Total Resource Utilization (TRU) Habitat

WP19-5211

James Pilkington, PE
Naval Facilities Engineering and Expeditionary Warfare Center

Final Debrief

05 August 2022

ESTCP

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
05/08/2022	ESTCP Project Outbrief	

4. TITLE AND SUBTITLE

Total Resource Utilization (TRU) Habitat

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

James Pilkington
Tami Relph
Gene Griffin

5d. PROJECT NUMBER
WP19-5211

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Facilities Engineering and Expeditionary Warfare Center
1000 23rd Avenue
Port Hueneme, CA 93043

8. PERFORMING ORGANIZATION REPORT NUMBER

WP19-5211

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Environmental Security Technology Certification Program
4800 Mark Center Drive, Suite 16F16
Alexandria, VA 22350-3605

10. SPONSOR/MONITOR'S ACRONYM(S)

ESTCP

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

WP19-5211

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The technical objectives of this project are listed below:

- Reduce solid and liquid waste streams at forward operating bases (FOBs)
  - -Eliminating transportation requirements of waste
  - -Eliminating open burn pits
  - -Reuse of graywater and treatment of blackwater
- Demonstrate individual capability and interoperability of:
  - -Solid waste Micro Auto-Gasification System (MAGS)
  - -Liquid waste Wastewater Electrochemical Treatment Technology (WETT) units

15. SUBJECT TERMS

Total Resource Utilization, TRU, Habitat

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			James Pilkington
UNCLASS	UNCLASS	UNCLASS	UNCLASS	29	19b. TELEPHONE NUMBER *(Include area code)* 805-982-1335

Project Team

Performer	Responsibility	POC
	Navy	
NAVFAC EXWC	Principal Investigator	James Pilkington, PE James.t.pilkington.civ@us.navy.mil
	Project Engineer	Gene Griffin gene.s.griffin.civ@us.navy.mil
	Project Engineer	Hunter Klein hunter.w.klein.civ@us.navy.mil
	Contractors	
Sustained Turn Reuse Recovery & Resource	Project Management, Test Development, Data Collection, Technical Support	Russ Emons Russ.Emons@SustainedTurn.com
TERRAGON Environmental Technologies Inc.	Technology Provider, Test & Analysis Support	Dr. Theodora Alexakis Theodora.Alexakis@terragon.net
	Technology Provider, Test & Analysis Support	Dr. Ramona Pristavita Ramona.Pristavita@terragon.net

Technical Objectives

- Reduce solid and liquid waste streams at forward operating bases (FOBs)
  - Eliminating transportation requirements of waste
  - Eliminating open burn pits
  - Reuse of graywater and treatment of blackwater
- Demonstrate individual capability and interoperability of:
  - Solid waste Micro Auto-Gasification System (MAGS)
  - Liquid waste Wastewater Electrochemical Treatment Technology (WETT) units

Performance Objectives

Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Quantitative Performance Objectives			
Solid Waste Reduction	% Organic waste mass reduction	>90%	Yes
Liquid Waste Reduction	% volume reduction	>90%	Yes
Water Quality	Treated effluent characteristics *(COD, BOD_5, TSS, TN, TP, pH, Total Coliform, E. coli, TDS, turbidity, hardness, free Cl^- residual)*	NSF/ANSI 350 standard (GW) TB MED 577 standard (GW) US EPA NPDES standard (BW)	No
Water Recovery	% wastewater available for reuse	60%	No
Thermal Energy Production	in kWh/h	>100kWh/h @ sustained 50kg/hr standard recipe solid waste input	Yes
Energy Use	Assess kWh/m^3 overall for site	<50% of existing fuel consumption for FOB waste and water operations	No
Transportability	System size and compactness	Fit each appliance into two Tricons or a single 20 ft. Intermodal container	Yes
Payback Period	CAPEX/OPEX costs	<12 months	No

Performance Objectives

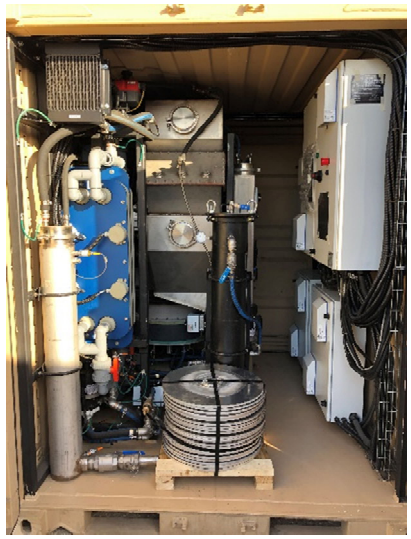
Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Qualitative Performance Objectives			
Ease of Use	Feedback from users on the system	Duties within skillset of on hand military Occupational Specialties	Not Demonstrated
Suitability for Operating Environment	Recorded issues related to temperature, humidity, and dust	Data collected to enhance ruggedness of follow-on iterations	Yes

Site Description

- Weapons and Tactics Instructor (WTI) Course
- Outside MCAS Yuma, Arizona
- Representative FOB environment
- Hosted by MAWTS-1
- 510 participants
- 8 week exercise
- 4 week demonstration

Test Design

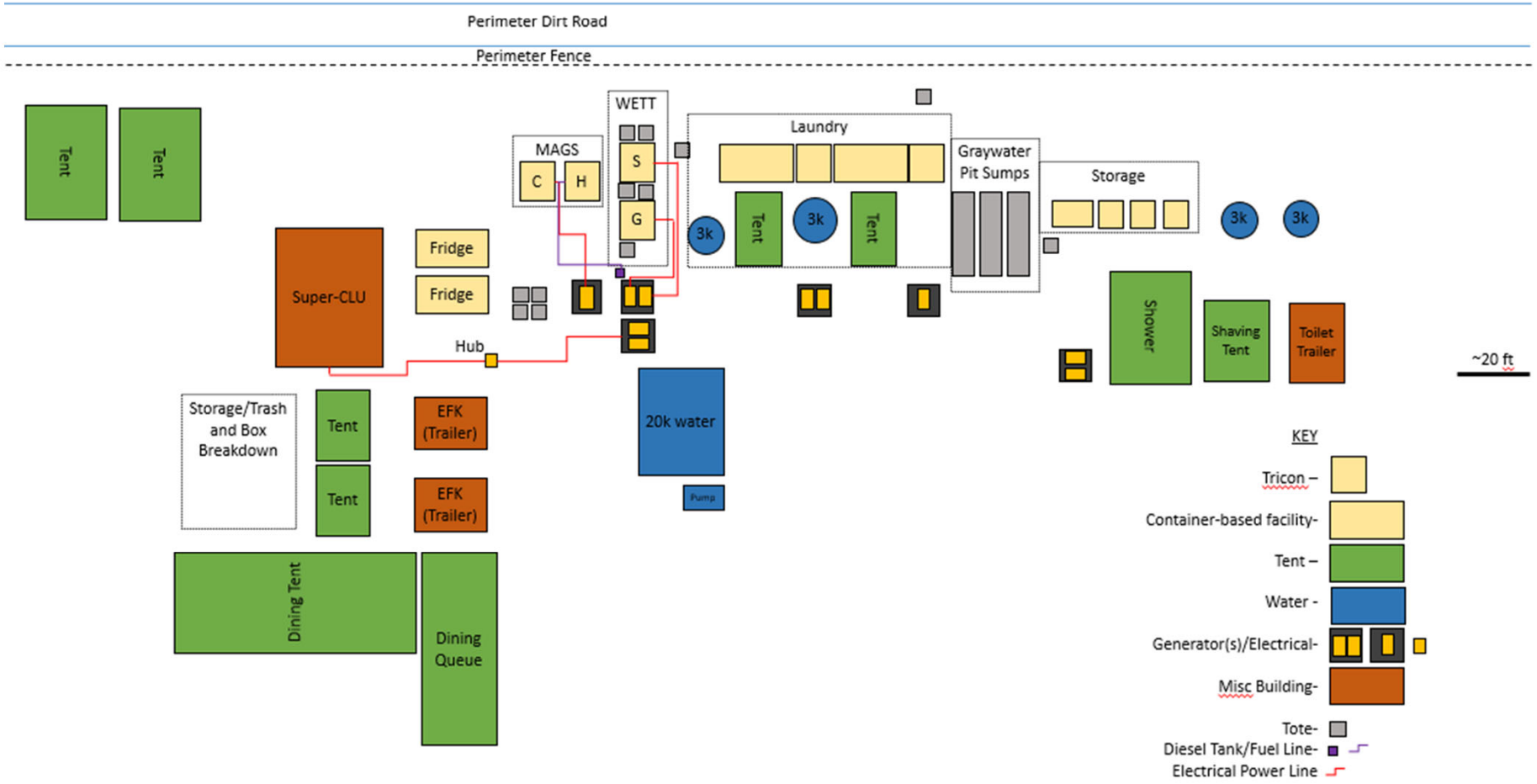
- Designed, built, and factory tested at Terragon
- Delivery to EXWC at Port Hueneme, CA
- Site confirmation and Demonstration Plan
- Inspected and later transported to Yuma, AZ



Design **Build** **Deliver**

Test Design

- Site layout and utility connections
- Baseline characterization from MWSS 371 notes



Test Design

- System commissioning
- Input power metering
- Water quality monitoring
- Waste characterization

Test Design

Dates and Activities	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Week
- Equipment Delivery - TRU Team Arrives	2/28/2021	3/1/2021	3/2/2021	3/3/2021	3/4/2021	3/5/2021	3/6/2021 System Delivery & MWSS Arrives	0
- Set-up of TRU Habitat at WTI - Begin Processing Water/Solids	3/7/2021 System Layout	3/8/2021 System Connection & Power Layout	3/9/2021 Laboratory Set-up	3/10/2021 Toilet Trailer Arrives	3/11/2021	3/12/2021 MAGS Operational	3/13/2021	1
- Commission WETT systems	3/14/2021	3/15/2021	3/16/2021	3/17/2021	3/18/2021	3/19/2021 WETT-G Operational	3/20/2021	2
- Field and Lab Testing	3/21/2021	3/22/2021	3/23/2021 WETT-S Operational	3/24/2021	3/25/2021	3/26/2021	3/27/2021	3
- System Decommissioning and Transport	3/28/2021	3/29/2021	3/30/2021	3/31/2021	4/1/2021 Disconnect System	4/2/2021 Stage for Transport	4/3/2021	4

Legend	
	Field Test
	Field and Lab Tests
	MAGS Lab Samples

Performance Assessment

Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Solid Waste Reduction	% Organic waste mass reduction	>90%	Yes

- Char effluent is non-hazardous and land-fillable
- Processed
  - Cardboard, Mess Hall Trash, Food Waste, Plastic, Fuel Contaminated Sand, Office Trash, Used WETT Filter Bags, Used MAGS Filter Bags, Meals Ready-to-Eat (MRE) Trash, MRE Flameless Heating Elements (Iron, Magnesium, Salt)
- Influent / Effluent:
  - Material Treated 3,128 lbs.
  - Char Produced 183 lbs.
  - Weight Reduction 94.1%

Performance Assessment

Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Liquid Waste Reduction	% volume reduction	>90%	Yes

- All liquids entering TRU are processed
- Excess sludge is dewatered
  - Solids are sent to MAGS
  - Liquids are sent to WETT-S
- Sludge volumes were not measured
- Past studies show sludge volumes of 5%
  - WETT-G sludge = 2% solids
  - WETT-S sludge = 5% solids

Performance Assessment

Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Water Quality	Treated effluent characteristics *(COD, BOD_5, TSS, TN, TP, pH, Total Coliform, E. coli, TDS, turbidity, hardness, free cl^- residual)*	NSF/ANSI 350 standard (GW) TB MED 577 standard (GW) US EPA NPDES standard (BW)	No

- WETT-G and WETT-S did not meet reuse standards
- Lack of water quality sampling
- WETT-S difficulties
- Highly concentrated blackwater influent streams

Constituent	Normal	WTI Conditions
COD	2,000-3,000	10,000+
pH	6-8	3-6

- Demonstration duration

Performance Assessment

Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Water Quality	Treated effluent characteristics *(COD, BOD_5, TSS, TN, TP, pH, Total Coliform, E. coli, TDS, turbidity, hardness, free cl^- residual)*	NSF/ANSI 350 standard (GW) TB MED 577 standard (GW) US EPA NPDES standard (BW)	No

- WETT-G Reductions
  - COD 45.1%
  - Turbidity 92.4%
  - TDS 64.3%
  - TSS 75%

- WETT-S Reductions
  - COD 63.1%
  - Turbidity 83.3%
  - Conductivity 13.6%

Performance Assessment

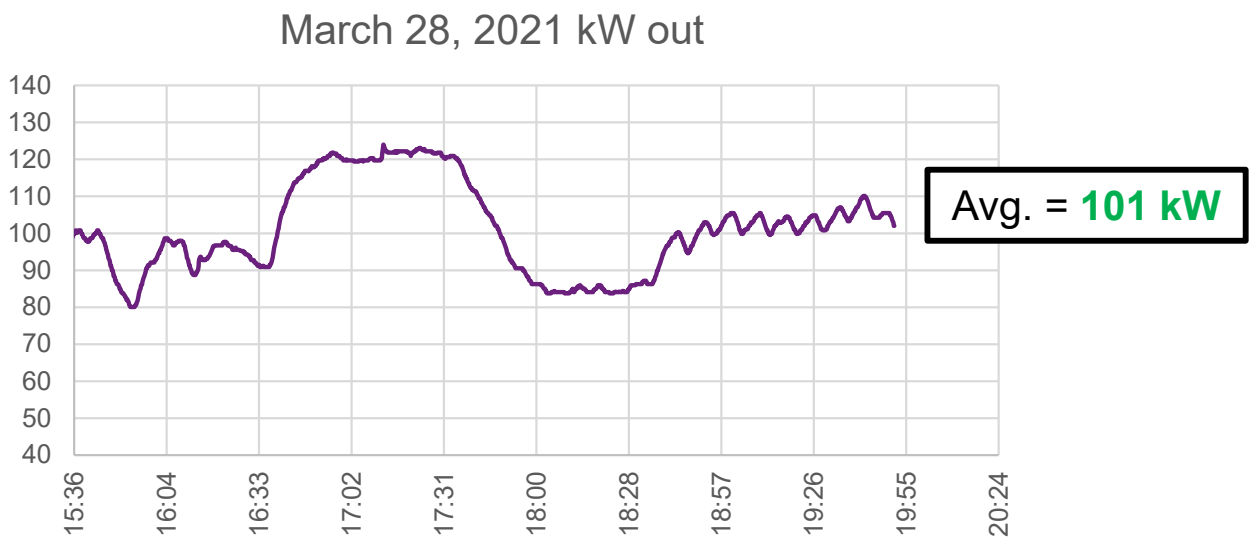
Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Water Recovery	% wastewater available for reuse	60%	No

- Effluent water did not meet full standards
  - Laundry wash water, dust suppression, toilet flushing, vehicle washing, construction use, firefighting
- No onsite reuse approved
- Parameters passed
  - pH, Total Nitrogen, TDS
- Parameters failed
  - Coliforms, Chlorine, BOD/COD, TSS, Turbidity
- Positive results expected when lessons learned are implemented

Performance Assessment

Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Thermal Energy Production	in kWh/h	>100kWh/h @ sustained 50kg/hr standard recipe solid waste input	Yes

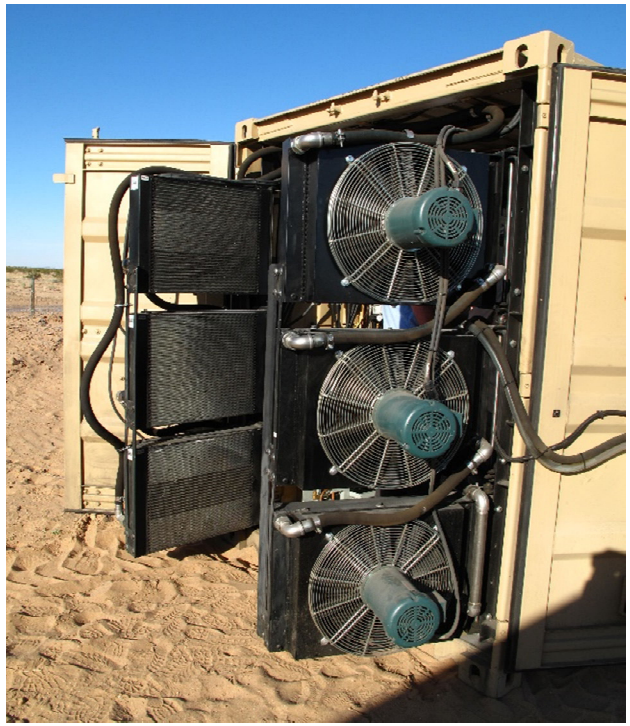
- Demonstration average of 69.9 kW output
- Dependent on influent solid waste composition and volume
- Higher loading (lbs/hr) = Higher energy output
- MAGS was not run at full capacity during the demo
  - Average throughput = 17 kg/hr



Performance Assessment

Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Energy Use	Assess kWh/m^3 overall for site	<50% of existing fuel consumption for FOB waste and water operations	No

- Graywater
  - WETT-G = 2.6 kWh/m^3
  - Contracted disposal = 8.47 kWh/m^3
- Blackwater
  - WETT-S = 12.4 kWh/m^3
  - Contracted disposal = 12.7 kWh/m^3
- Solid Waste
  - MAGS = 260 kWh/m^3
  - Contracted disposal = 4.2 kWh/m^3
  - With waste heat reuse = +397.3 kWh/m^3



Liquid waste contracted disposal costs are based on the transportation fuel savings due to WETT's reduction in potable water demand (due to non-potable reuse). Solid waste contracted disposal costs are based on the fuel required to remove and dispose of solid waste at the FOB.

Performance Assessment

Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Transportability	System size and compactness	Fit each appliance into two Tricons or a single 20 ft. Intermodal container	Yes

- No damage occurred during shipment and setup
  - Montreal, Quebec to Port Hueneme, CA
  - Port Hueneme, CA to Yuma, AZ
  - Yuma, AZ to Port Hueneme, CA
- Trucking transport
- Forklift transport

Performance Assessment

Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Payback Period	CAPEX/OPEX costs	<12 months	No

- High initial cost for only a four-week demonstration
- Calculated three scenarios
  1. Four-week WTI demonstration
  2. Two eight-week WTI events
  3. 48-week operation in similar environment to WTI
- Need to reuse MAGS thermal energy

Scenario	Total Run Time (Weeks/Year)	ROI (Years)	Success Criteria Achieved?
1	4	112.4	No
2	16	10.6	No
3	48	1.36	No

Lessons Learned

- Need accurate information on expected waste streams
- Need accurate baseline data
- Dedicated water sampling personnel
- Separate liquid waste streams based on concentration and volume
- Mix graywater with highly concentrated blackwater
- Utilize MAGS thermal heat
- Increase demonstration duration

Cost Assessment

- Simple payback period (ROI) calculation was used for cost assessment
- Recurring costs include consumables and spare parts
- Yearly reduction of fuel use is the path to the largest cost savings
- Indirect cost savings not included in ROI
  - Human health benefits of not using burn pits
  - Force protection benefits of limiting FOB in/out traffic
  - Convoy reductions

Cost Assessment

- Cost Assessment consists of objective and subjective measures.
  - Objective costs drivers modeled after NIST 135 life cycle cost assessment.
    - Commodity cost vary widely – Yuma costs used
    - Reduced to fuel quantity converted to $, and labor hours.
  - Subjective factors expressed in terms of Force Protection, Operational flexibility, etc. are not quantified in this presentation.
- Comparison made between TRU subcomponents and available technologies
  - Solid Waste: MAGS : Expeditionary Solid Waste Disposal System (ESWDS)
  - Greywater: WETT-G : Shower Water Reuse System (SWRS)
- Bottom Line:
  - TRU is the only system that generates cost savings in all operational use cases.
  - Payback period accelerates with commodity costs

Scale-up

- Scale-up increases cost savings
- Demonstration identified valuable lessons learned
- Proper WETT calibration for anticipated waste streams
- No issues with system to system connections
- Full-scale site logistics require detailed planning (footprint, piping, power, disposal)
- WETT EC capacity increase is undergoing testing
- Different configurations possible
  - Normal – MAGS, WETT-G, WETT-S
  - Water Heavy – MAGS, 2x (WETT-G & WETT-S)
  - Solids Heavy – 2x MAGS, WETT-G, WETT-S

Next Steps

- Ideal Scenario
  - Implement lessons learned
  - Complete additional demonstration at WTI
- Immediate Path Forward
  - Complete Final Report
  - Complete Acquisitions Package
  - Transition system to interested parties
    - US Army ERDC Construction Engineering Research Laboratory
    - Marine Corps Air Ground Combat Center Twentynine Palms
    - NAVFAC EXWC ExPO Expeditionary Basing

Technology Transfer

- 2021 SERDP ESTCP Symposium Presentation
  - ♦ Audio and video
- Acquisition Package
  - ♦ Still in development, Fact Sheet included
- Installation Reach Out
  - ♦ MCAGCC 29 Palms, ExPO
  - ♦ MCB Camp Pendleton
- ESTCP Webinar

Key Points

- MAGS is robust and reliable for solid waste reduction
- WETT systems can address previously untreated waste streams
- MAGS and WETT compliment each other to form TRU
- Highly mobile and robust system
- Force protection benefits confirmed in demonstration

BACKUP SLIDES

WP19-5211: Total Resource Utilization Habitat

Performers:

- NAVFAC EXWC, Terragon Inc., Sustained Turn Corp.

Technology Focus

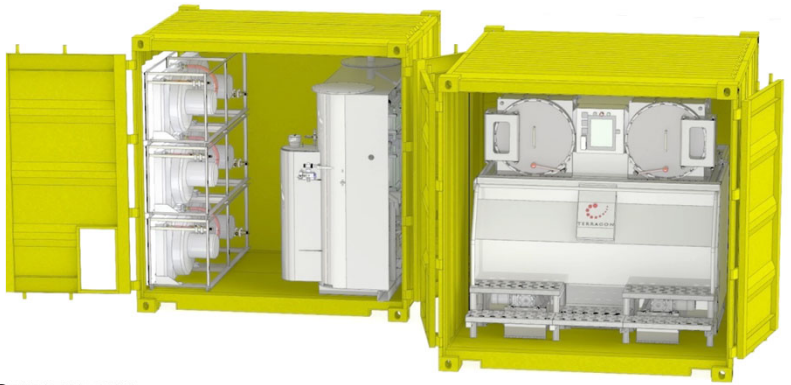
- Interoperable solid waste gasification unit with electro-coagulation/electro-oxidation technologies for solid and liquid waste processing, reuse, and energy recovery

Demonstration Site

- USMC Weapons and Tactics Instructor's (WTI) course in Yuma, AZ

Demonstration Objectives

- Reduce solid/liquid waste disposal by 90%, with 60% water recovery



Project Progress and Results

- Demonstration completed at 2021 Spring WTI

Implementation Outlook

- Detailed presentation with audio/video available
- Acquisition Package & Fact Sheet
- Providing test results to potential new users
- Continued successful demonstration will pave way to implementation and technology transition