



# ENERGY STAR®

## Residential Dishwasher Cleaning Performance Stakeholder Webinar

U.S. Department of Energy  
U.S. Environmental Protection Agency  
February 27, 2012

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2	Summary of Stakeholder Comments
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# Residential Dishwashers



- ENERGY STAR Version 5.0 Residential Dishwasher Specification became effective January 20, 2012
- EPA intends to add the ENERGY STAR Test Method for Determining Residential Dishwasher Cleaning Performance (in development) to the test requirements for the future Version 6.0 specification

# EPA–DOE Memorandum of Understanding



- On September 30, 2009, EPA and DOE signed a memorandum of understanding (MOU) designed to enhance and strengthen the ENERGY STAR program

EPA: Brand Manager	DOE: Technical Support
<ul style="list-style-type: none"><li>• New Products</li><li>• Performance Levels</li><li>• Marketing &amp; Outreach</li><li>• Product Database</li><li>• Monitoring &amp; Verification</li></ul>	<ul style="list-style-type: none"><li>• Test Methods</li><li>• Metrics</li><li>• Monitoring &amp; Verification</li></ul>

# EPA-DOE ENERGY STAR Team



- As part of the MOU, DOE is the lead for writing and updating ENERGY STAR test methods
- Navigant is contracted by DOE to write new test methods and validate and/or update existing test methods
- DOE team will provide overview and support of findings related to the test method

# Webinar Objective

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- Discuss stakeholder feedback on Phase 1 testing presented at the Dishwasher Cleanability Webinar, September 19, 2011
- Review Phase 2 testing approach and results
- Discuss Draft 1 Test Method

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# Comments Overview



- Received comments from 14 stakeholders on Phase 1 testing
- Comments were in five key areas:
  - Test goals
  - Test method
  - Repeatability and reproducibility
  - Reference dishwasher
  - Scoring method for cleaning performance evaluation

# Test Goal Comments



- Cleaning performance should be determined on the same cycles as energy and water consumption
  - Provides meaningful comparison to consumers
  - Avoids increased test burden of operating additional cycles for cleanability
- Cleaning performance should include the heavy, medium, and light soil cycles
  - Mitigates possibility of circumvention

# Test Method Comments



- DOE test procedure in 10 CFR 430, Subpart B, Appendix C should be used for determining cleaning performance
  - AHAM DW-1-1992, as referenced in Appendix C, should be used for soil preparation and application
    - Maintain grid and half-plate soiling
    - Minimizes test burden
    - Harmonizes with energy and water measurement
  - No filter cleaning between test cycles
- IEC 60436 is well-established, but would add significant cost and test burden

# Repeatability and Reproducibility Comments



- The primary criterion for evaluating the test method is that it be repeatable and reproducible
- Differentiation among units is secondary
  - Low differentiation is acceptable if the repeatability is high

# Reference Dishwasher Comments



- Use of reference dishwasher supported by multiple stakeholders
- Should be specifically designed
- Unlikely that a manufacturer would produce a U.S.-specification reference unit due to cost and complexity
- Some manufacturers have the reference dishwasher specified in IEC 60436
- No third party labs currently have the IEC reference dishwasher but some may be willing to purchase it

# Scoring Method Comments



- Scoring method from one test procedure should not be used to evaluate results of a different test procedure
  - Because no scoring method is referenced in the DOE test procedure, any technique may be acceptable
- AHAM scoring method may be the most appropriate method to use for ENERGY STAR because U.S. technicians have most experience with it

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# Phase 2 Testing Objectives



- Evaluate the viability of the DOE test procedure as a measure of cleaning performance
  - Derive cleanability from heavy, medium, and light soil cycles
- Determine repeatability with this approach
- Investigate impact of a reference dishwasher with the DOE test procedure

# Units Tested



- Conducted performance testing on 9 units at an internal DOE laboratory
  - Five units repeated from Phase 1 testing
  - One non-soil sensing dishwasher
- Seven units met 2012 Tier 1 criteria
  - One unit met water consumption criteria but not energy use
  - One unit met 2009 criteria but not 2012 criteria
- Used IEC reference dishwasher for normalizing the performance of all units

# Phase 2 Test Method



- Operated two preconditioning cycles on soil-sensing units to ensure turbidity sensor calibration
- Performed heavy, medium, and light cycles per Appendix C
- Repeated the test series three times on each unit with filter cleaning and clean-up cycles between each test series
  - Done to observe repeatability of test method
  - Only one series would be required for DOE certification and ENERGY STAR qualification

# Scoring Methods Investigated



- Focused on two scoring methods that produced most repeatable results from Phase 1:
  - IEC scoring method
  - DOE-developed Hybrid scoring method intended to address limitations of IEC method for many small particles
- Did not further investigate AHAM scoring method after it was shown to produce least repeatable results in Phase 1 testing
- Operator learning curve for AHAM and IEC scoring methods are comparable

# Calculation of Performance Metric Investigated



- Investigated three calculation methods:
  - 100-point Performance Metric
    - Developed based on Cleaning Index calculation in AHAM DW-1-2009
  - 100-point normalized Performance Metric
    - Similar to 100-point Performance Metric but normalized to the performance of the reference dishwasher for each cycle
  - IEC calculation method
    - Logarithm of ratio of unit-under-test (UUT) performance and reference unit performance

# Additional Investigative Tests



- Performed additional repeatability tests to investigate turbidity sensor response
- Tested effect of loading pattern on Performance Metric
- Analyzed results to determine variability associated with grader
- Evaluated constant soil load in reference dishwasher for all three test cycles

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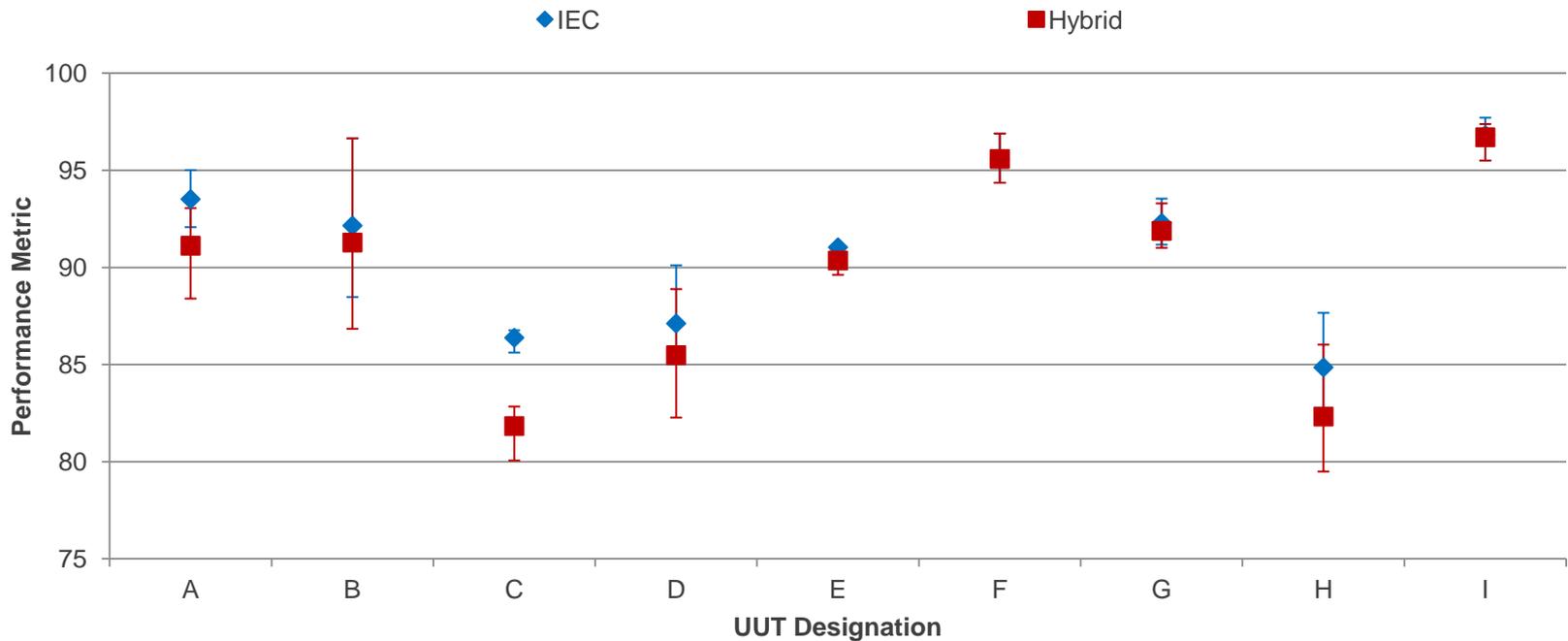


# Scoring Method and Calculation

# Comparison of Scoring Methods



- IEC scoring method is proposed in Draft 1
  - Provides more repeatable results than hybrid scoring
  - Scores items from 0 (most dirty) to 5 (clean)

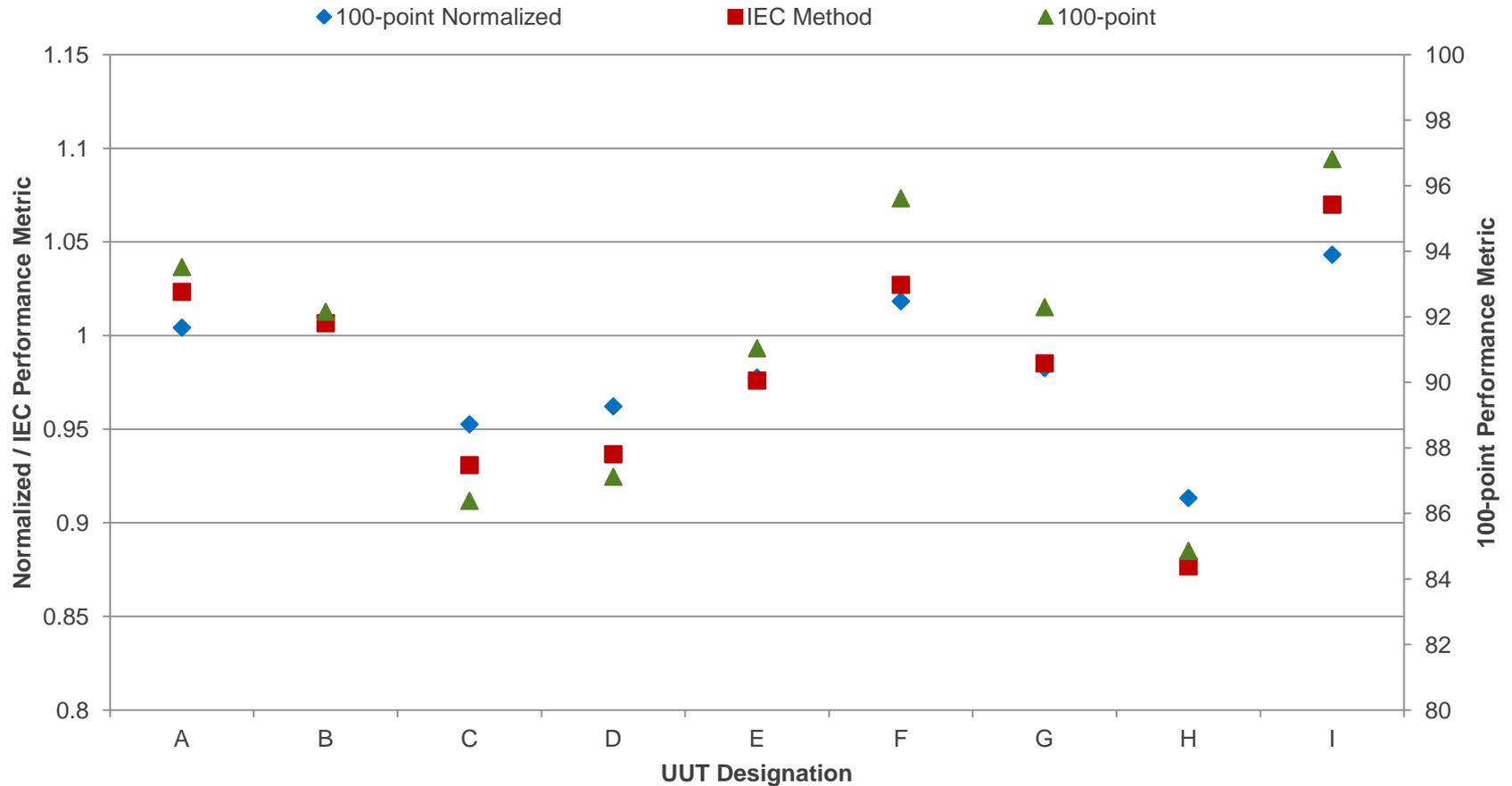


# Calculation of Performance Metric

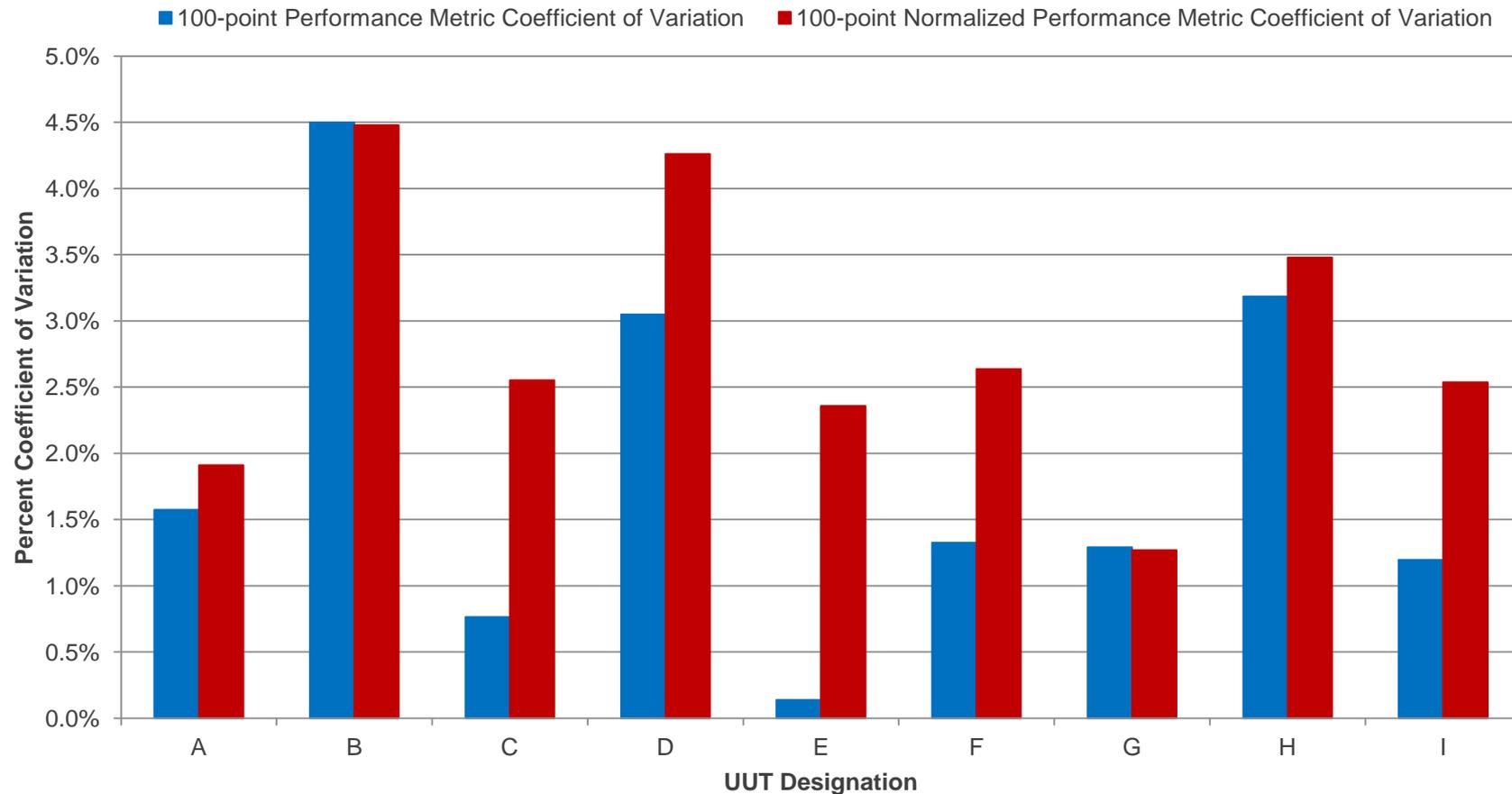


- 100-point Performance Metric proposed in Draft 1 Test Method
  - Reduced cost and burden with greatest repeatability
- 100-point normalized Performance Metric could be used if stakeholders concur
  - Did not improve test-to-test repeatability in Phase 2 tests
- IEC calculation method not ideal because it is designed for 5 tests with constant load

# Comparison of Calculation Methods



# Comparison of 100-point and Normalized Performance Metrics



# Reference Dishwasher Performance



- IEC reference dishwasher did not improve test-to-test repeatability
  - DOE test load uses less soil, even for the heavy soil cycle, compared to IEC test load
    - Variability for each unit is low even before normalizing the Performance Metric with the reference dishwasher
- Variability in performance of reference dishwasher outweighs variability associated with soil loads
  - Introduces additional variability in the normalized Performance Metric calculations

# Use of Reference Dishwasher



- Generally supported by stakeholders
- Increased burden
  - High cost (~\$18,000)
  - European power supply setup required
  - Additional time and labor for soiling and scoring
- Use of reference dishwasher is not proposed in Draft 1 Test Method
  - DOE requests comment on requiring the use of a reference dishwasher
  - May be included in future draft if stakeholders support using a reference dishwasher

# Proposed 100-point Performance Metric Calculation



- Calculation of Per-Cycle Cleaning Metric at each soil load:

$$CM_i = 100 - \frac{(12.5 \times N_{4,i} + 25 \times N_{3,i} + 50 \times N_{2,i} + 75 \times N_{1,i} + 100 \times N_{0,i})}{N}$$

- Calculation of Performance Metric as weighted average:

$$PM = W_h \times CM_h + W_m \times CM_m + W_l \times CM_l$$

# Scoring of Flatware Items



- No scoring of flatware is proposed in Draft 1

	Number of Items Scored	Performance Metric Range Over 9 Units
With Flatware	94	90.2 – 97.2
Without Flatware	51	84.9 – 96.8

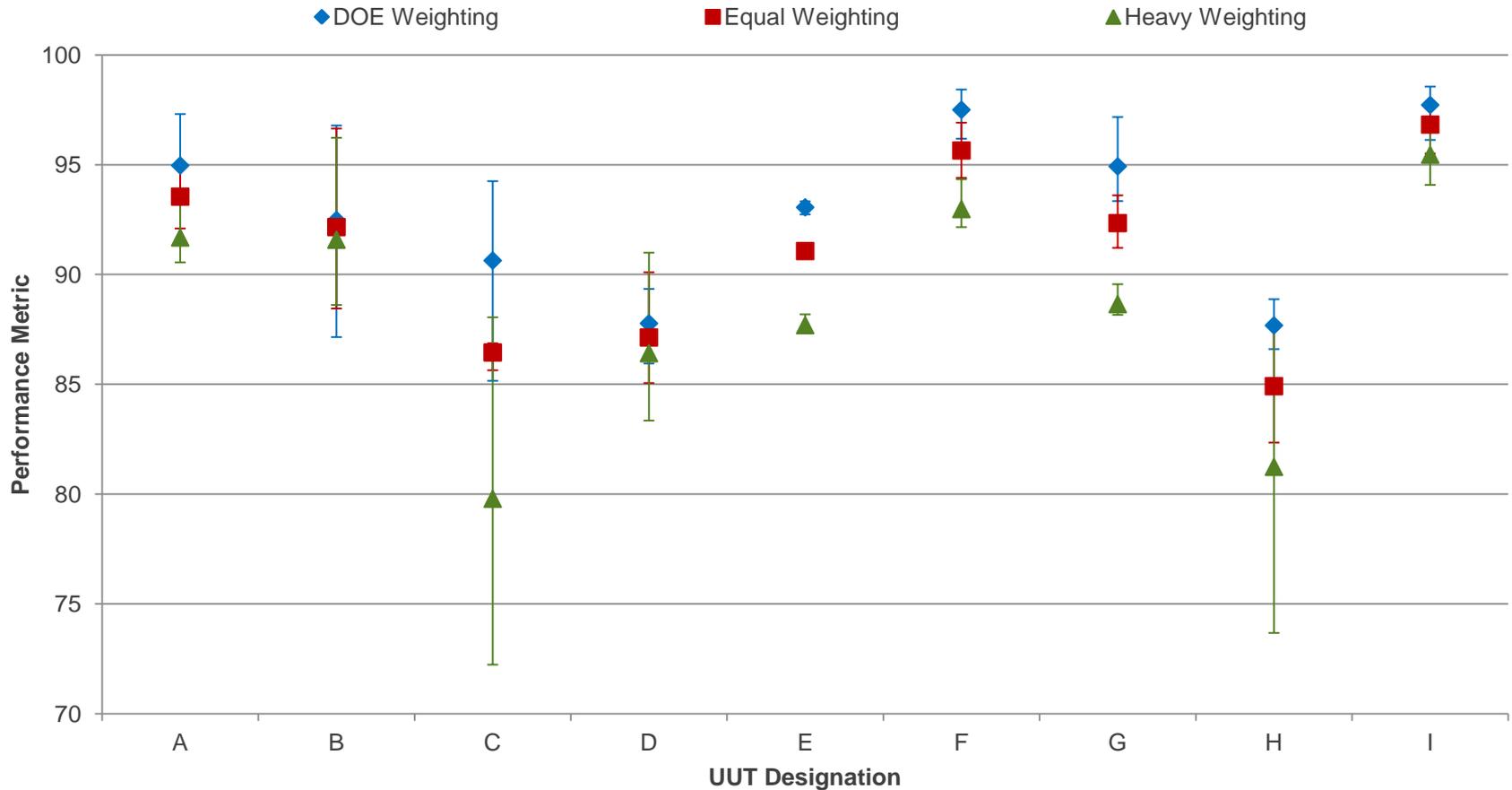
- Flatware is typically completely clean (score of 5)
- Increases differentiation between units
- Decreases test burden
- Slightly increases test-to-test variability of a unit

# Weights per Soil Cycle



- Investigated different weighting factors applied to heavy, medium, and light cycles
  - Weights from Appendix C (5% heavy cycle, 33% medium cycle, 62% light cycle)
  - Equal weights to all cycles
  - Maximum weight to heavy cycle (85% heavy cycle, 10% medium cycle, 5% light cycle)
- Equal weighting is proposed in Draft 1
  - Best balance of repeatability and differentiation
  - Mitigates possibility of circumvention

# Comparison of Different Weighting per Soil Cycle





# Cleanability Performance vs. Energy and Water Consumption

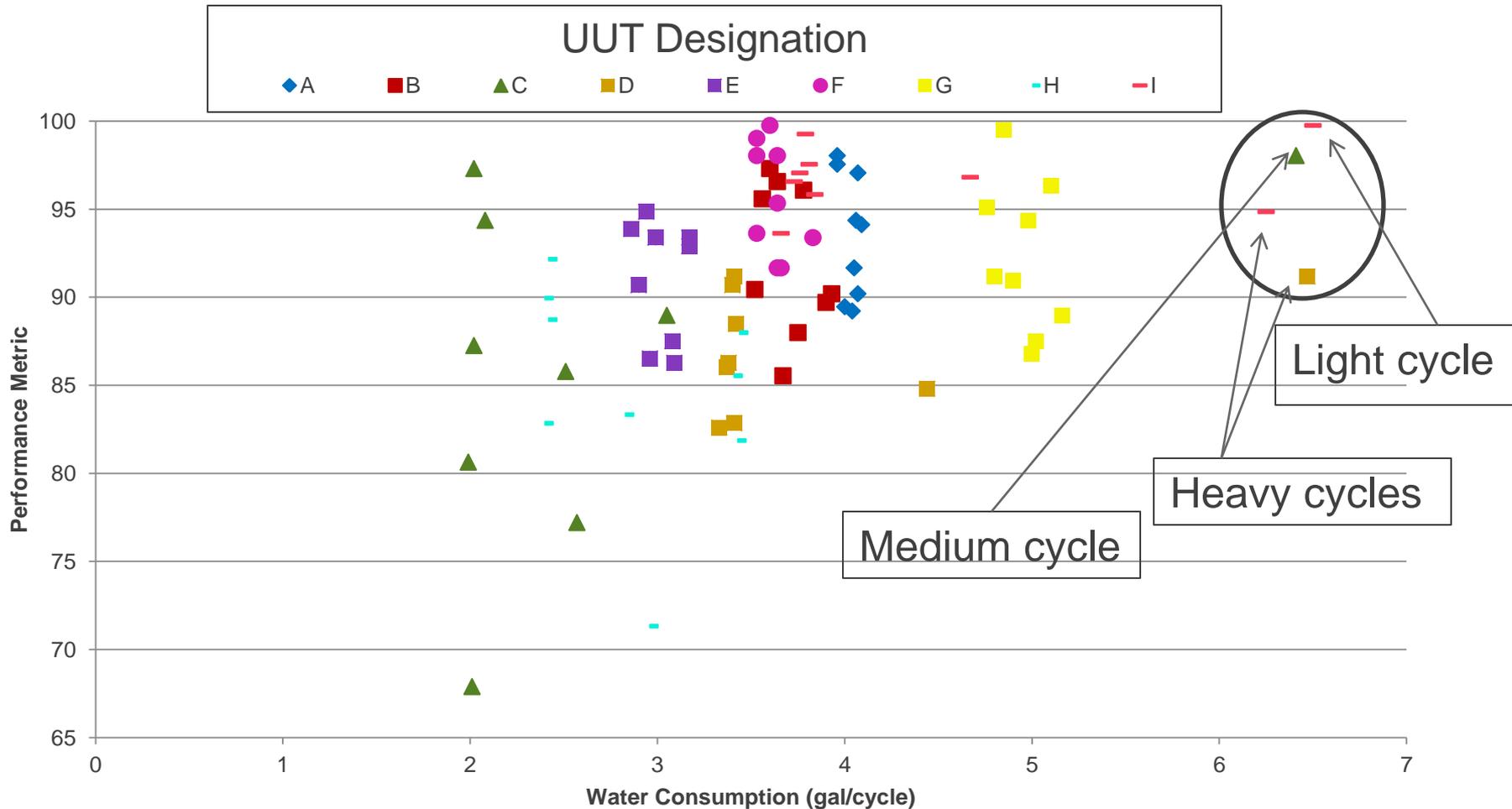
# Energy and Water Consumption



- Cleanability performance typically increased with increasing energy and water consumption
  - In some cases, good cleanability achieved at lower energy and water levels
  - Reached an upper limit beyond which Performance Metric did not increase significantly
- For some units, a higher energy and/or water use cycle would be triggered for light, medium, or heavy soils
  - Additional repeatability tests did not indicate a trend for increased energy or water consumption



# Performance Metric vs. Water Consumption



# Additional Repeatability Tests



- Performed four additional test series on three units to investigate turbidity sensor response
  - Selected units occasionally exhibited outlying energy and/or water consumption during initial Phase 2 tests
  - Outlying values were observed under various soil loads

# Additional Repeatability Tests - Results

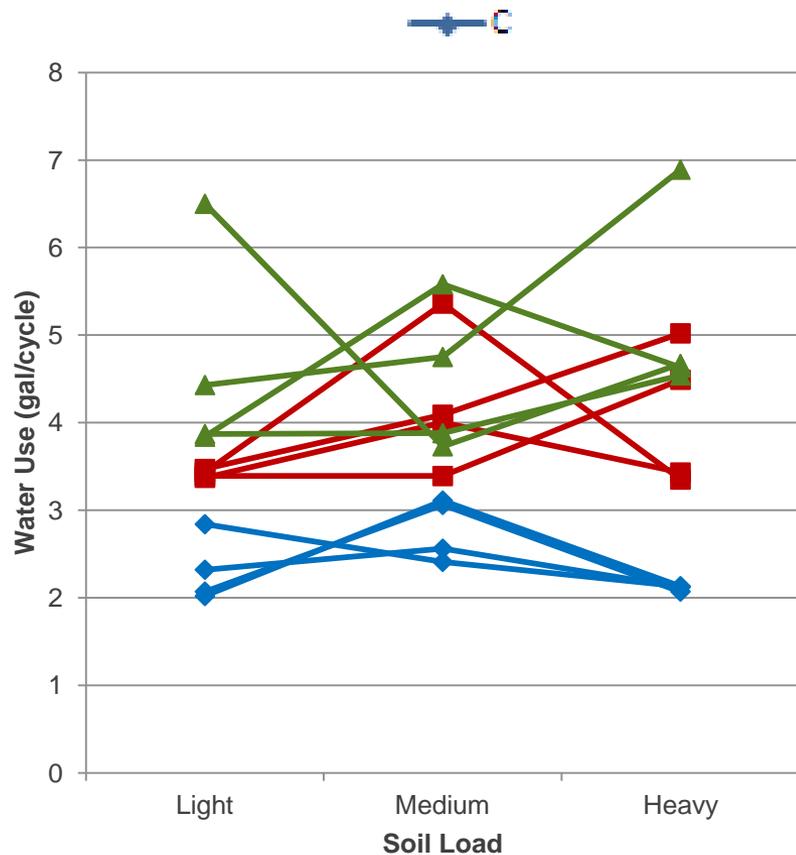


- Repeatability tests did not indicate a pattern for anomalous performance
  - Believed to be due to unpredictable cycle responses to constant soil load for certain units, not inconsistencies inherent in test method or test conduct
  - DOE has observed similar infrequent anomalous behavior during dishwasher ENERGY STAR verification tests in third-party labs

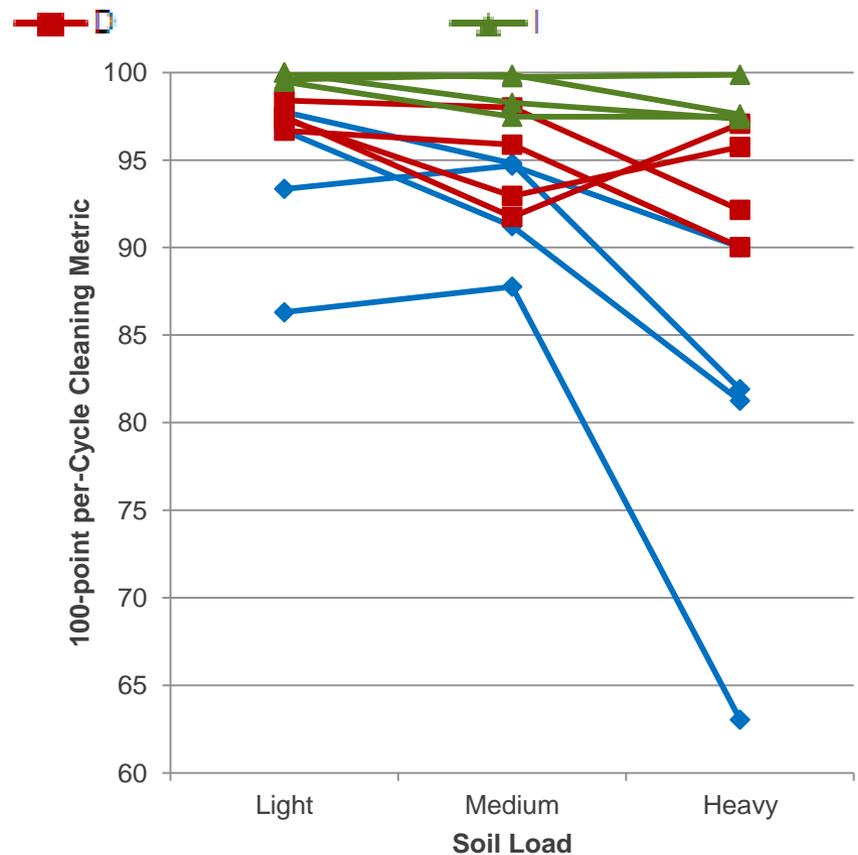
# Water Consumption and Performance Metric vs. Soil Load



## Water Consumption



## Per-cycle Cleaning Metric





# Additional Investigative Tests

# Loading Pattern

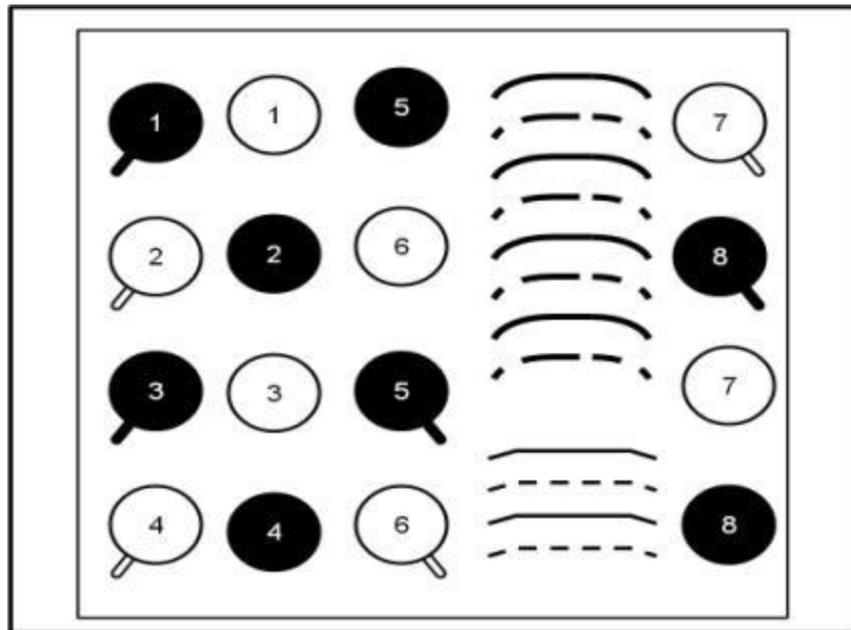


- Investigated three different loading patterns:
  - Alternate clean and soiled items
  - All soiled items towards the periphery of the racks
  - All soiled items towards the center of the racks
- Operated three test series on two units and reference dishwasher using only heavy load
- Loading pattern had minimal effect on the Performance Metric
  - However, Draft 1 proposes the alternate loading pattern to ensure tests are conducted consistently

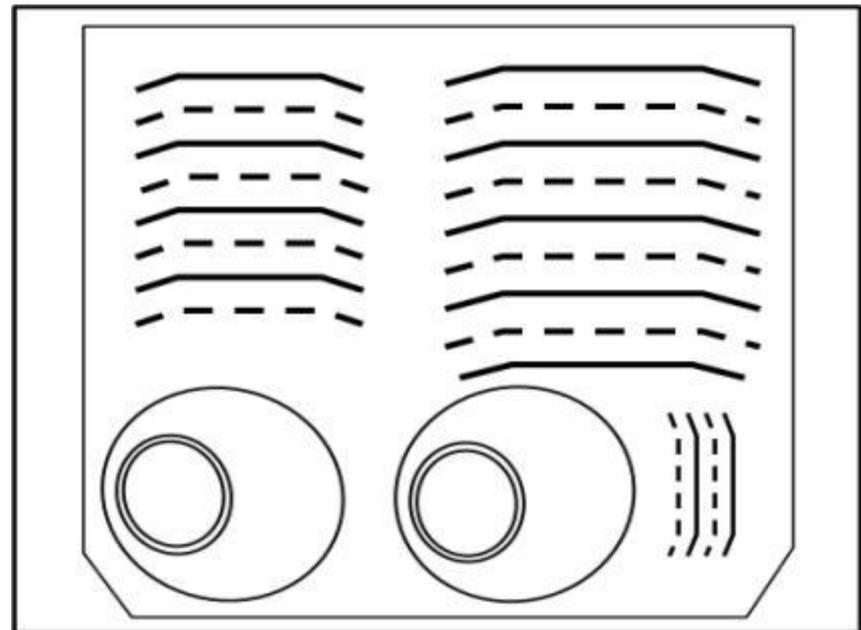
# Performance Metric and Schematic of Alternate Loading Pattern



UUT Designation	Performance Metric		
	Alternate soil and clean items	Soiled items towards periphery	Soiled items towards center
H	87.8	87.7	89.8
I	97.0	98.5	97.6



TOP RACK



BOTTOM RACK

# Grader-to-Grader Variability

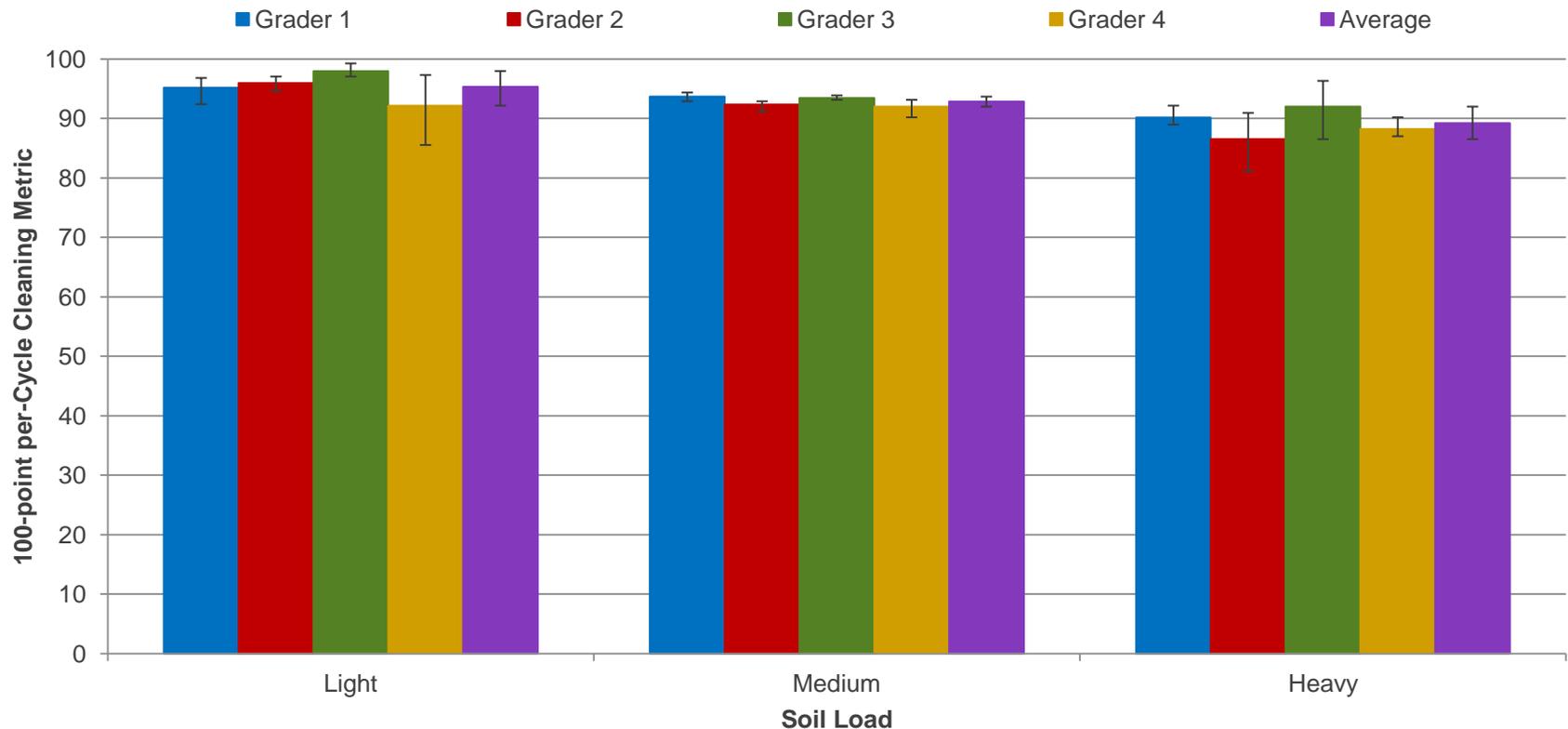


- Compared performance across different graders to determine whether a “grader bias” exists
- Investigated this variability for reference unit
  - Difficult to assess grader variability on UUTs
- Observed some grader-to-grader variability in the 100-point scores
  - No clear bias towards high or low scores for any grader
  - Variability could be due to changes in the soils

# Grader-to-grader Variability – Results for Reference Unit



- Between 3 – 6 data points used to calculate average values and error bars for each grader



# Constant Soil Load in Reference Dishwasher



- Investigated constant soil load (heavy) on reference dishwasher while using heavy, medium, and light soil loads on UUT
  - Purpose of reference unit is to remove variability due to soil preparation, application, etc.
  - Varying soil load on reference dishwasher yields varying Per-Cycle Cleaning Metric because reference dishwasher is non-soil sensing
- Operated three test series on two units and reference dishwasher

# Constant Load in Reference Dishwasher – Results



- Draft 1 does not propose a constant heavy soil load for reference dishwasher
  - Results do not indicate a significant change in Performance Metric of UUT
  - Would increase test burden

UUT Designation	Performance Metric	
	Constant soil load in reference	Heavy, medium, light soil load in reference
H	77.4	84.9
I	96.8	96.8

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# Test Setup



- Setup according to Appendix C
- Ambient conditions for scoring
  - Light must have a color temperature of 3500 – 4500 K
  - Luminance at plane of evaluation should be 1000 – 1500 lux
- Water hardness should be between 0 – 85 ppm

# Test Cycles



Soil-sensing Unit	Non-soil Sensing Unit
Pre-conditioning 1	Pre-conditioning*
Pre-conditioning 2*	Energy/water consumption cycle per Appendix C*
Sensor heavy load*	Sensor heavy load
Sensor medium load*	Sensor medium load
Sensor light load*	Sensor light load

\* Currently required for measuring energy and water use under Appendix C

# Scoring and Calculation



- Score all items, excluding flatware, according to Table 1 in section 6.7.1 of IEC 60436
- Calculate per-cycle Cleaning Metric
- Calculate Performance Metric with equal weights for heavy, medium, and light cycle

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# Next Steps

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- Perform testing on compact dishwashers to confirm applicability of Draft 1 test method
- Review stakeholder feedback from today's webinar and update Draft 1 test method
- Perform validation tests with Draft 1 test method after any revisions in response to stakeholder feedback

# Estimated Timeline



Date	Milestone
September 19, 2011	Initial stakeholder webinar
February 17, 2012	Draft 1 Test Method distributed
February 27, 2012	Stakeholder webinar to discuss Draft 1 Test Method
March 19, 2012	Draft 1 comment period ends
June 2012	Draft 2 Test Method distributed
July 2012	Stakeholder webinar to discuss Draft 2 Test Method
August 2012	Final Test Method Published
Second half of 2012	EPA begins Version 6.0 spec development

# Contact Information

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Please send any additional comments to [appliances@energystar.gov](mailto:appliances@energystar.gov) or contact:

Amanda Stevens, EPA  
[Stevens.Amanda@epamail.epa.gov](mailto:Stevens.Amanda@epamail.epa.gov)

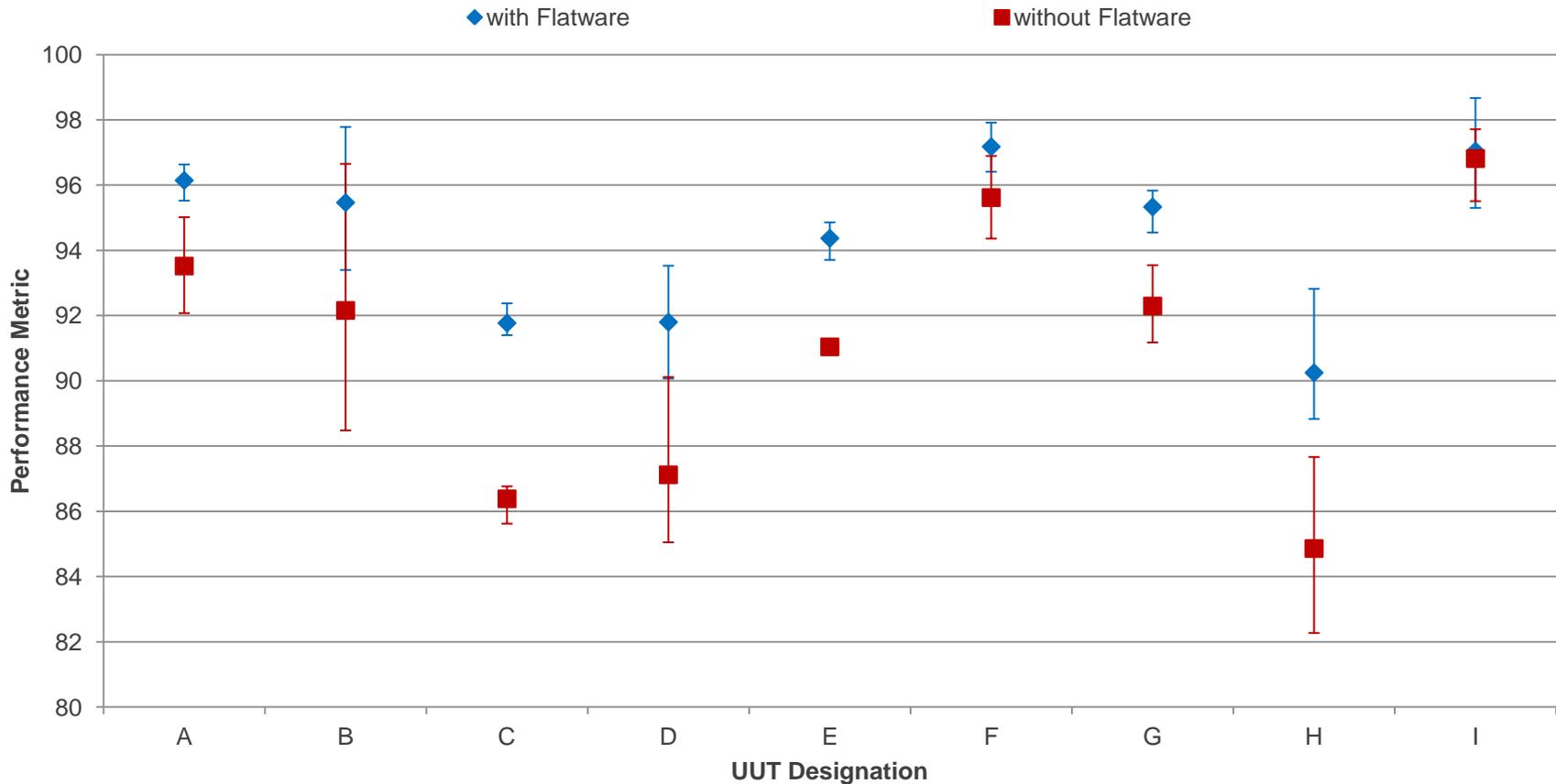
Ashley Armstrong, DOE  
[Ashley.Armstrong@ee.doe.gov](mailto:Ashley.Armstrong@ee.doe.gov)

Mansi Thakkar, Navigant  
[Mansi.Thakkar@navigant.com](mailto:Mansi.Thakkar@navigant.com)

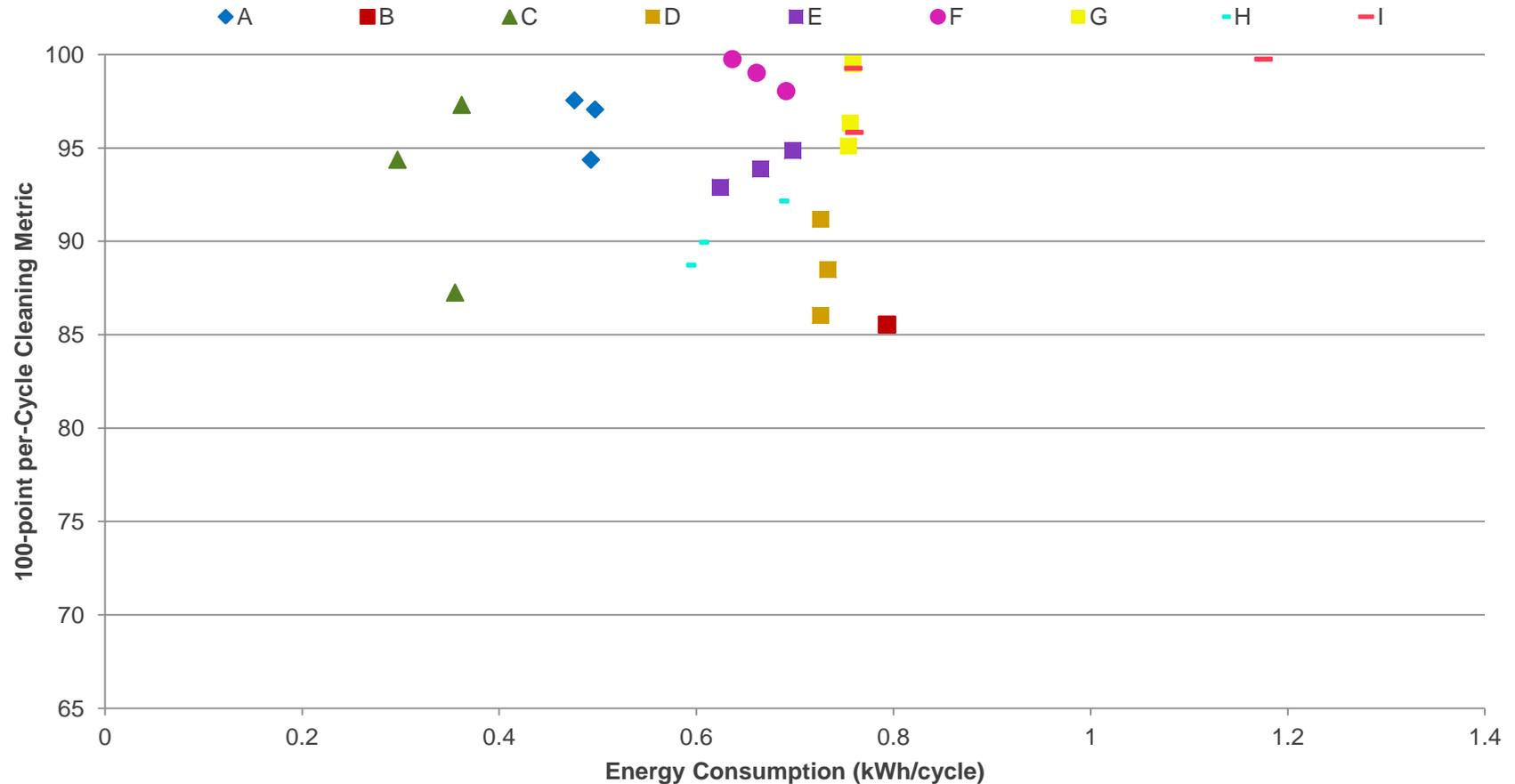


# Additional Information

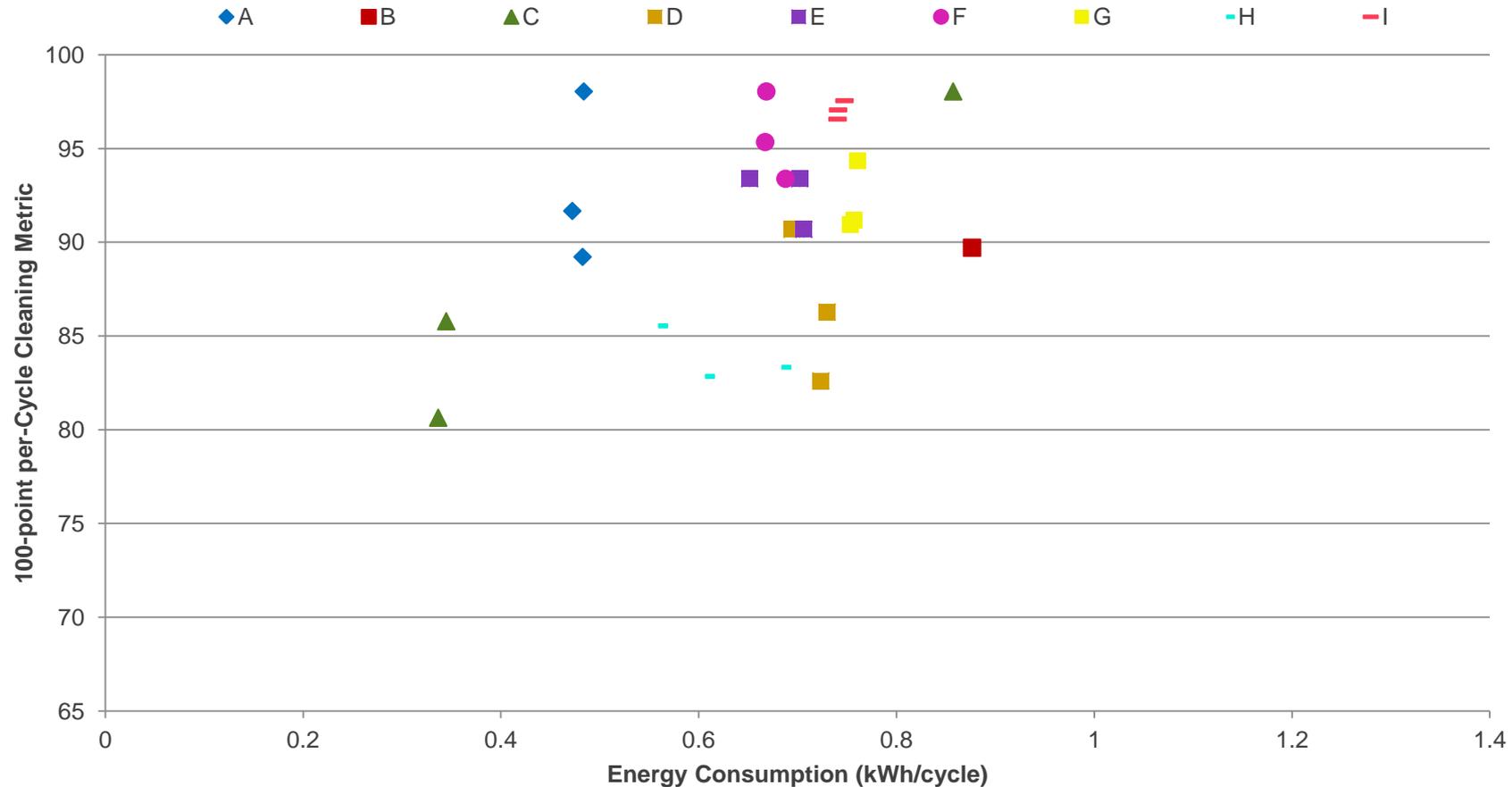
# Comparison with and without Flatware



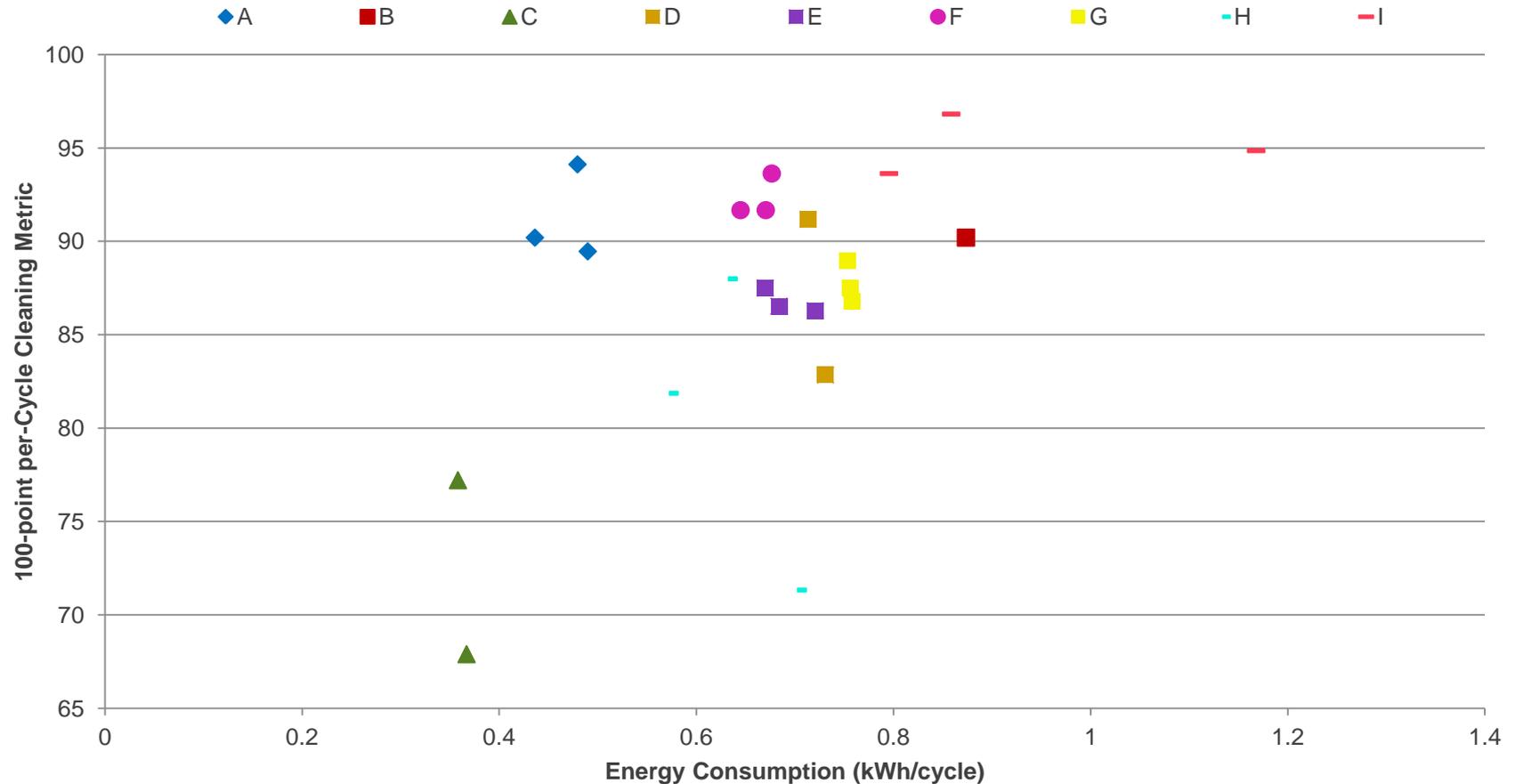
# Per-Cycle Cleaning Metric vs. Energy Consumption – Light Load



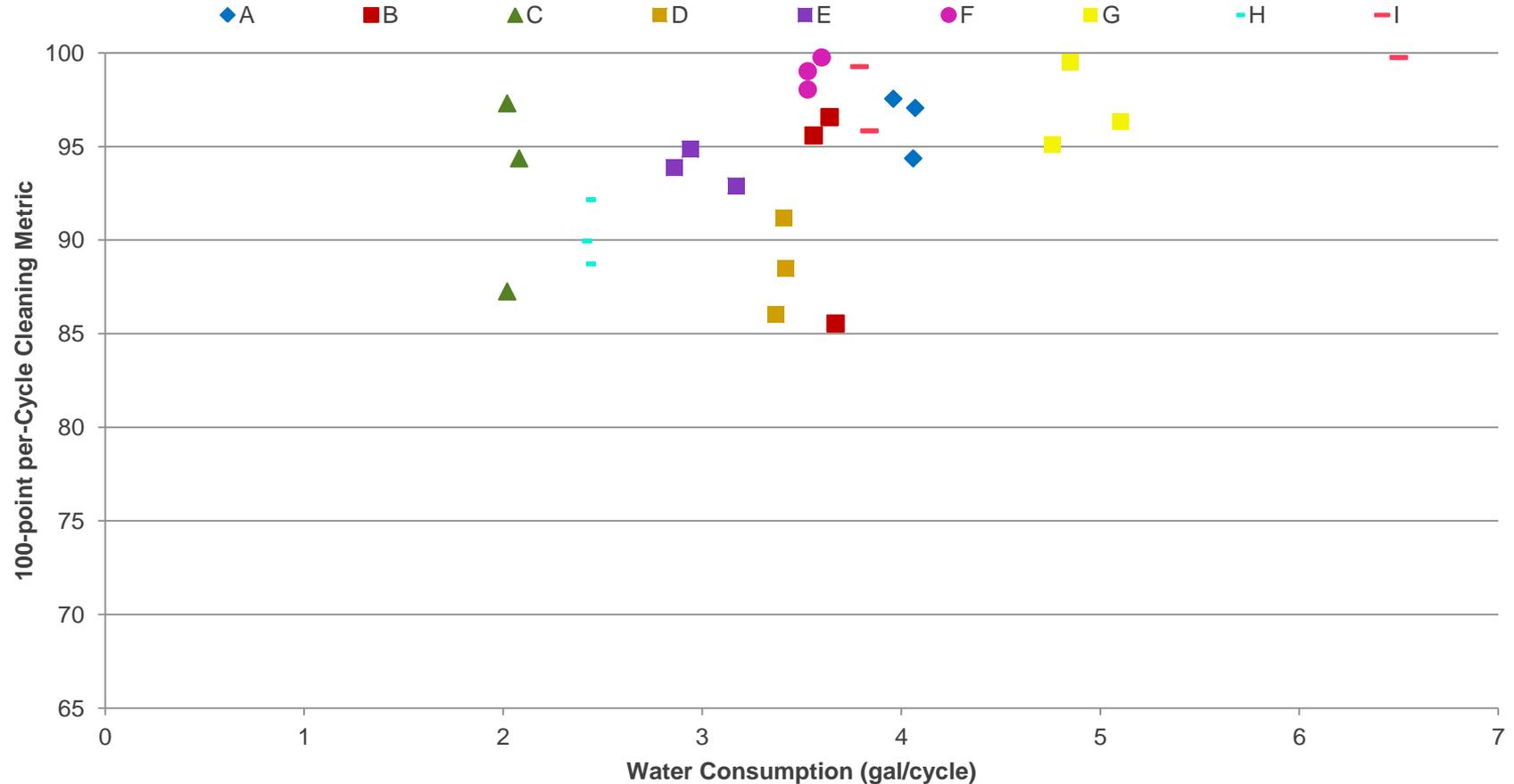
# Per-Cycle Cleaning Metric vs. Energy Consumption – Medium Load



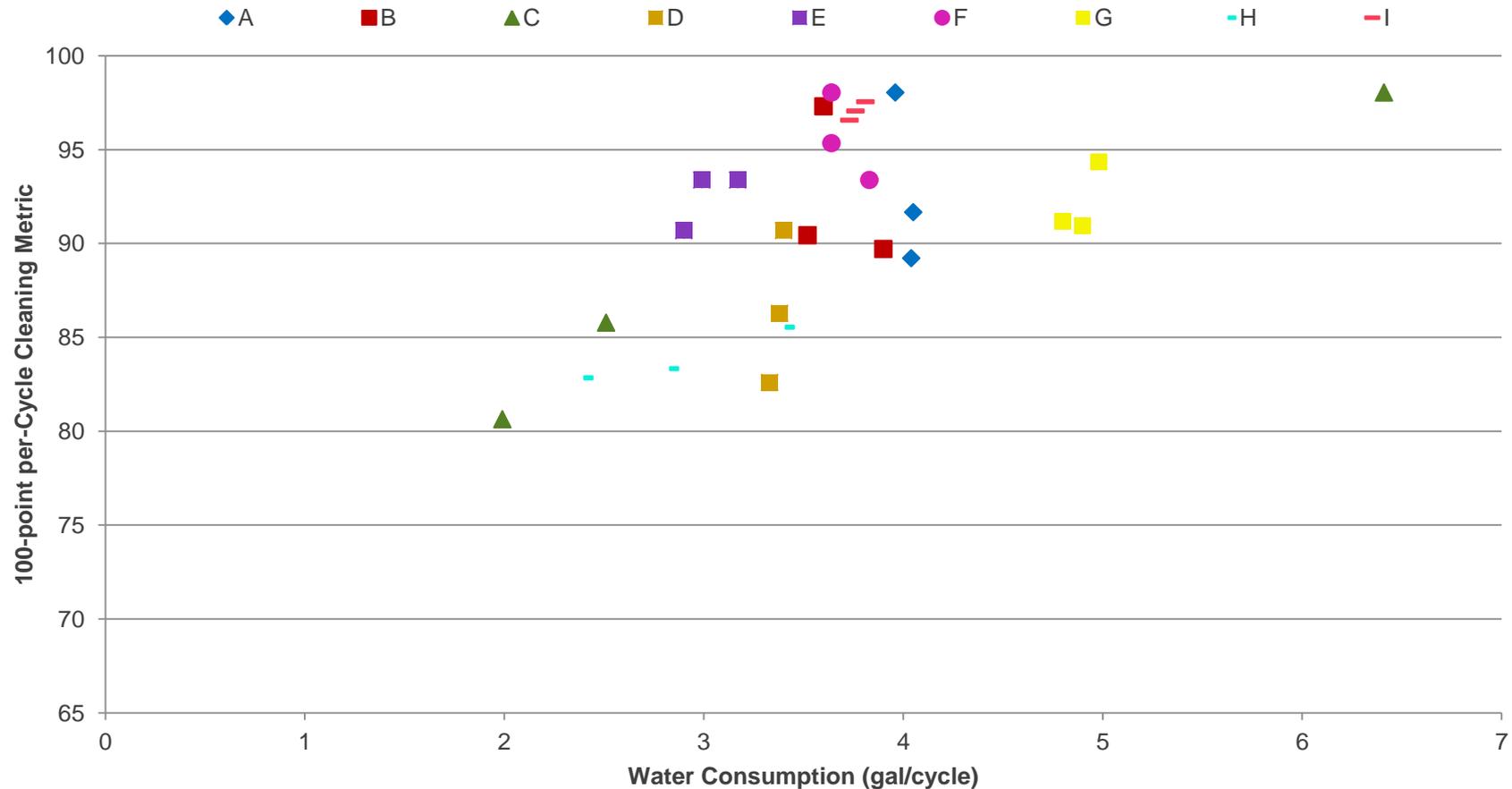
# Per-Cycle Cleaning Metric vs. Energy Consumption – Heavy Load



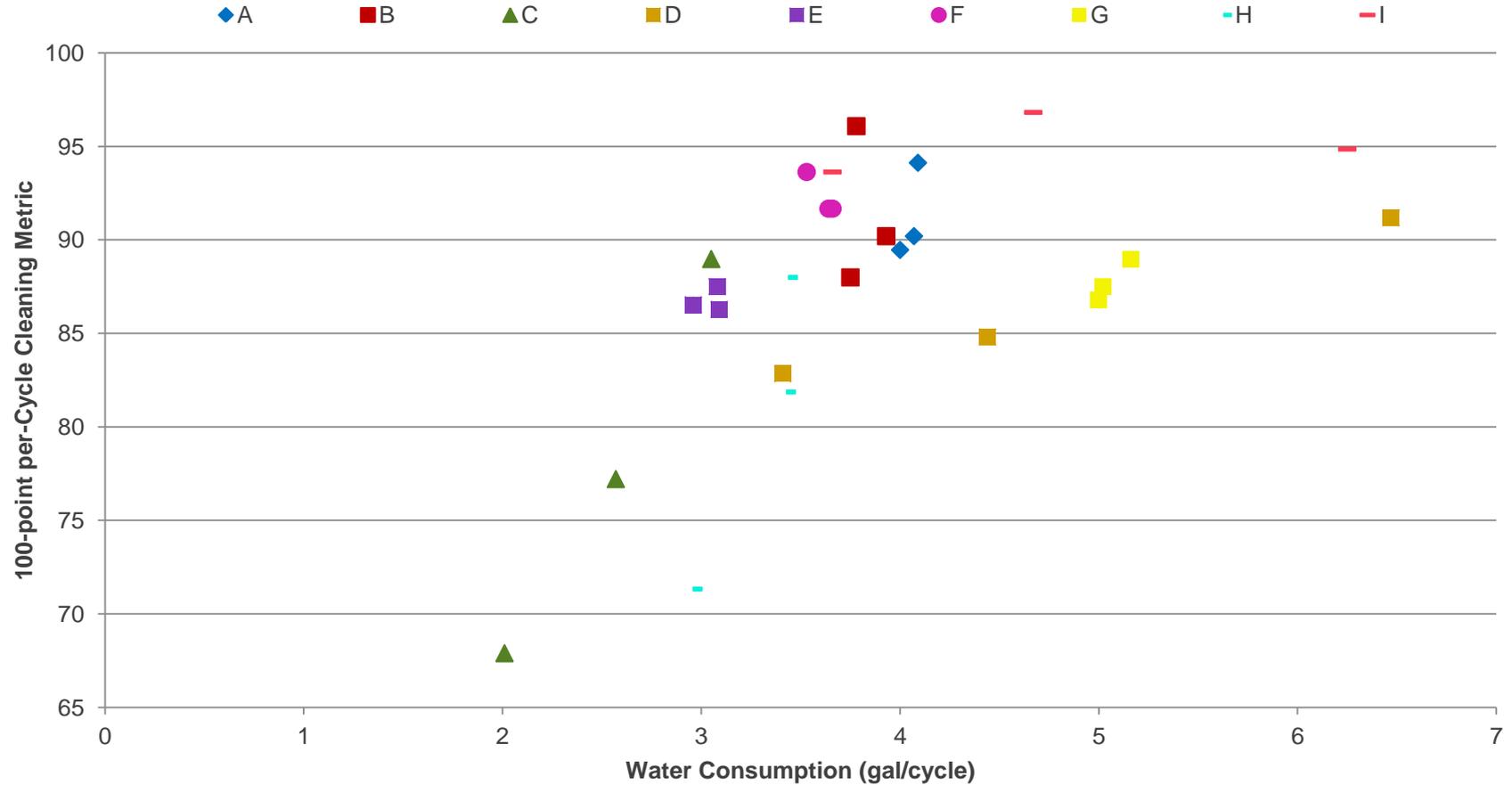
# Per-Cycle Cleaning Metric vs. Water Consumption – Light Load



# Per-Cycle Cleaning Metric vs. Water Consumption – Medium Load



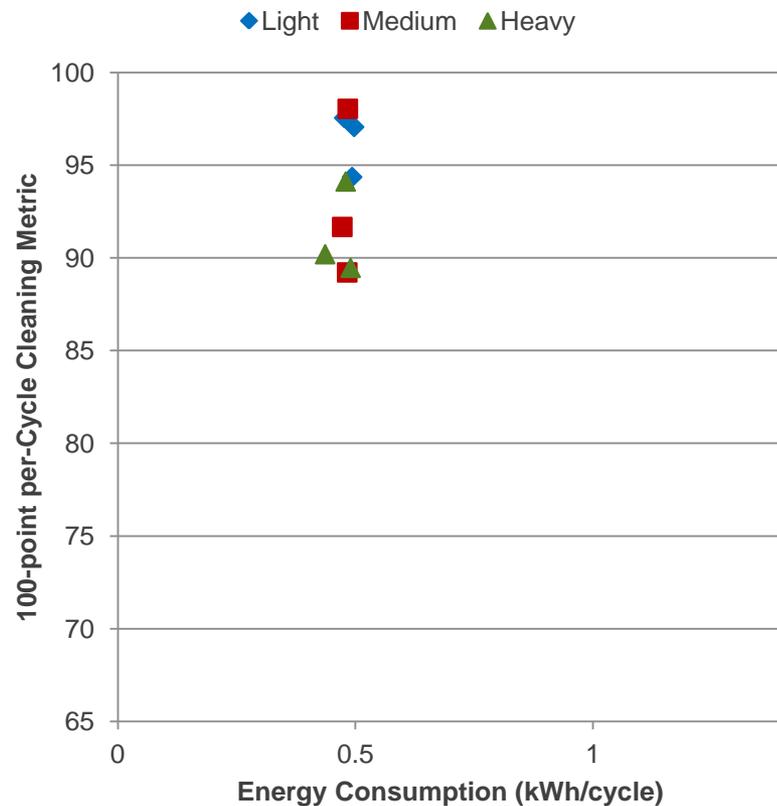
# Per-Cycle Cleaning Metric vs. Water Consumption – Heavy Load



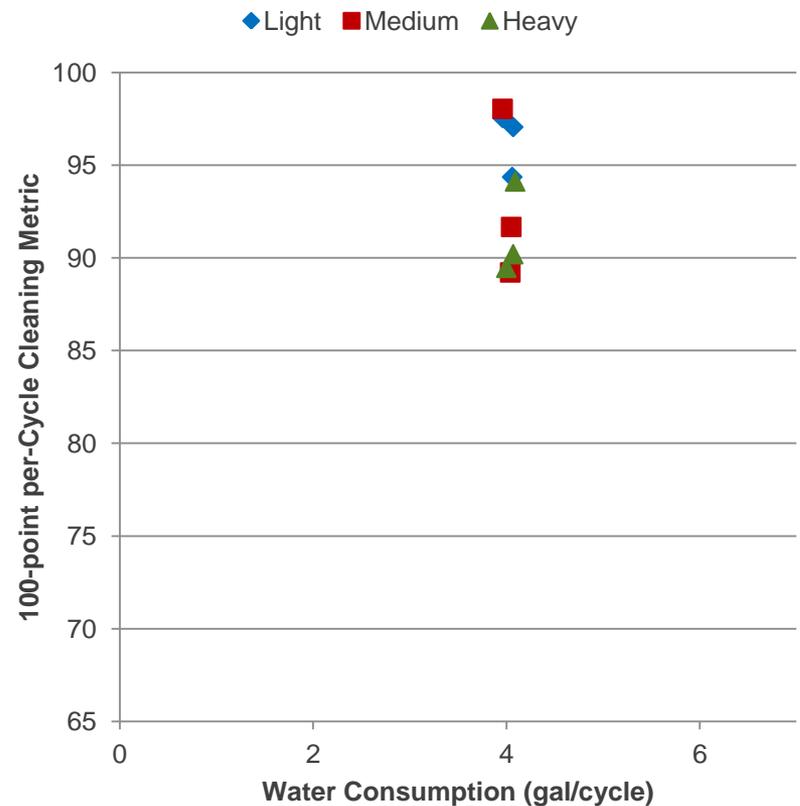
# Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT A



## Energy Consumption



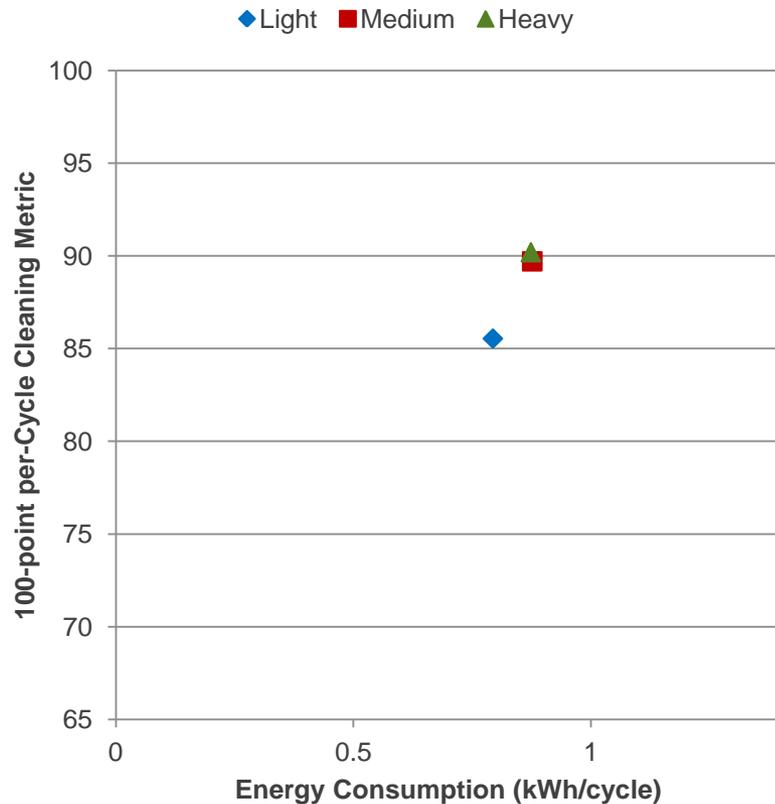
## Water Consumption



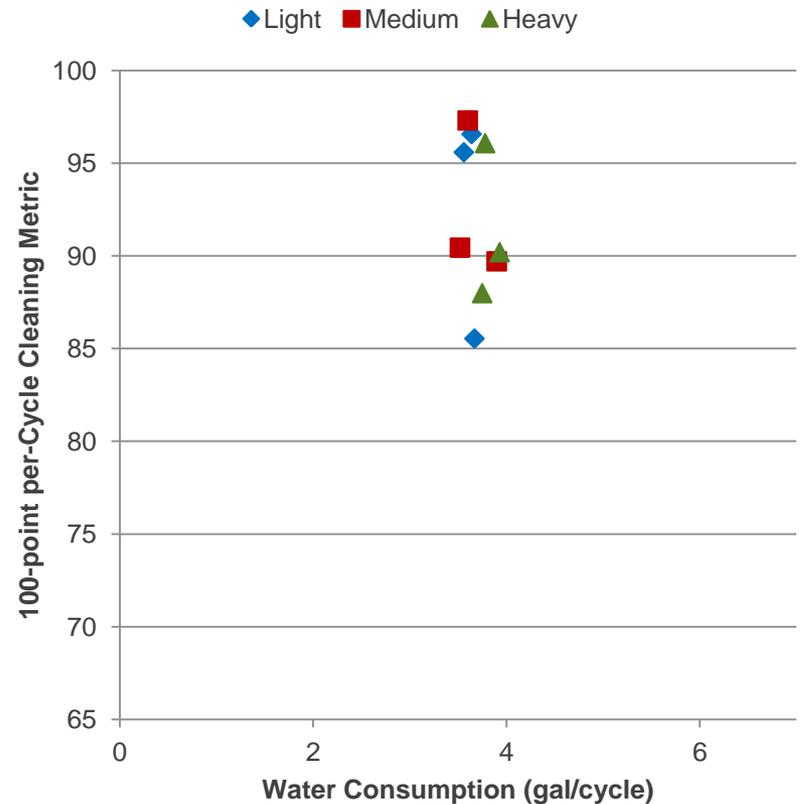
# Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT B



## Energy Consumption



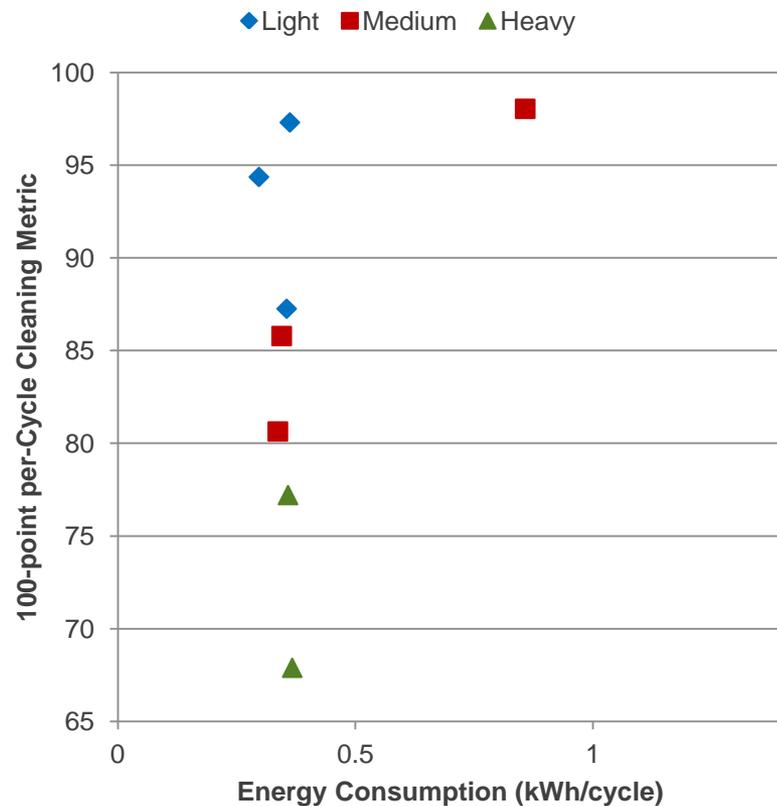
## Water Consumption



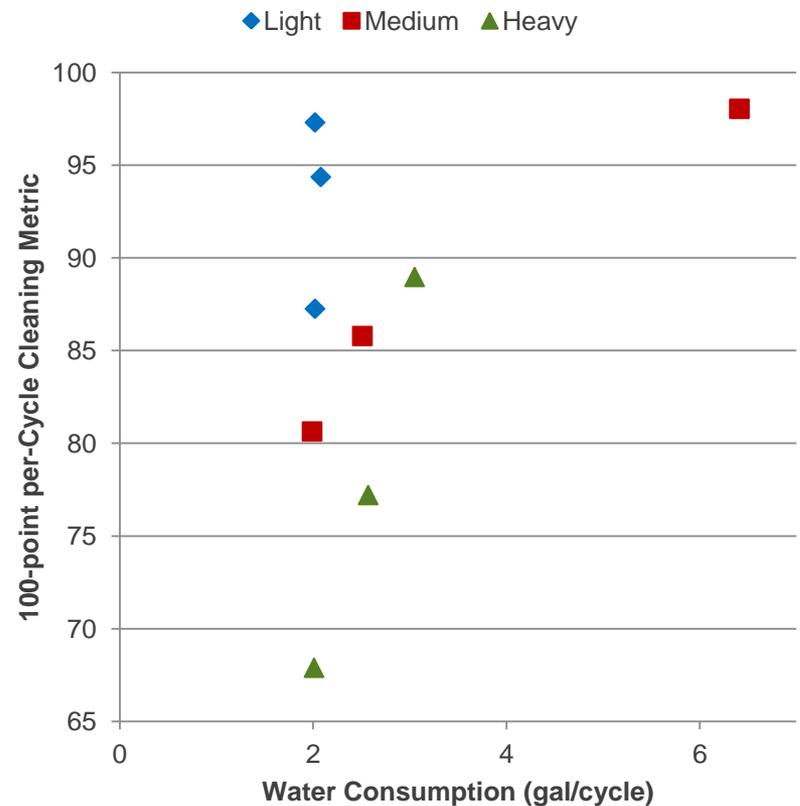
# Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT C



## Energy Consumption



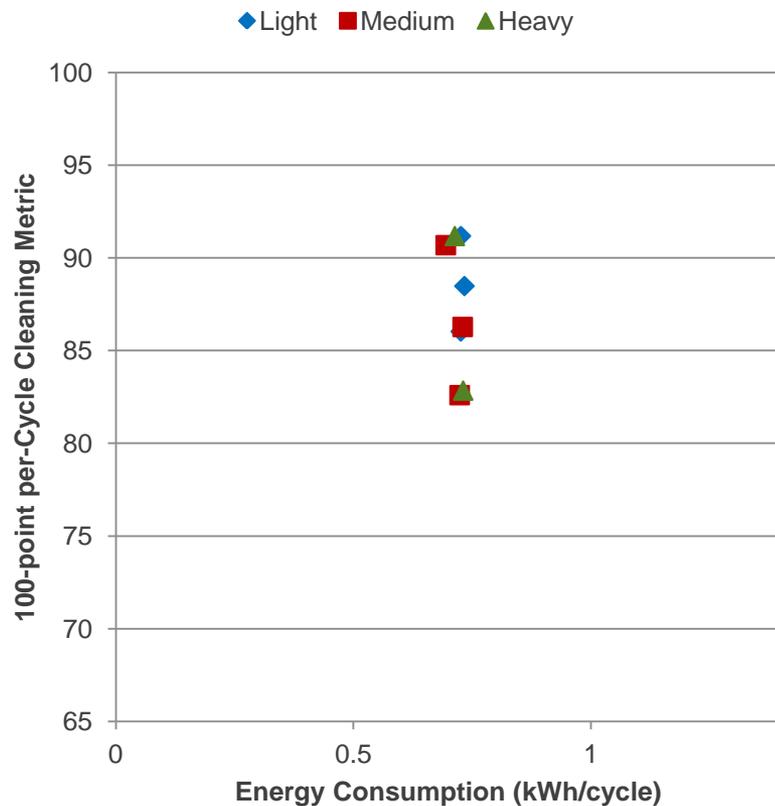
## Water Consumption



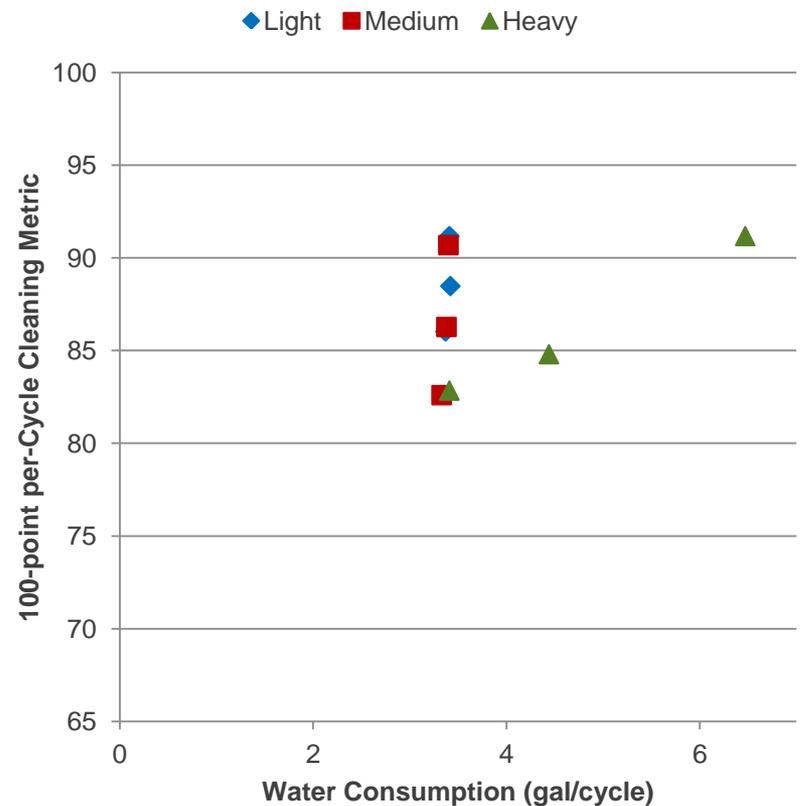
# Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT D



## Energy Consumption



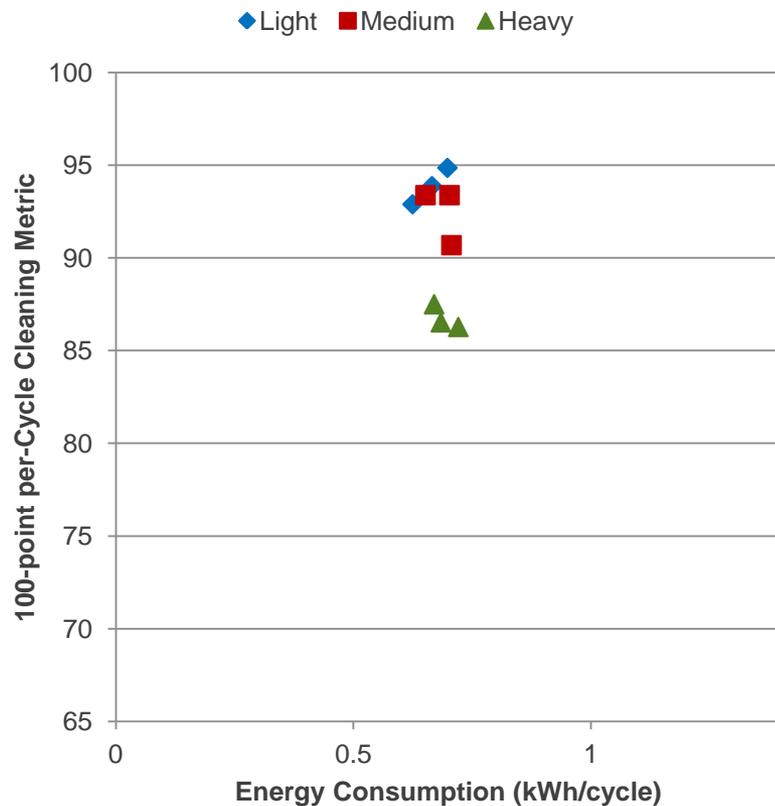
## Water Consumption



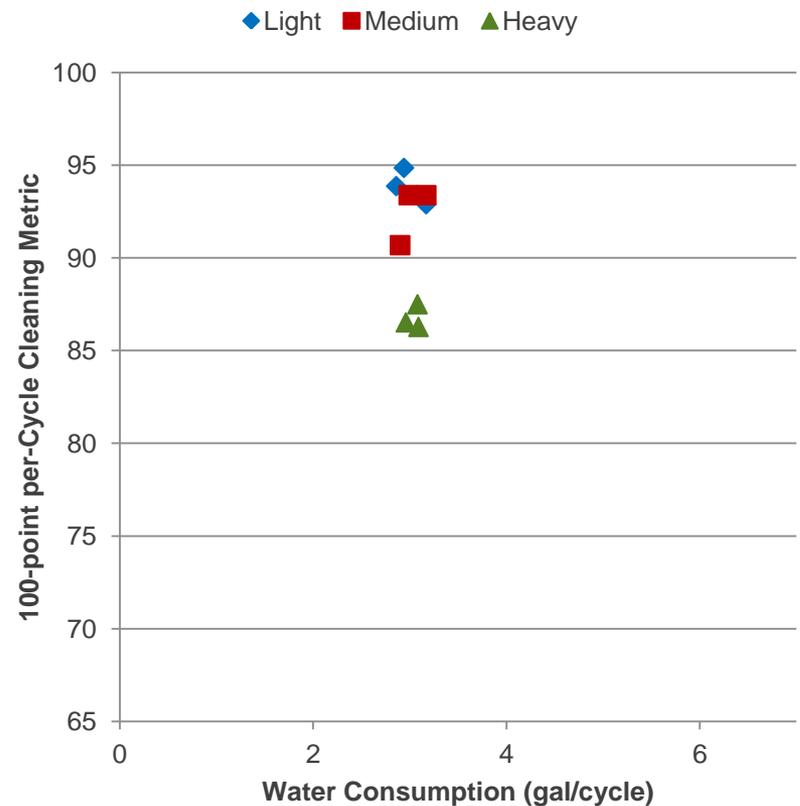
# Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT E



## Energy Consumption



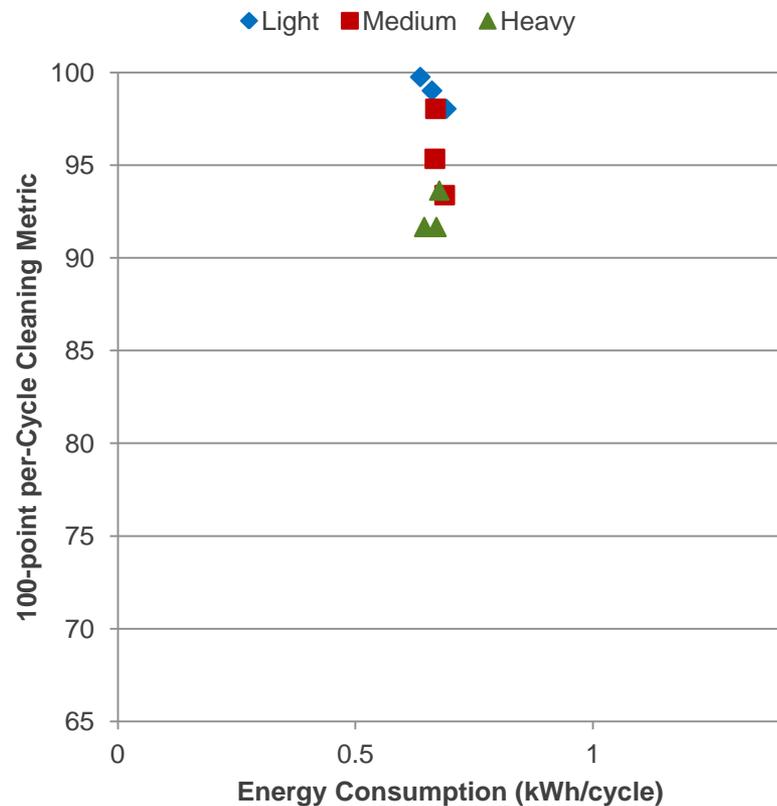
## Water Consumption



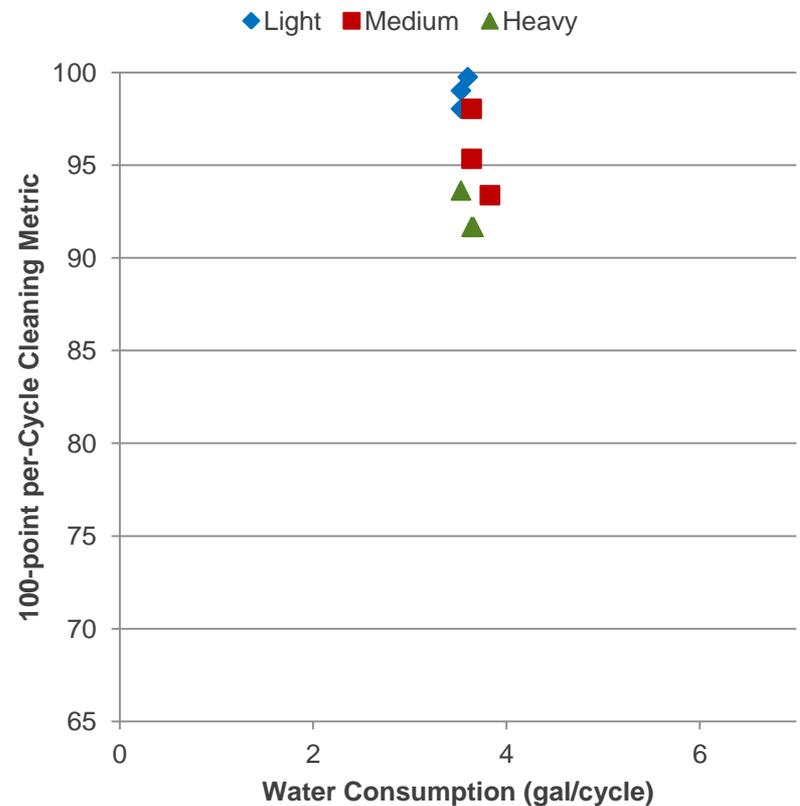
# Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT F



## Energy Consumption



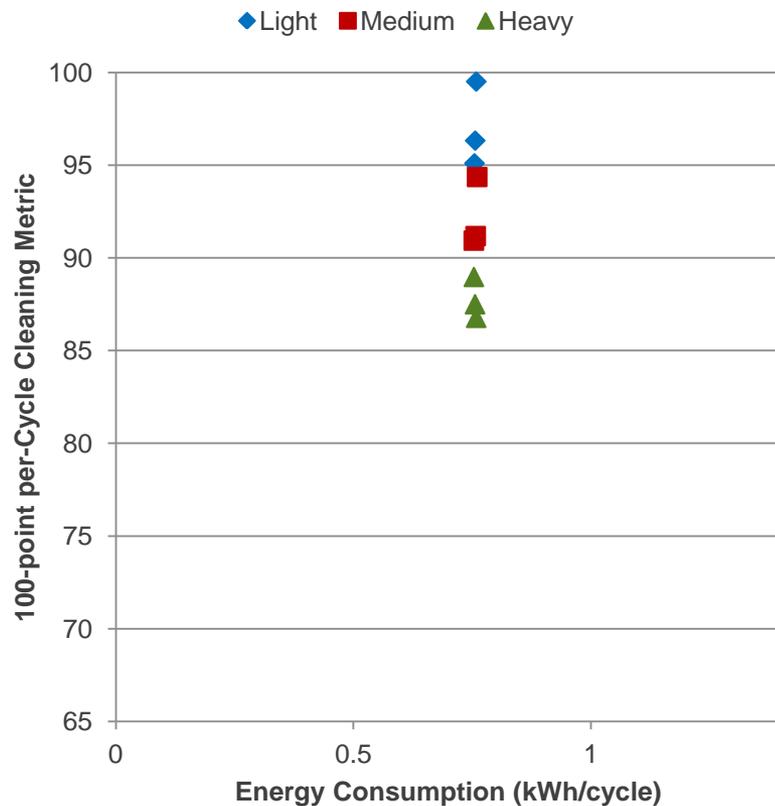
## Water Consumption



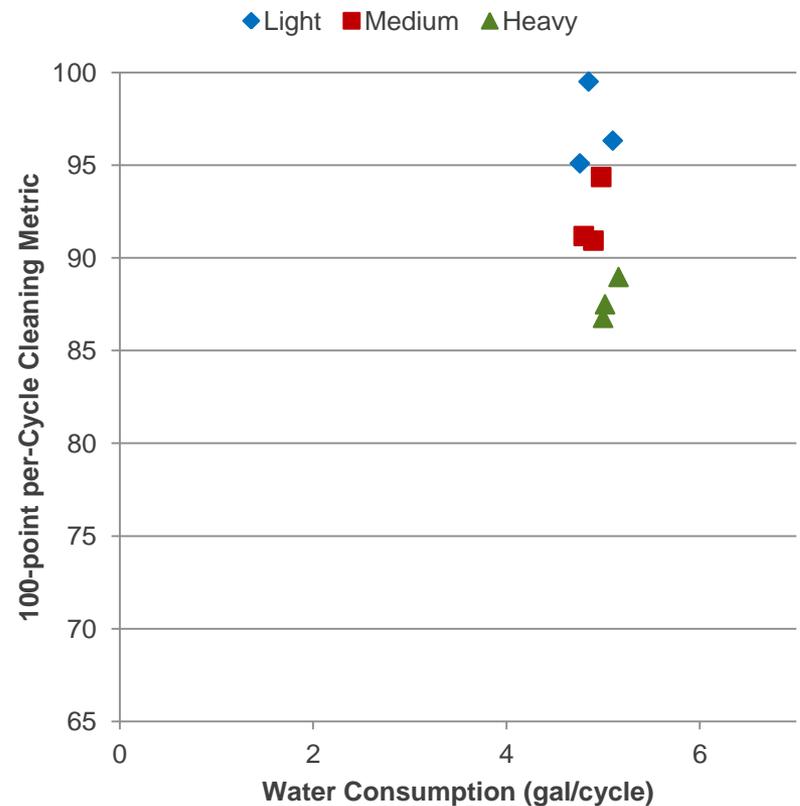
# Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT G



## Energy Consumption



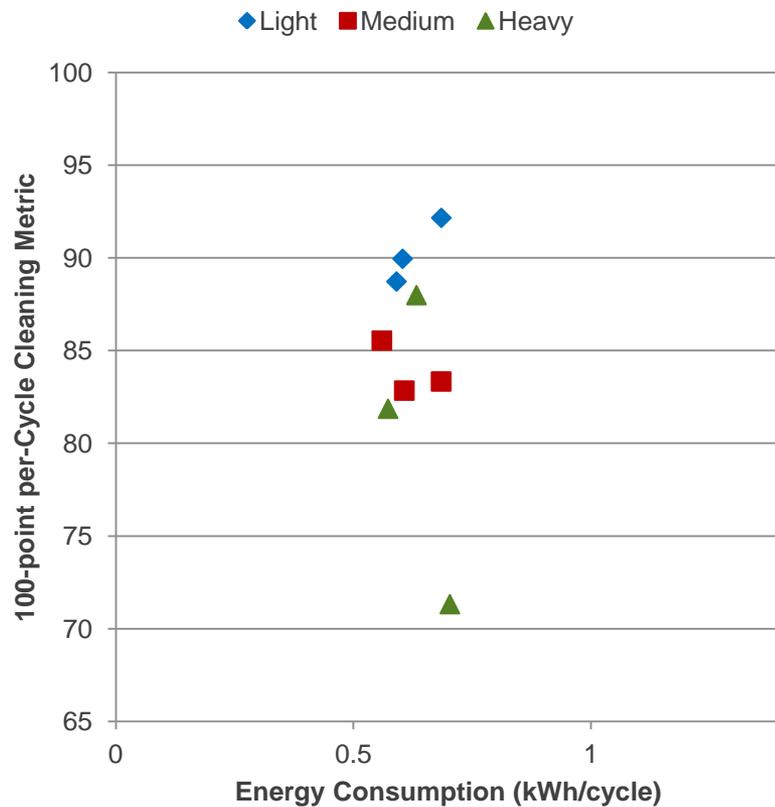
## Water Consumption



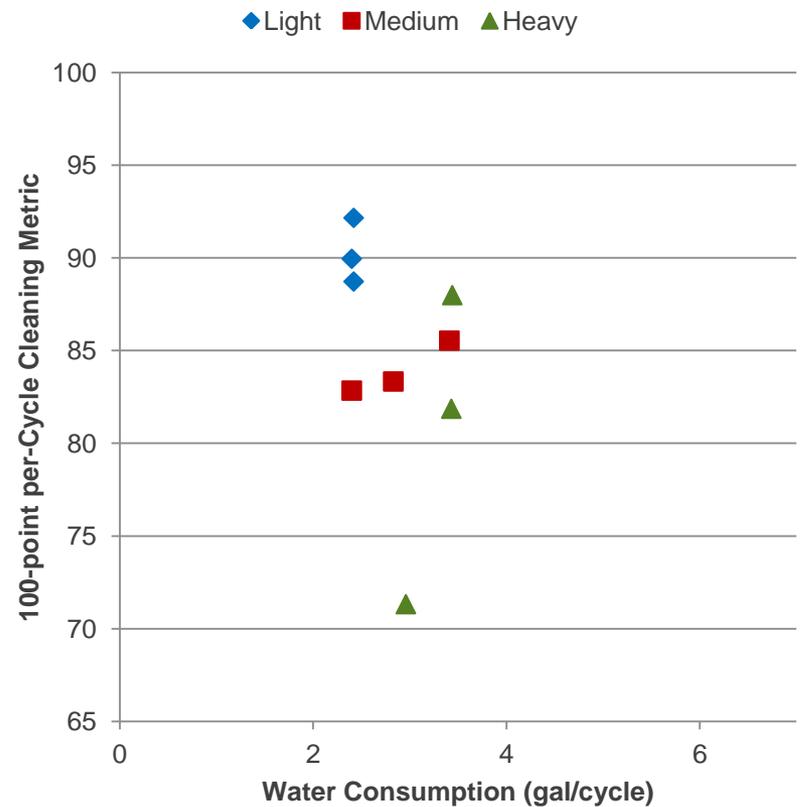
# Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT H



## Energy Consumption



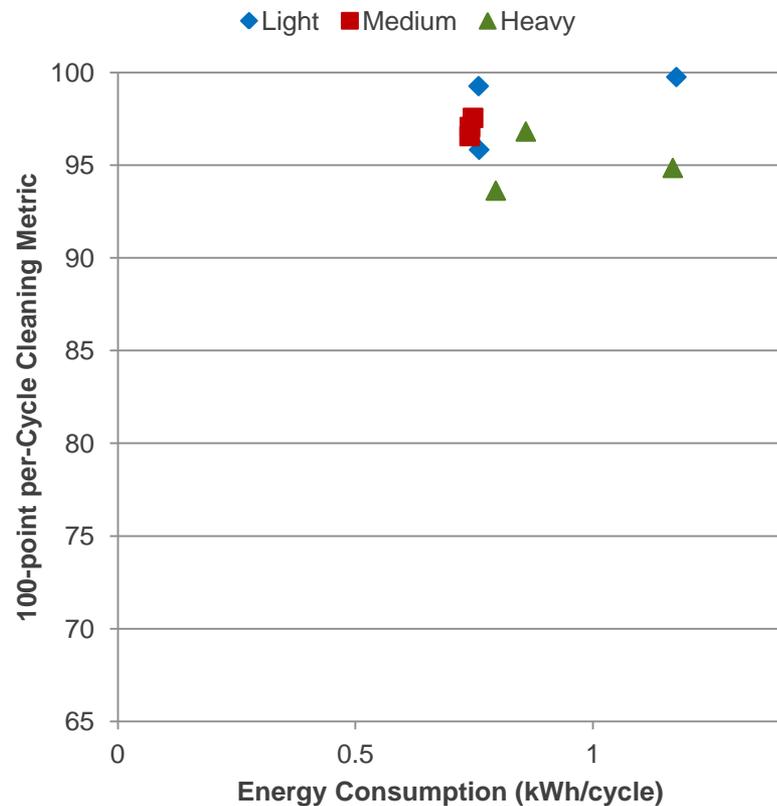
## Water Consumption



# Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT I



## Energy Consumption



## Water Consumption

