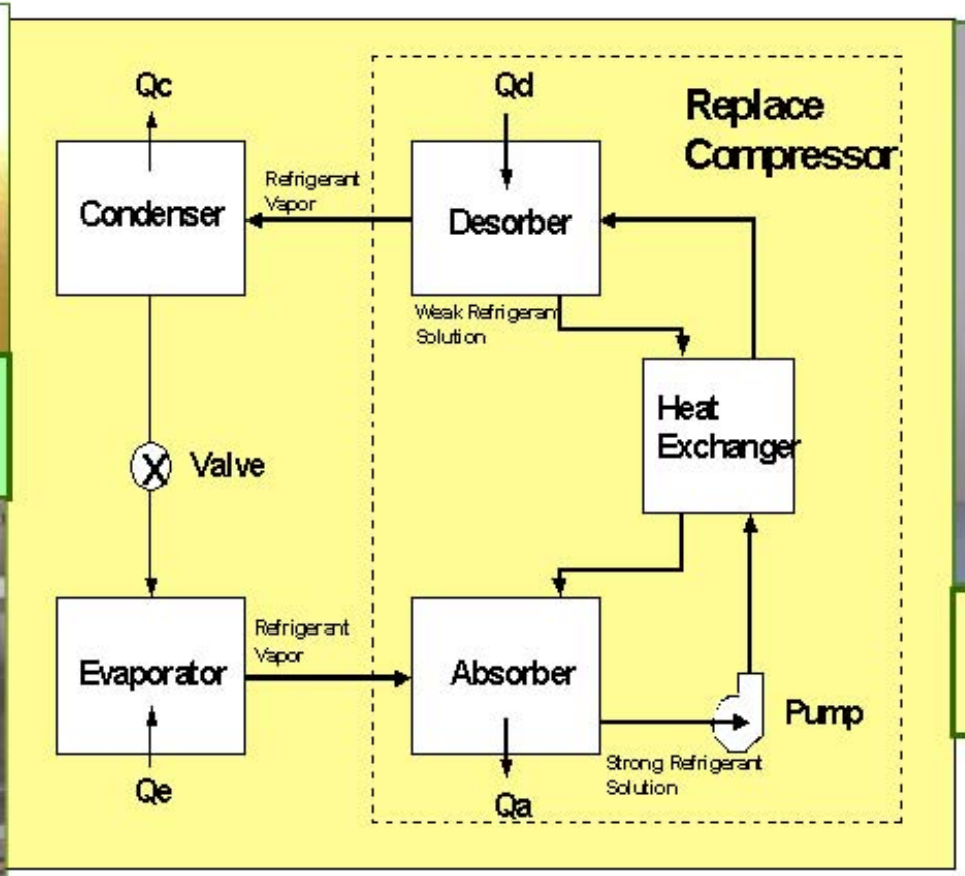
US Army CERDEC CCHP
Technologies & Objectives

- Enabling Technologies:
  - Novel heat exchanger geometries/materials, compressor designs, fluid handling/mixing, refrigeration cycles, and work recovery devices
  - Vapor compression – low-GWP fluorocarbons and natural refrigerants
  - Absorption – ammonia, lithium-bromide, and other novel cycles
  - Adsorption – zeolite/silica-gel/graphite/desiccant sorbents and heat pipes
  - Organic Rankine Cycle (ORC) and other waste energy utilization processes
- Objectives:
  - Combined power and environmental control units (reduced size, weight, and parasitic loads compared to stand-alone configuration)
  - Improved power generation and/or environmental control efficiencies
  - Safer, more environmentally-friendly refrigerants (non-flammable, low global warming, and zero ozone depletion)
  - Reduced logistics, maintenance requirements

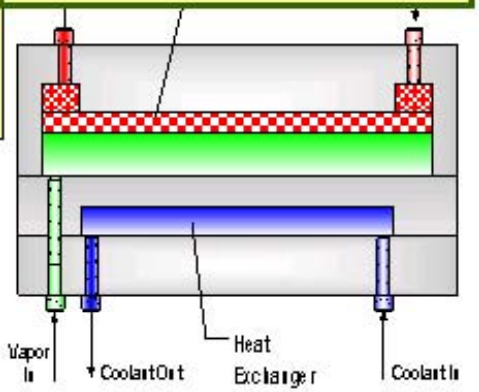
US Army CERDEC CCHP
Ammonia-Water Absorption



Fractal Desorber (100 µm channels)



Microwick Absorber (310 µm channels)



Work to-date performed in cooperation with Pacific Northwest National Lab (PNNL), Oregon State University, University of Oregon, and Portland State University

TRL 3 Breadboard Demonstrated FY08 (COP ~0.4)
TRL 4 Integrated Demonstrator in FY10

- Absorption-Specific Technology Hurdles:
  - Smaller, lighter, more efficient vacuum pumps for lithium-bromide (Li-Br)
  - Novel ways to prevent / mitigate crystallization for Li-Br
  - Increase coefficient of performance (COP) of ammonia-water absorption to be comparable with lithium bromide[1] and all absorption COP to be comparable with VC
  - Ammonia release monitoring, prevention, and mitigation
  - Operation on low-quality waste heat from power source
- Generalized CCHP Technology Hurdles:
  - Operation in extreme cold environments below water freezing point
  - Longevity and safety characteristics of various sorbents and desiccants
  - Some CCHP technologies that show potential for very low system dry weight have inferior fuel consumption compared with traditional systems already in-use
  - Lowering the cost/availability of microchannel heat exchangers to tube and fin prices through breakthrough manufacturing process development
  - Part-load performance of power source and/or waste energy recovery devices
  - Some of best work recovery devices also tend to be the loudest (turbines, etc)

- The low-GWP refrigerant replacements:
  - Replacements for R-134a in vehicular heating ventilation and air conditioning (HVAC) systems are still being debated (CO_2 vs. HFO-1234yf)
  - Replacements for R-22 are tentatively R-407 and R-410a, which have been agreed upon as the near-term standards for stationary / mobile HVAC units by PM MEP
- Flammable and/or toxic fluids for either application will be a tough sell to the Army requirements and safety communities (hydrocarbons, HFO-1234yf, ammonia, metal hydrides, etc.)
- Thermal degradation, performance, and safety characteristics of each refrigerant should be well-understood prior to system development/integration

CCHP Applications

Project Manager Mobile Electric Power (PM MEP) Managed Items[2]

Small Sets

- 2kW Military Tactical Generator, Manportable/Skid Mounted, Diesel/JP8 Fueled, AC(60Hz) and DC(28VDC)
- 3kW Tactical Quiet Generator, Skid Mounted, Diesel Fueled (60 Hz and 400Hz)


Medium Sets

- 5kW, 10kW, 15kW, 30kW, and 60kW, Skid Mounted, Diesel Fueled Tactical Quiet Generator, 60Hz and 400Hz
- AMMPS – Advanced Medium Mobile Power Sources



Large Sets

- 100kW and 200kW Tactical Quiet Generator (TQG), Skid Mounted, Diesel Fueled, 60Hz
- 840kW Deployable Power Generation and Distribution System (DPGDS), Diesel Fueled


Power Unit/Power Plant (PU/PP)

- Trailer Mounted Tactical Quiet Generators in the 3kW, 5kW, 10kW, 15kW, 30kW, 60kW, 100kW, and 200kW Power Ratings.
- 20 Different Models That Use 4 Different But Standardized TACOM Trailer Models


Power Distribution Illumination System Electric (PDISE)

Man-portable, Reliable, Modular, Quick Assembly Standardized Electrical Management and Distribution System Components

40 AMP/PHASE DISTRIBUTION SYSTEM
60 AMP DISTRIBUTION SYSTEM
100 AMP/PHASE FEEDER SYSTEM
200 AMP/PHASE FEEDER SYSTEM
UTILITY RECEPTACLE AND LIGHTING KIT

HI-POWER

Hybrid Electric Intelligent Power Management

Develop a Tactical Hybrid–Electric Power System for use at Forward Operating Bases to minimize logistics fuel consumption related to power generation.

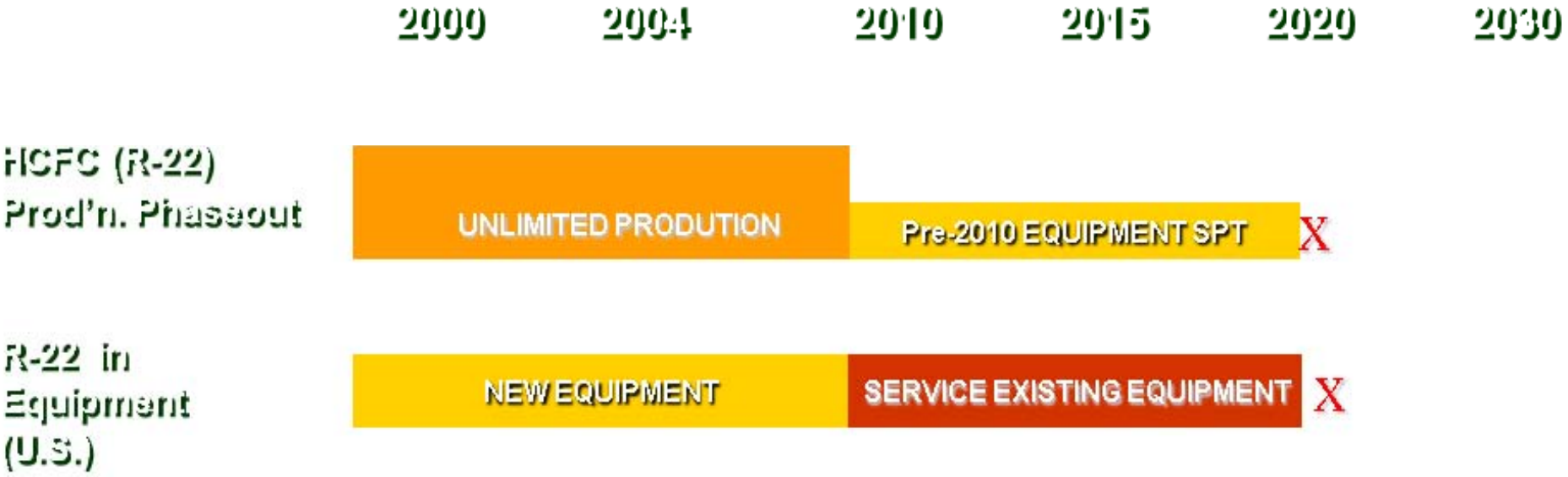

Improved Environmental Control Units (IECU)

New Generation of ECUs Utilizing Zero Ozone Depleting Refrigerants. Ruggedized Form, Fit, and Function Replacement Systems with Embedded Diagnostics.

9K, 18K, 36K, and 60K BTUH sizes.

HCFC R-22 Phase-Out

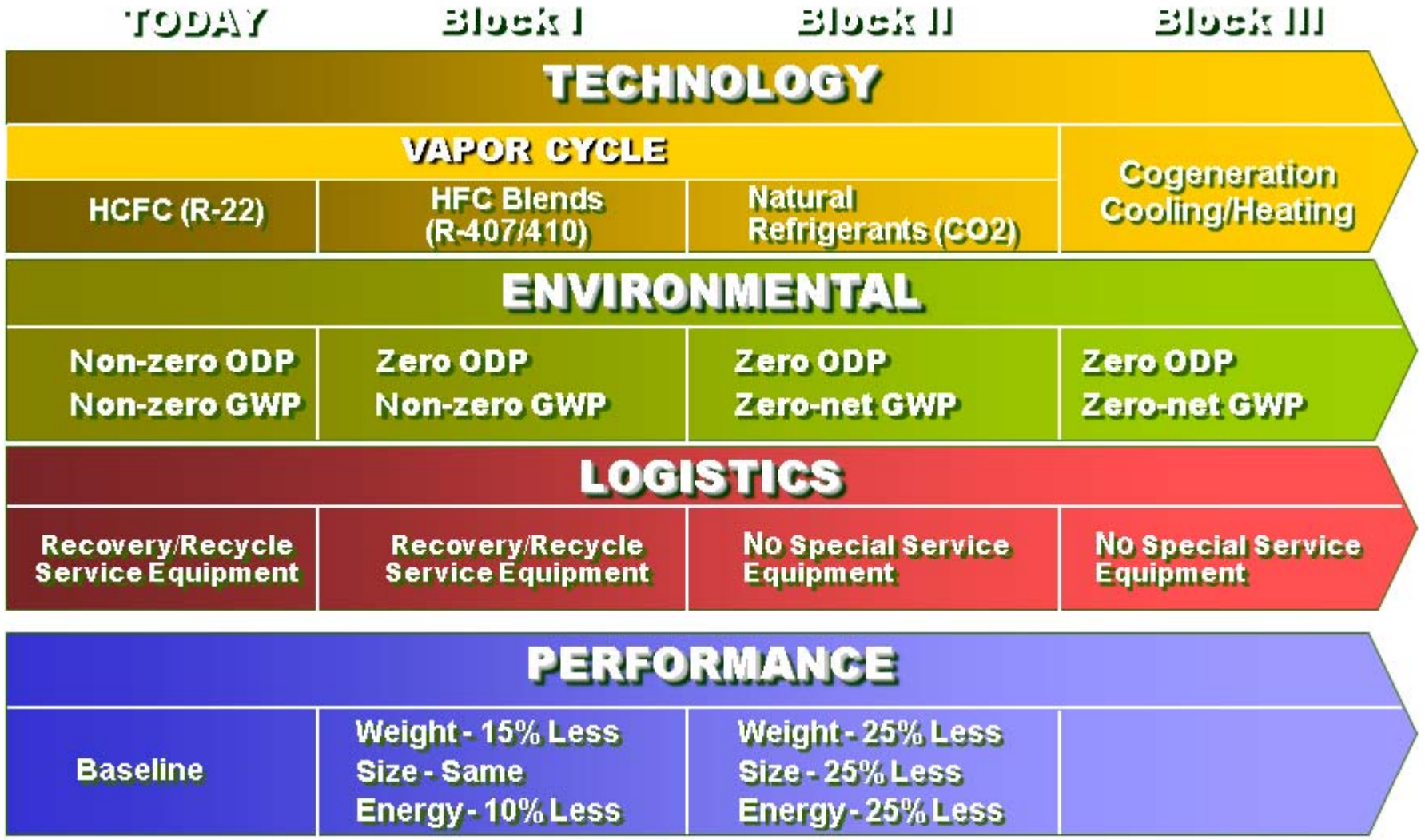
Clean Air Act - Phase-Out of Production and Consumption of R-22



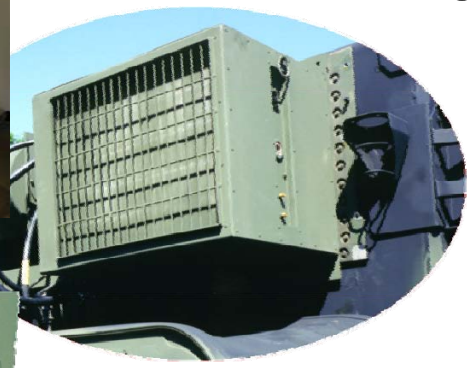
Operational Requirements Document approved October 2004

- **Blk I: Zero ozone depleting refrigerants**
- **Blk II: Blk I plus Zero-net Global Warming**
- **Blk III: Blk II plus self-powered w/Exportable Power**

US Army Environmental Control Unit (ECU) Roadmap



Standard Integrated Command Post Shelter (SICPS)



- Fielded System[3]:
  - o 290-kg total dry weight (ECU+APU)
  - o 1-gal/hr (3.8-L/hr) fuel consumption
  - o 75-dB(A) inside shelter
  - o 208-kg, 10-kWe APU
    - o 3600-rpm turbocharged engine
  - o 82-kg, 5.3-kWt (1.5-ton) ECU
    - o Vapor compression
    - o Split-pack with R-134a
- CERDEC FY11 CCHP Targets:
  - o TRL-5: Integrated demonstrator
  - o 205-kg total dry weight (ECU+APU)
  - o 0.7-gal/hr (2.6-L/hr) fuel consumption
  - o 55-dB(A) inside shelter
  - o 3-kWe net power, 5.3-kWt cooling

Soft-wall Shelters and Tents

- Fielded System[3]:
  - o 1120-kg total dry weight (ECU + Gen)
  - o 1.5-gal/hr (5.7-L/hr) fuel consumption
  - o 920-kg, 15-kWe Tactical Quiet Gen (TQG)
  - o 200-kg, 10.5-kWt (3-ton) ECU
    - o Vapor compression (VC)
    - o Unitary with R-22
- Next-Generation (AMMPS and IECU):
  - o 994-kg total dry weight (ECU + Gen)
  - o 1.275-gal/hr (4.8-L/hr) fuel consumption
  - o 814-kg, 15-kWe AMMPS
  - o 180-kg, 10.5-kWt (3-ton) IECU (VC, R-410a)
- CERDEC FY11 CCHP Targets:
  - o TRL-5: Integrated demonstrator
  - o 840-kg total dry weight (ECU + Gen)
  - o 1.05-gal/hr (4-L/hr) fuel consumption
  - o 5-kWe net power out , 10.5-kWt net cooling

CCHP Applications
Mission Weight Analysis

Mission Weight: Various Technologies

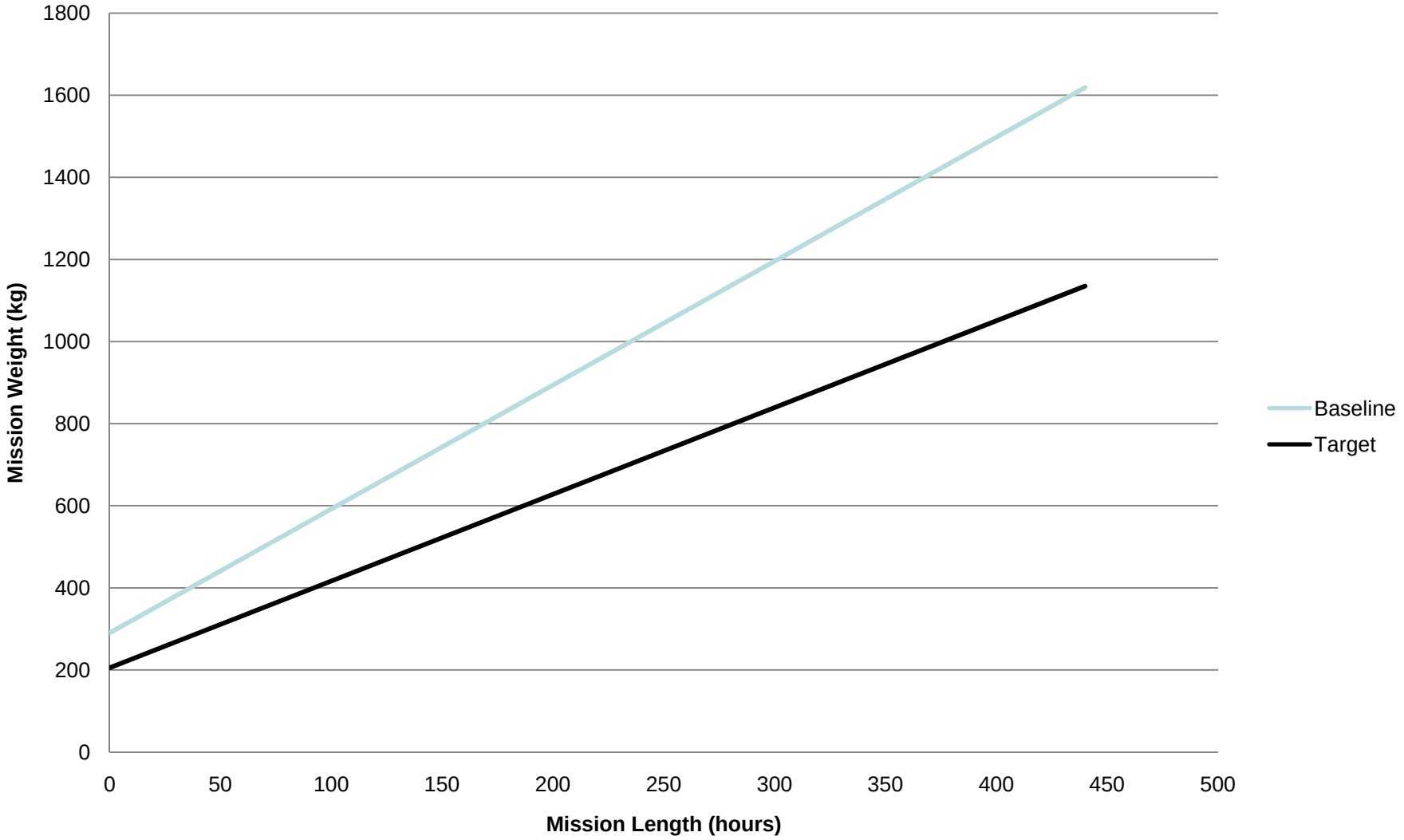
SICPS Application

Mission time	Baseline	Target
GAL/HR:	*1*	*0.7*
hour	**kg**	**kg**
0	290	205
40	410.8	289.56
80	531.6	374.12
120	652.4	458.68
160	773.2	543.24
200	894	627.8
240	1014.8	712.36
280	1135.6	796.92
320	1256.4	881.48
360	1377.2	966.04
400	1498	1050.6
440	1618.8	1135.16

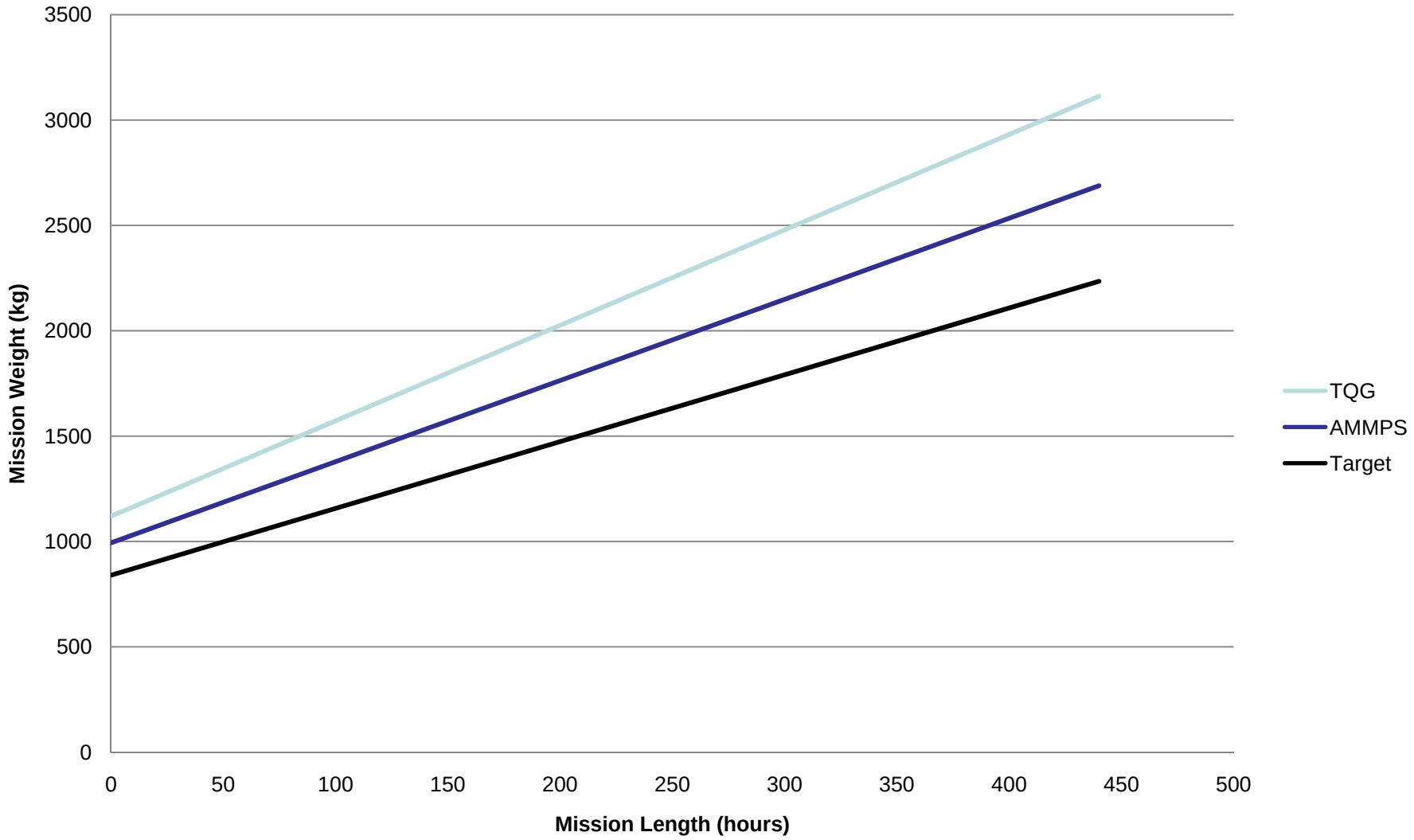
Tent Application

Mission time	TQG	AMMPS	Target
GAL/HR:	*1.5*	*1.275*	*1.05*
hour	**kg**	**kg**	**kg**
0	1120	994	840
40	1301.2	1148.02	966.84
80	1482.4	1302.04	1093.68
120	1663.6	1456.06	1220.52
160	1844.8	1610.08	1347.36
200	2026	1764.1	1474.2
240	2207.2	1918.12	1601.04
280	2388.4	2072.14	1727.88
320	2569.6	2226.16	1854.72
360	2750.8	2380.18	1981.56
400	2932	2534.2	2108.4
440	3113.2	2688.22	2235.24

CCHP Systems for a 3-kWe / 5.3-kWt SICPS Application



CCHP Systems for a 5-kWe / 10.5-kWt Tent Application



- **RECOVERY / STIMULUS** for Smaller Lighter Co-generation and Absorption Environmental Control Technologies
  - BAA #W909MY-09-R-0011
  - Released: 13 Apr 2009, Closes: 15 May 2009
  - Proposals that show the greatest potential to fully-address one or both topics while simultaneously **creating or retaining the greatest number of jobs** are preferred
- **Small Business Innovative Research (SBIR) Topic #A09-090** - Heat Actuated Cooling
  - Now in pre-solicitation
  - Proposals accepted from 18 May 2009 until 17 June 2009

Closing

- Microchannel heat exchangers, ejector heat pumps, and other near-term CCHP component enhancements hold significant promise, but require manufacturing and process technology development prior to becoming cost-competitive with tradition VC
- Major component-level technical breakthroughs are needed to bring absorption technologies to the field and make them competitive on a weight and size basis with VC and other CCHP
- Refrigerant characteristics need to determined up-front: toxic, flammable, and/or expensive fluids will be a tough sell to the operational community
- Low dry weight for a CCHP system is NOT viewed as favorable by the user community if fuel consumption exceeds that of the baseline
- Know your system's waste heat characteristics over entire operational profile PRIOR to designing your waste energy recovery device (especially at part-loads)

References

1. Horuz, I. “A comparison between ammonia-water and water-lithium bromide solutions in vapor refrigeration systems.” International Communications in Heat and Mass Transfer, Vol. 25, Issue 5, July 1998, Pg. 711.

2. Richard, Paul. “Mobile Electric Power for Today and Tomorrow.” Joint Service Power Expo, 25 April 2007. PM MEP Website: http://www.pm-mep.army.mil/pdffiles/Joint_Service_Power_Expo_25Apr07.pdf

3. Department of Defense (DoD) Project Manager for Mobile Electric Power (PM MEP) Website: http://www.pm-mep.army.mil/technicaldata/index.htm