



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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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">• New Products• Performance Levels• Marketing & Outreach• Product Database• Monitoring & Verification	<ul style="list-style-type: none">• Test Methods• Metrics• Monitoring & Verification

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



- 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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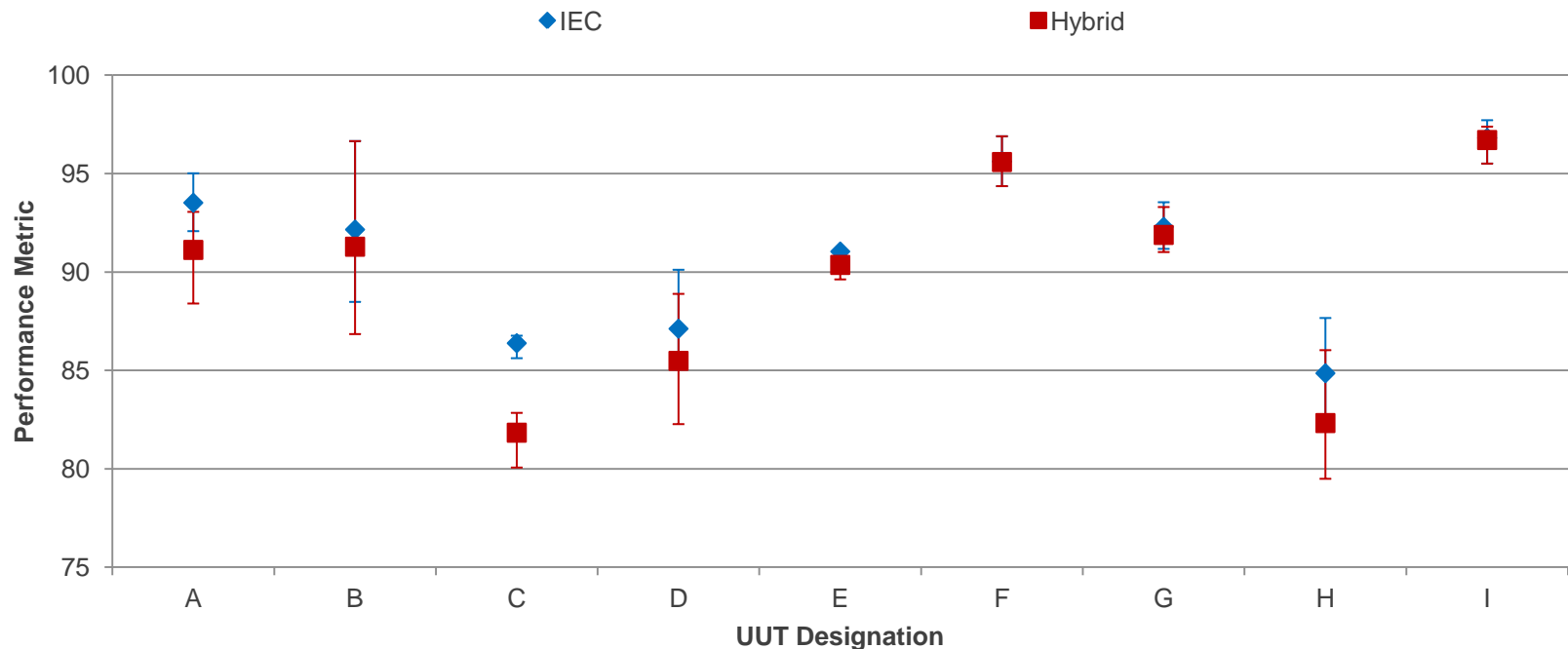


Scoring Method and Calculation

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)

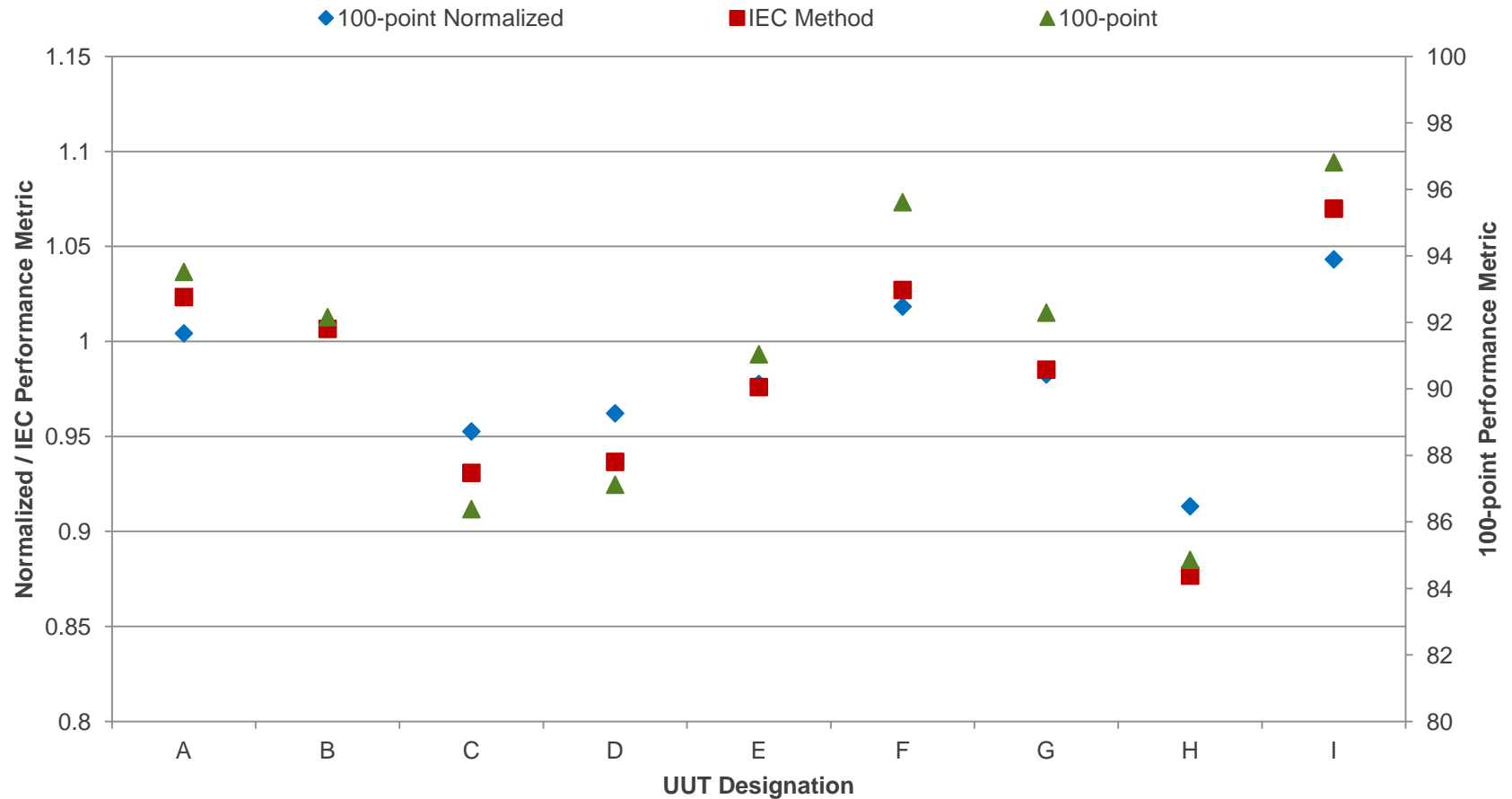


Calculation of Performance Metric

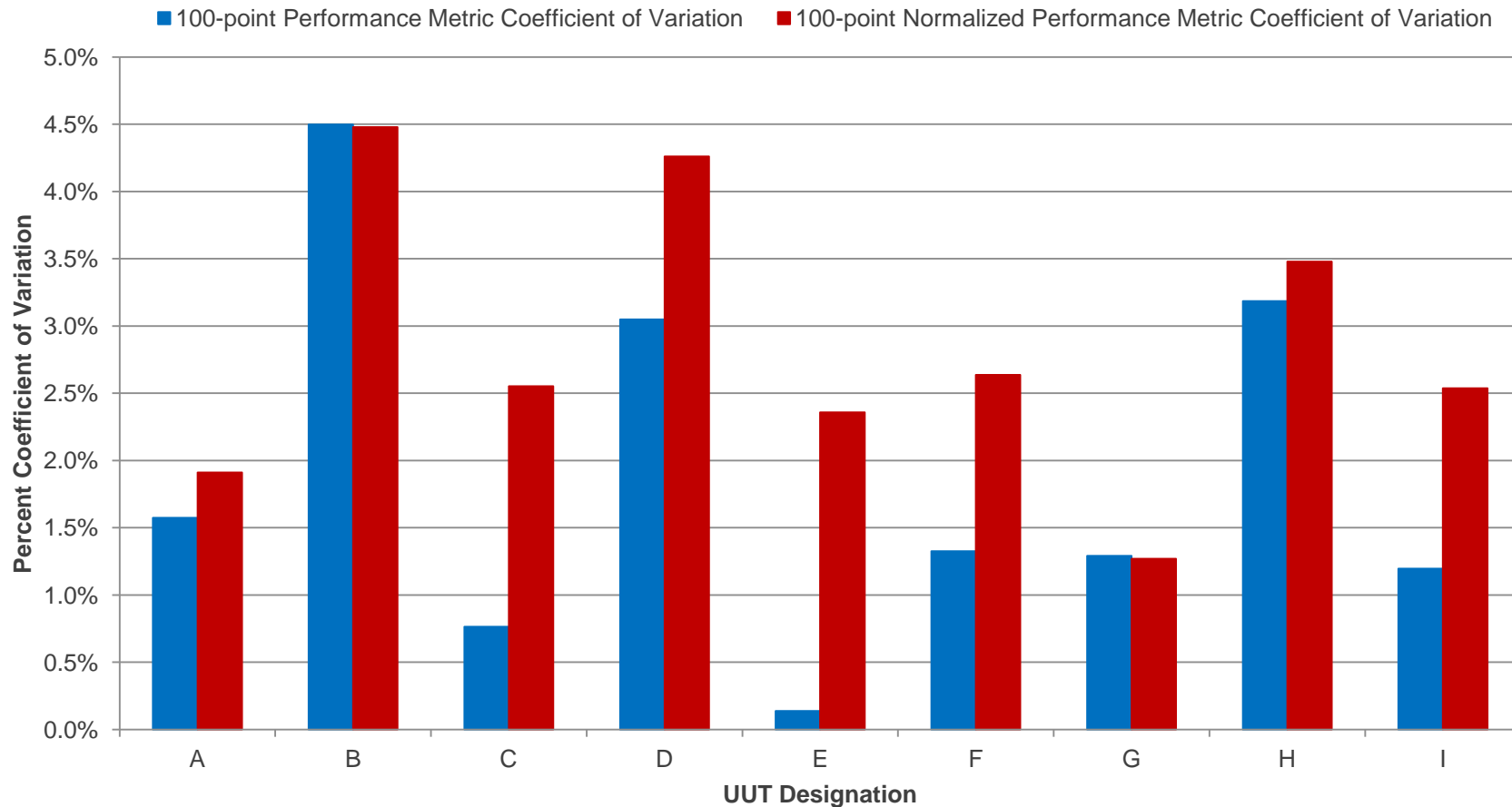


- 100-point Performance Metric proposed in Draft 1 Test Method
 - Reduced cost and burden with greatest repeatability
- 100-point normalized Performance Metric could be used if stakeholders concur
 - Did not improve test-to-test repeatability in Phase 2 tests
- IEC calculation method not ideal because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

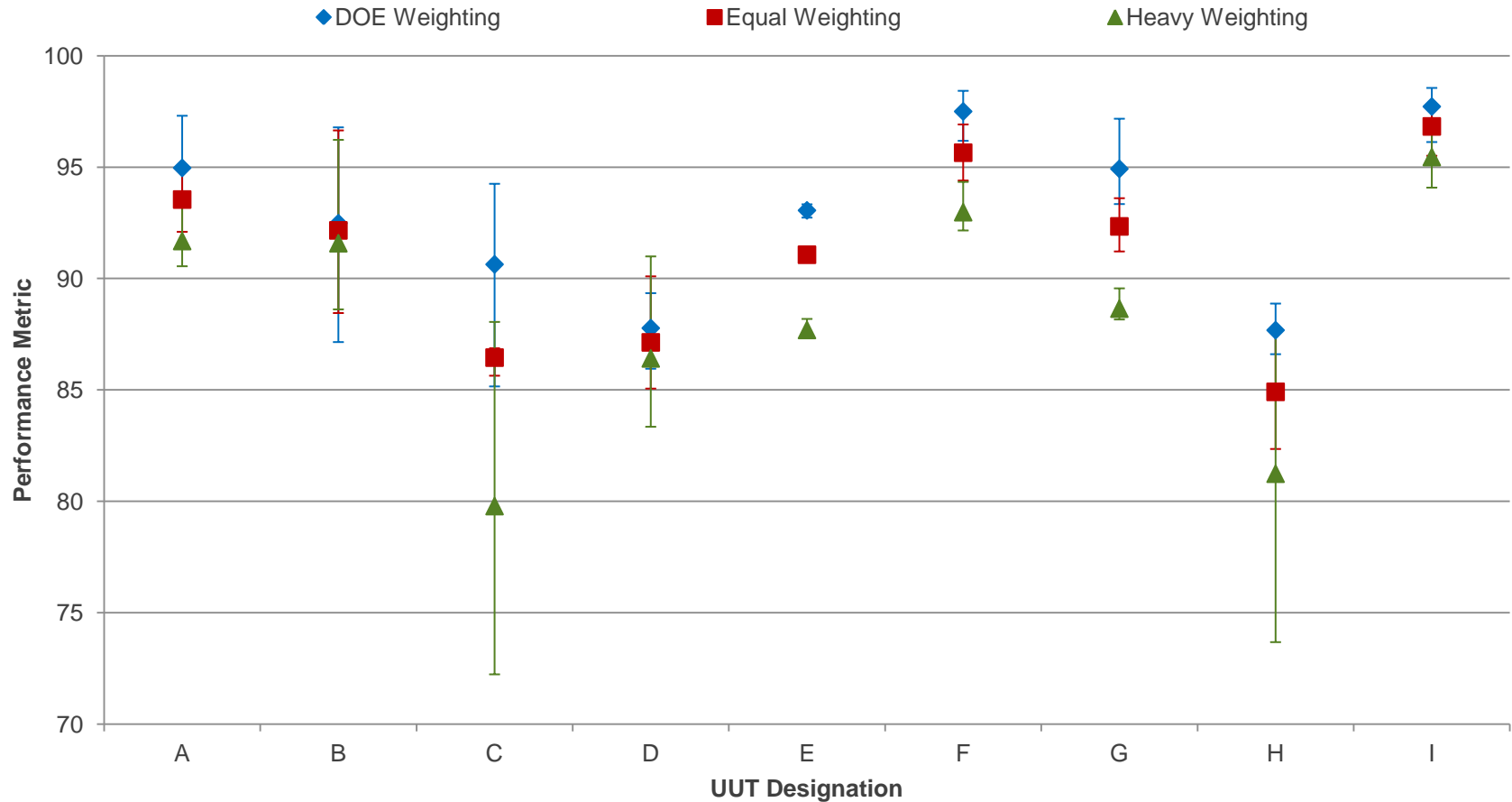
- Flatware is typically completely clean (score of 5)
- Increases differentiation between units
- Decreases test burden
- Slightly increases test-to-test variability of a unit

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





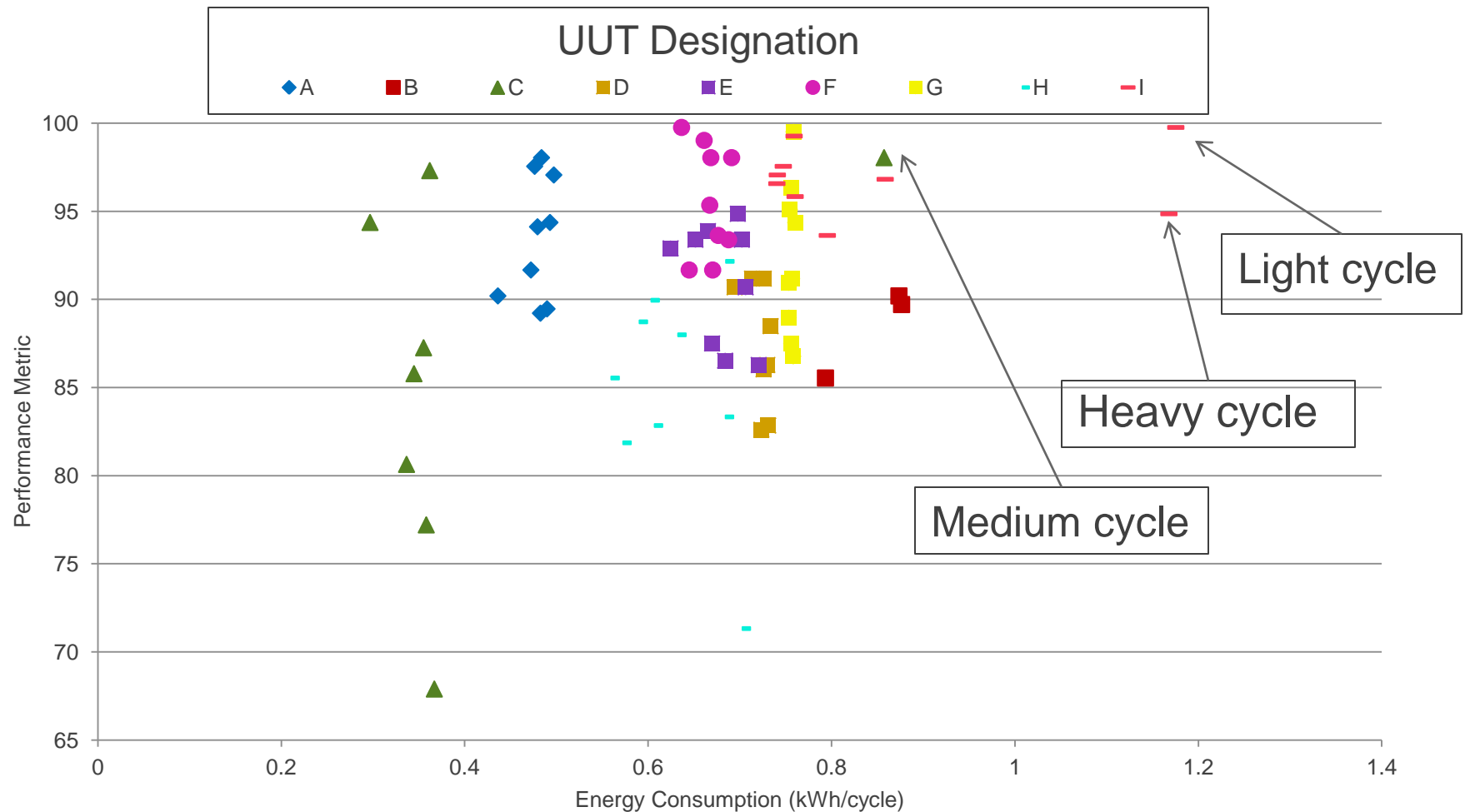
Cleanability Performance vs. Energy and Water Consumption

Energy and Water Consumption

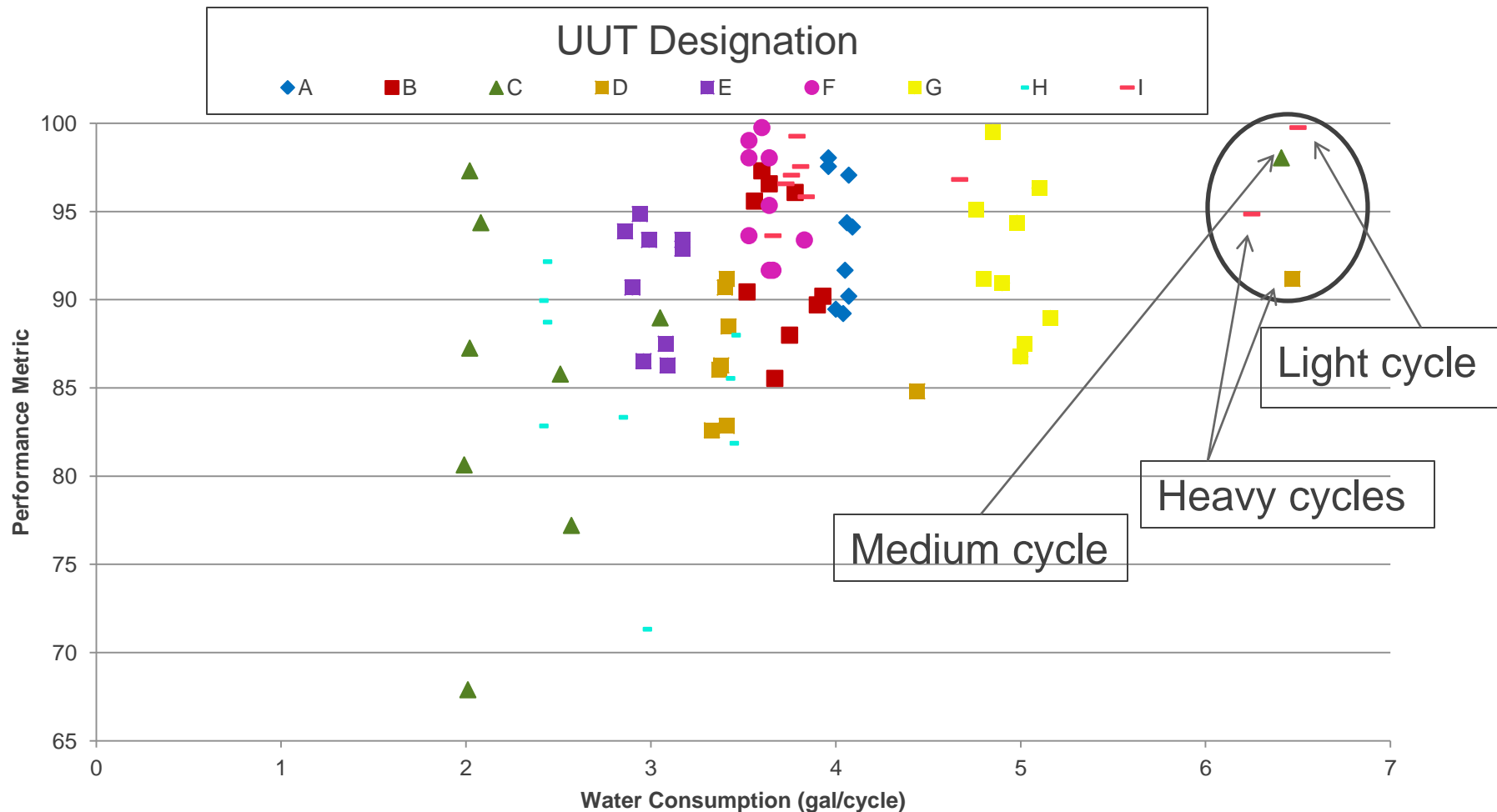


- Cleanability performance typically increased with increasing energy and water consumption
 - In some cases, good cleanability achieved at lower energy and water levels
 - Reached an upper limit beyond which Performance Metric did not increase significantly
- For some units, a higher energy and/or water 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. Energy 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

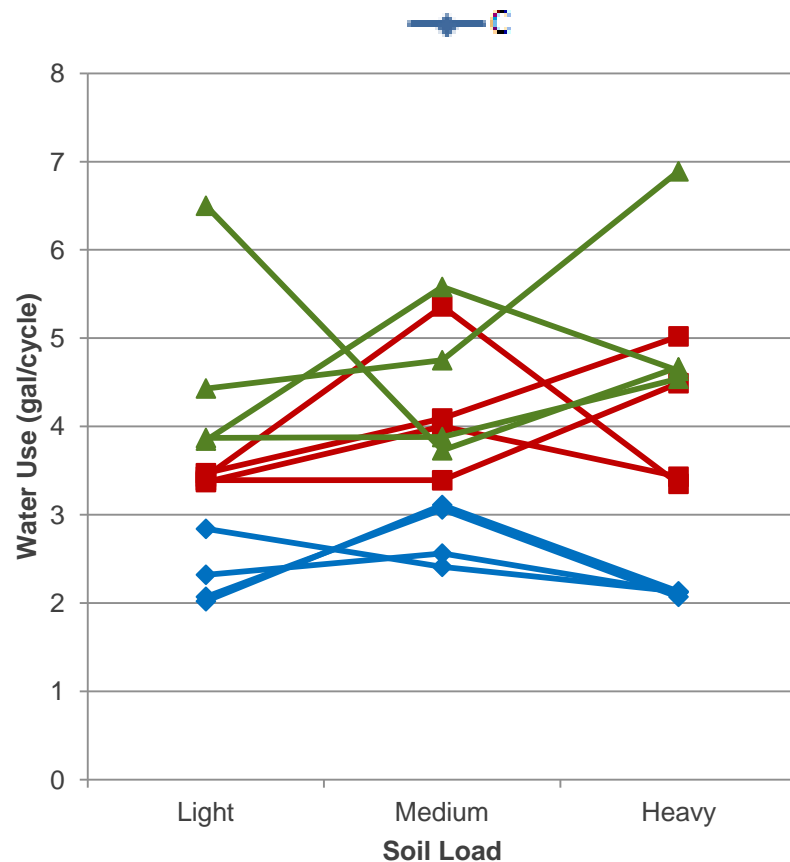


- Repeatability tests did not indicate a pattern for anomalous performance
 - Believed to be due to unpredictable cycle responses to constant soil load for certain units, not inconsistencies inherent in test method or test conduct
 - DOE has observed similar infrequent anomalous behavior during dishwasher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

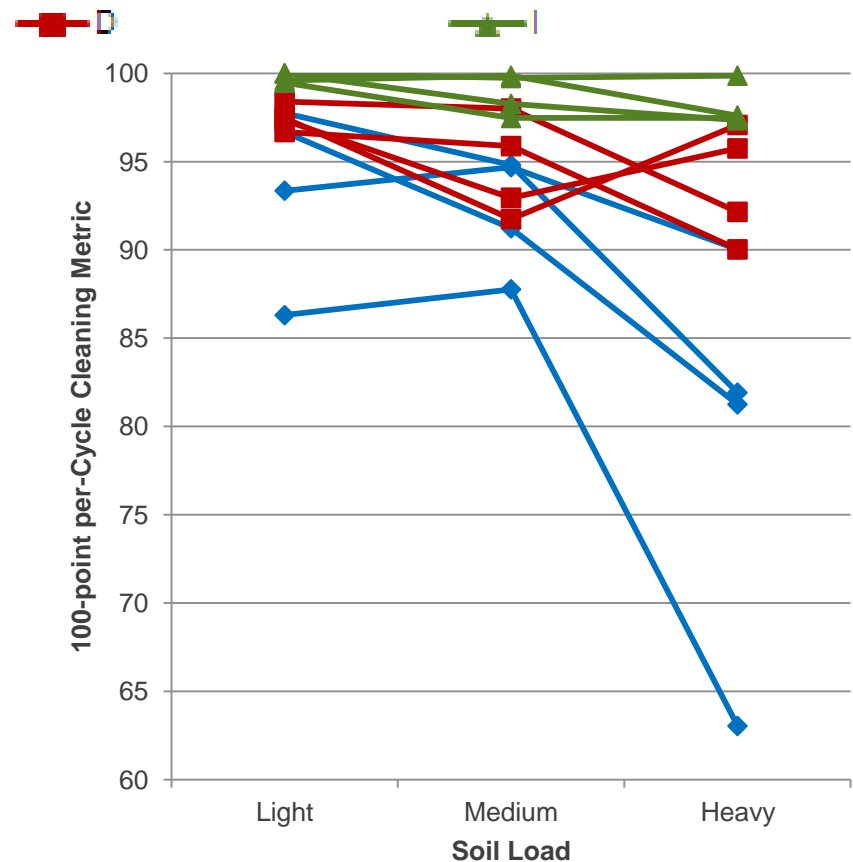
Water Consumption and Performance Metric vs. Soil Load



Water Consumption



Per-cycle Cleaning Metric





Additional Investigative Tests

Loading Pattern

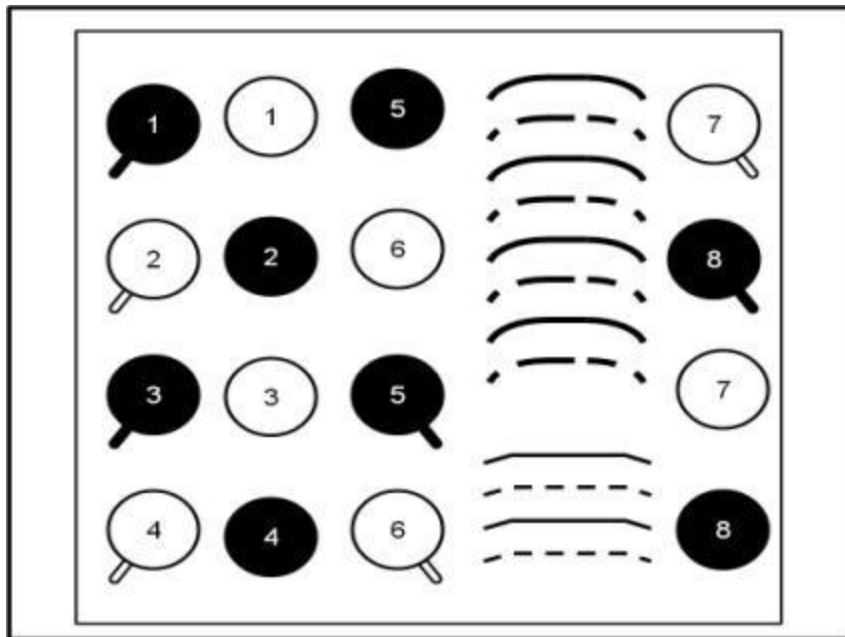


- Investigated three different loading patterns:
 - Alternate clean and soiled items
 - All soiled items towards the periphery of the racks
 - All soiled items towards the center of the racks
- Operated three test series on two units and reference dishwasher using only heavy load
- Loading pattern had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

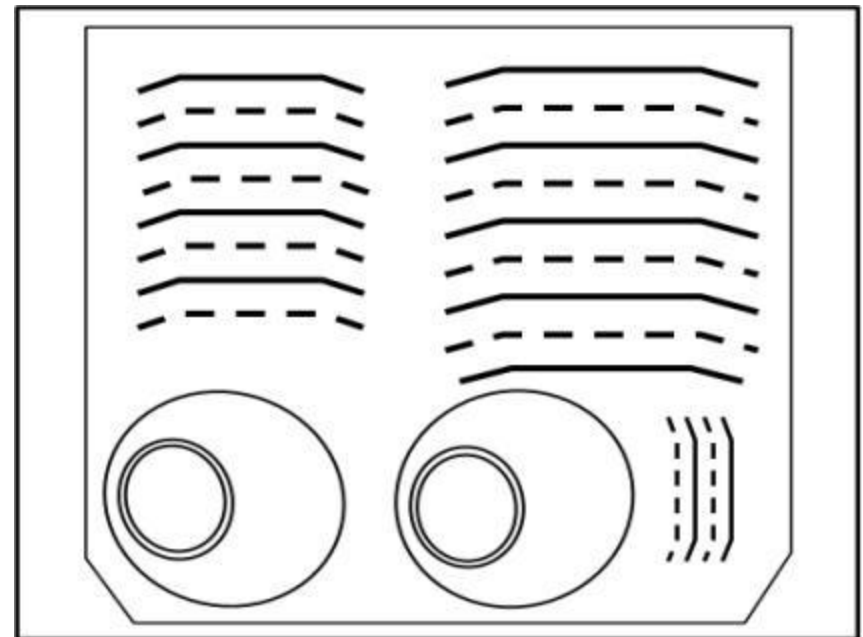
Performance Metric and Schematic of Alternate Loading Pattern



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

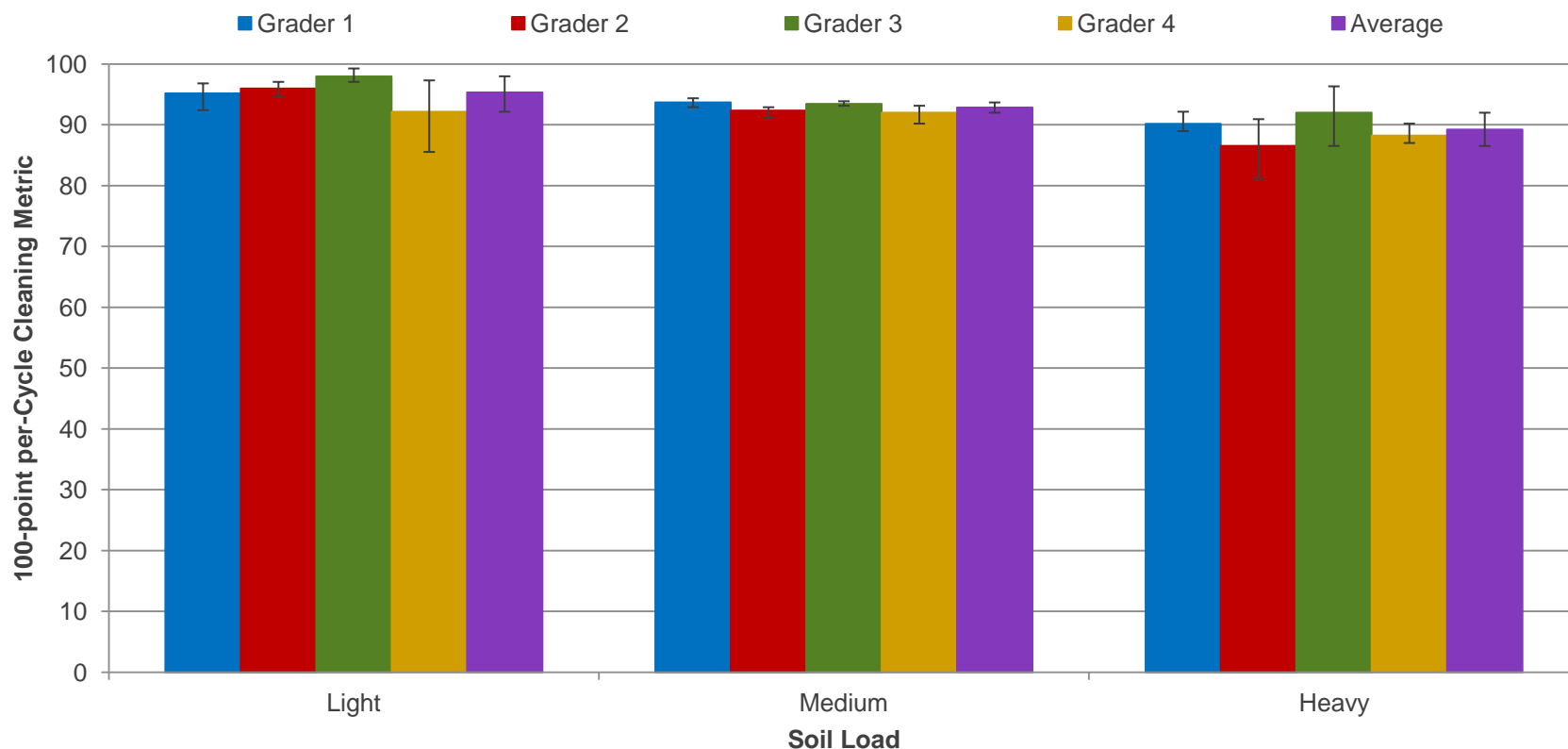


- Compared performance across different graders to determine whether a “grader bias” exists
- Investigated this variability for reference unit
 - Difficult to assess grader variability on UUTs
- Observed some grader-to-grader variability in the 100-point scores
 - No clear bias towards high or low scores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



- 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



Please send any additional comments to
appliances@energystar.gov or contact:

Amanda Stevens, EPA
Stevens.Amanda@epamail.epa.gov

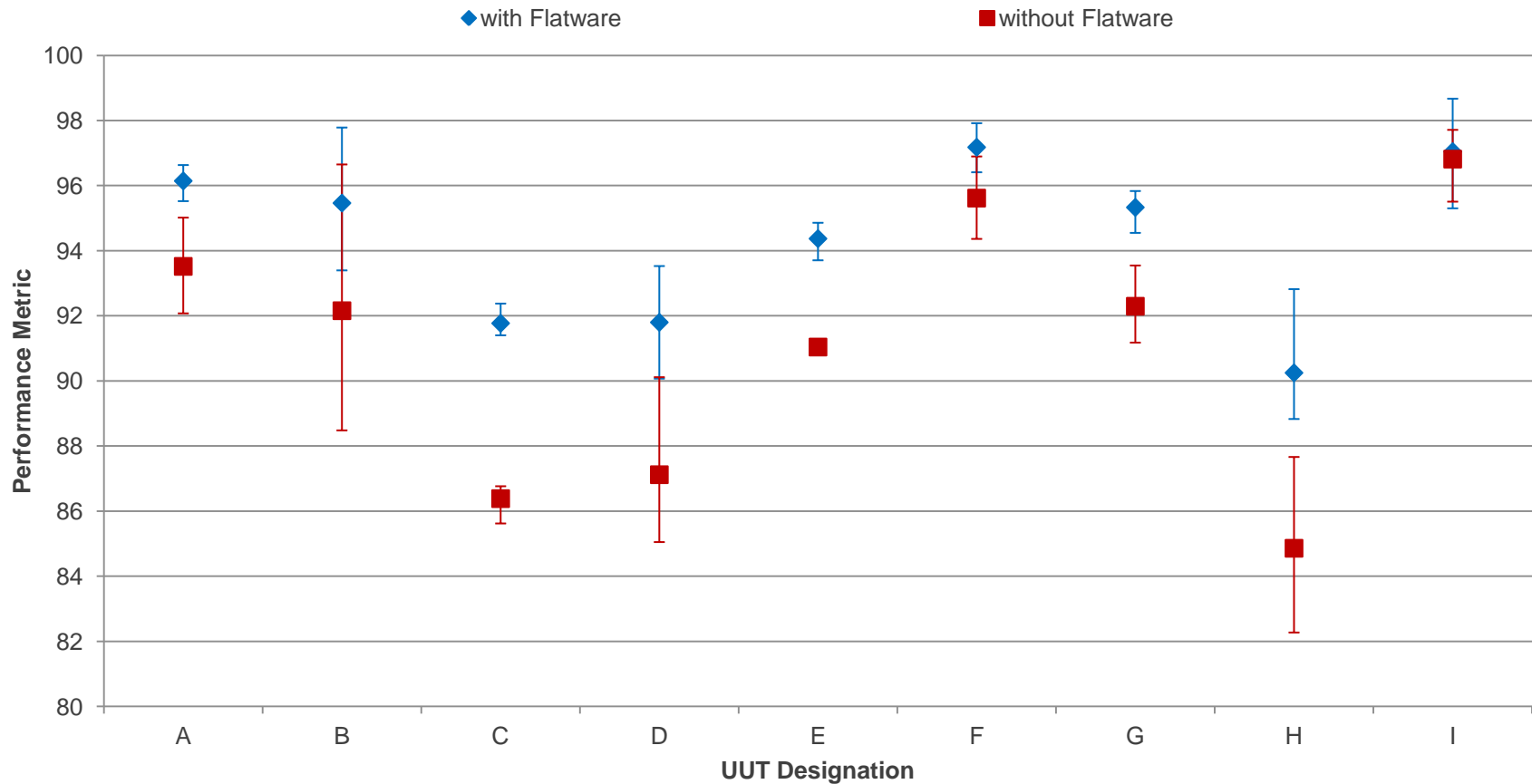
Ashley Armstrong, DOE
Ashley.Armstrong@ee.doe.gov

Mansi Thakkar, Navigant
Mansi.Thakkar@navigant.com

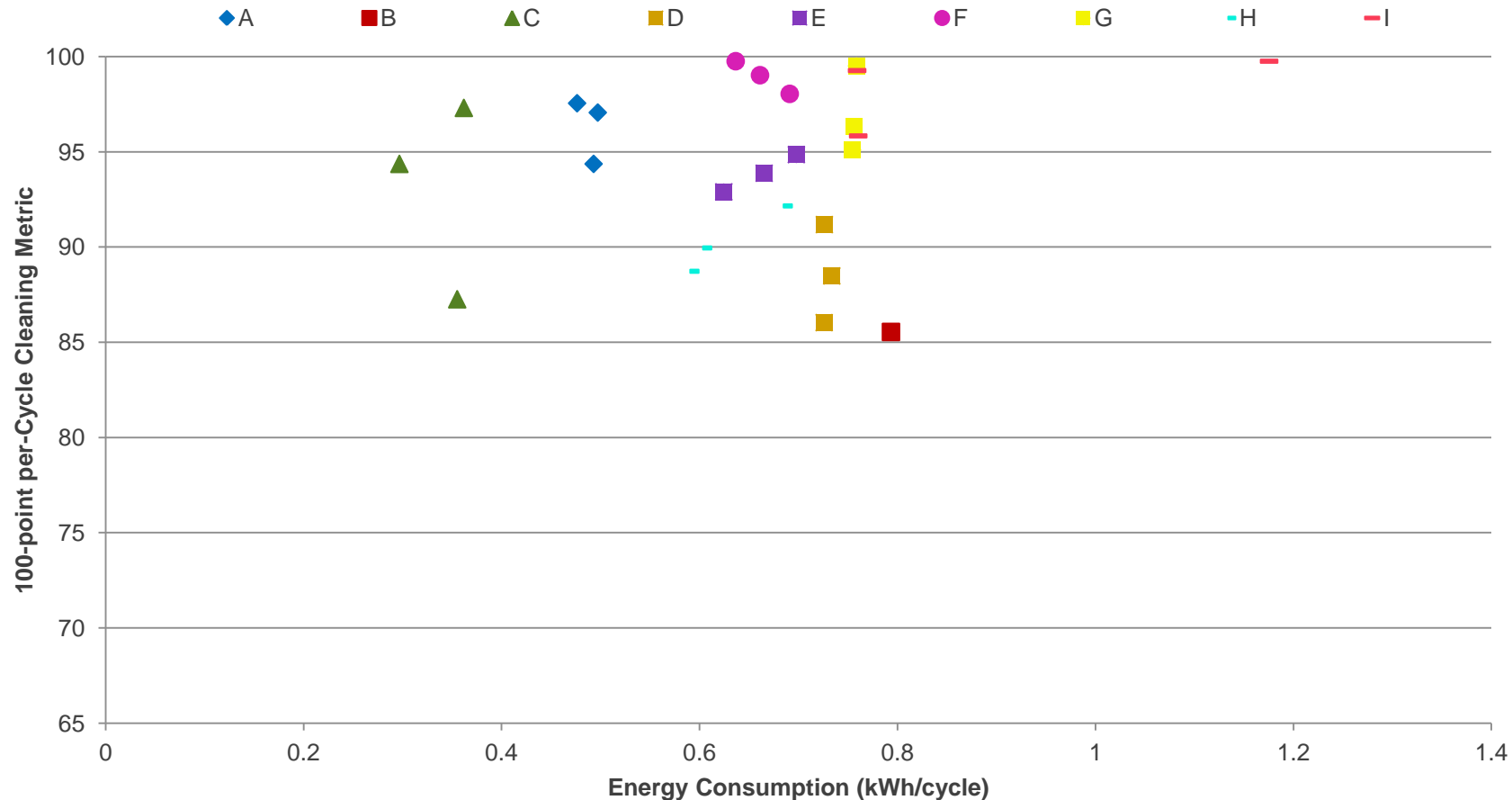


Additional Information

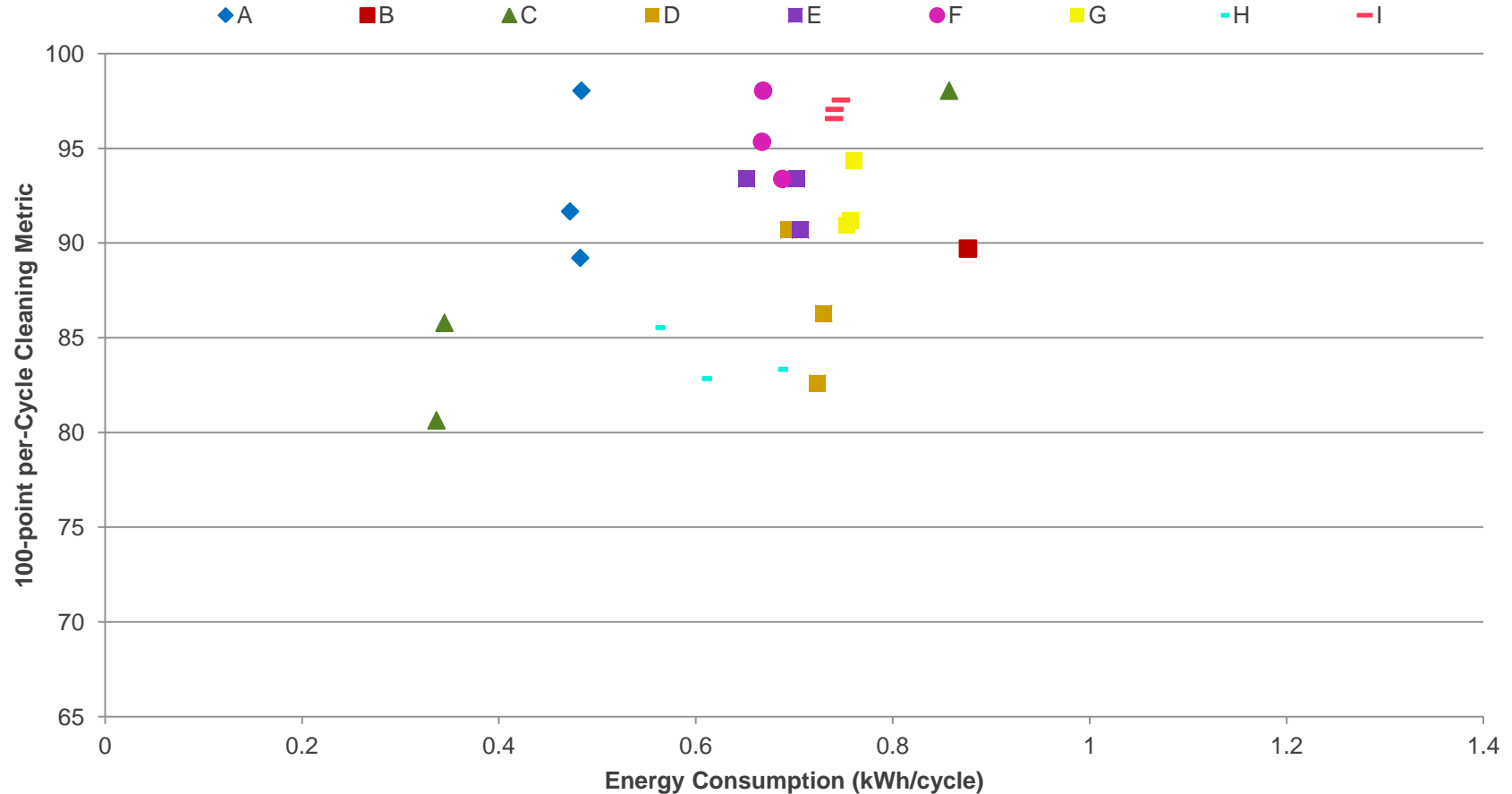
Comparison with and without Flatware



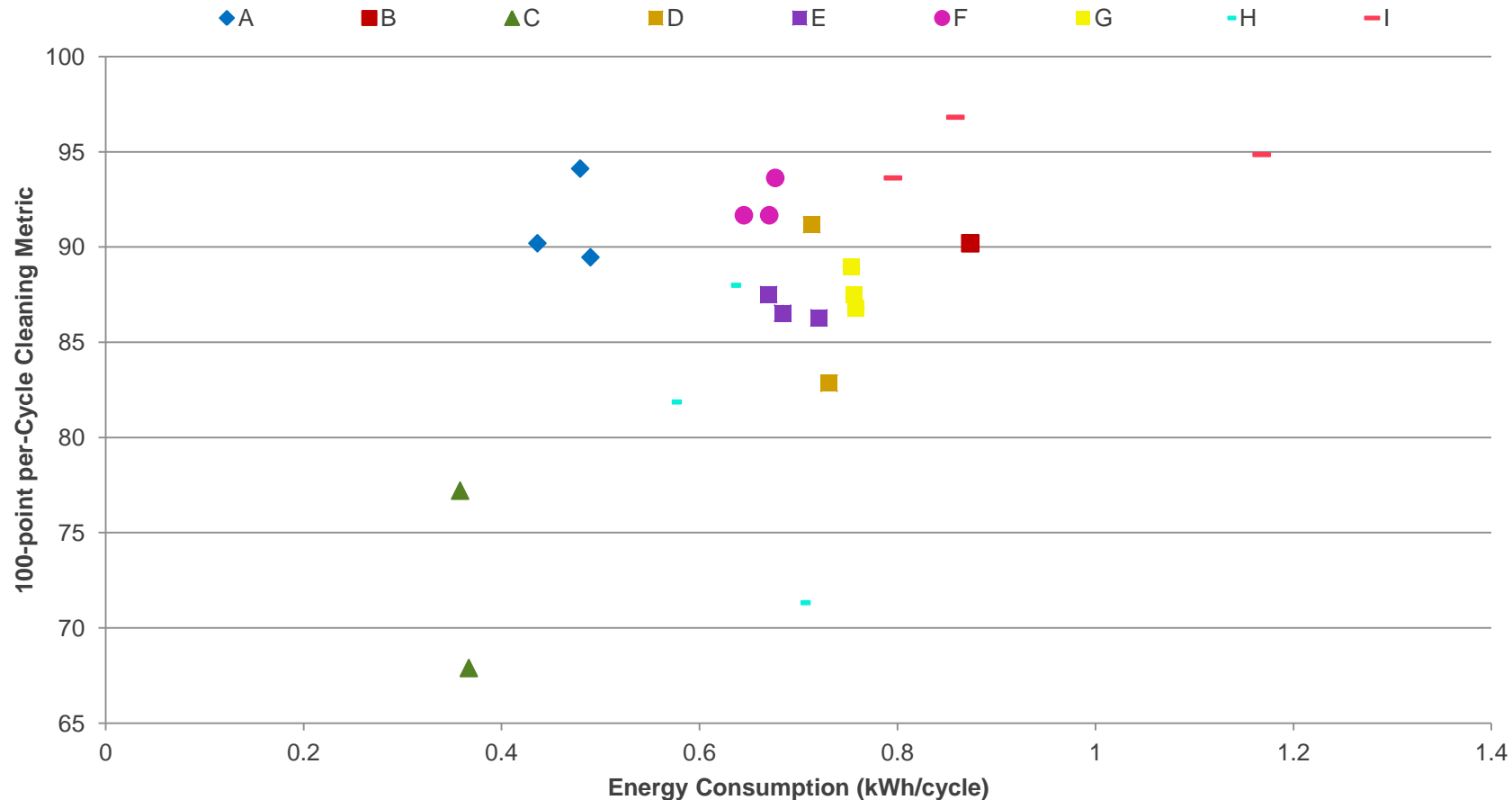
Per-Cycle Cleaning Metric vs. Energy Consumption – Light Load



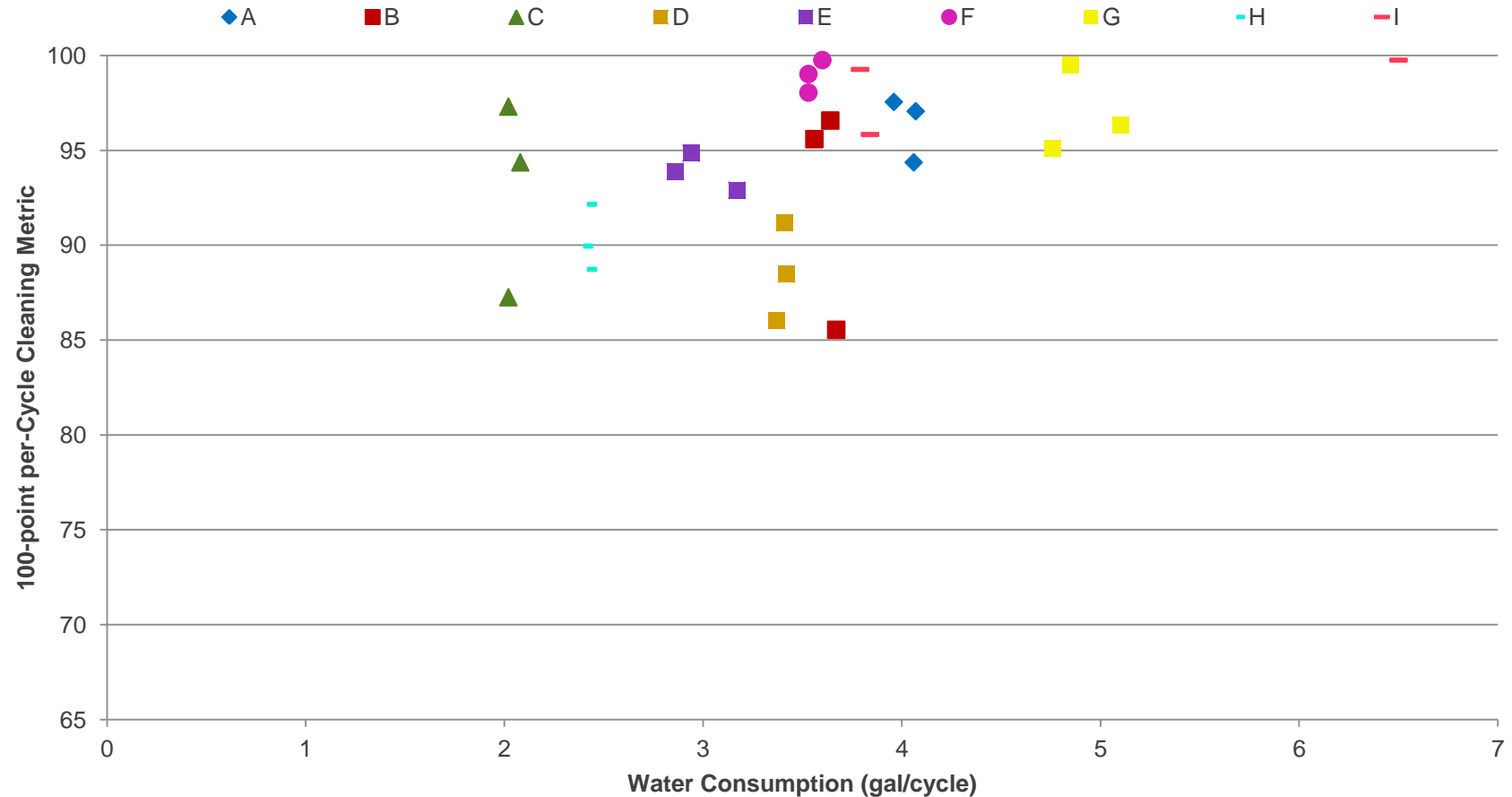
Per-Cycle Cleaning Metric vs. Energy Consumption – Medium Load



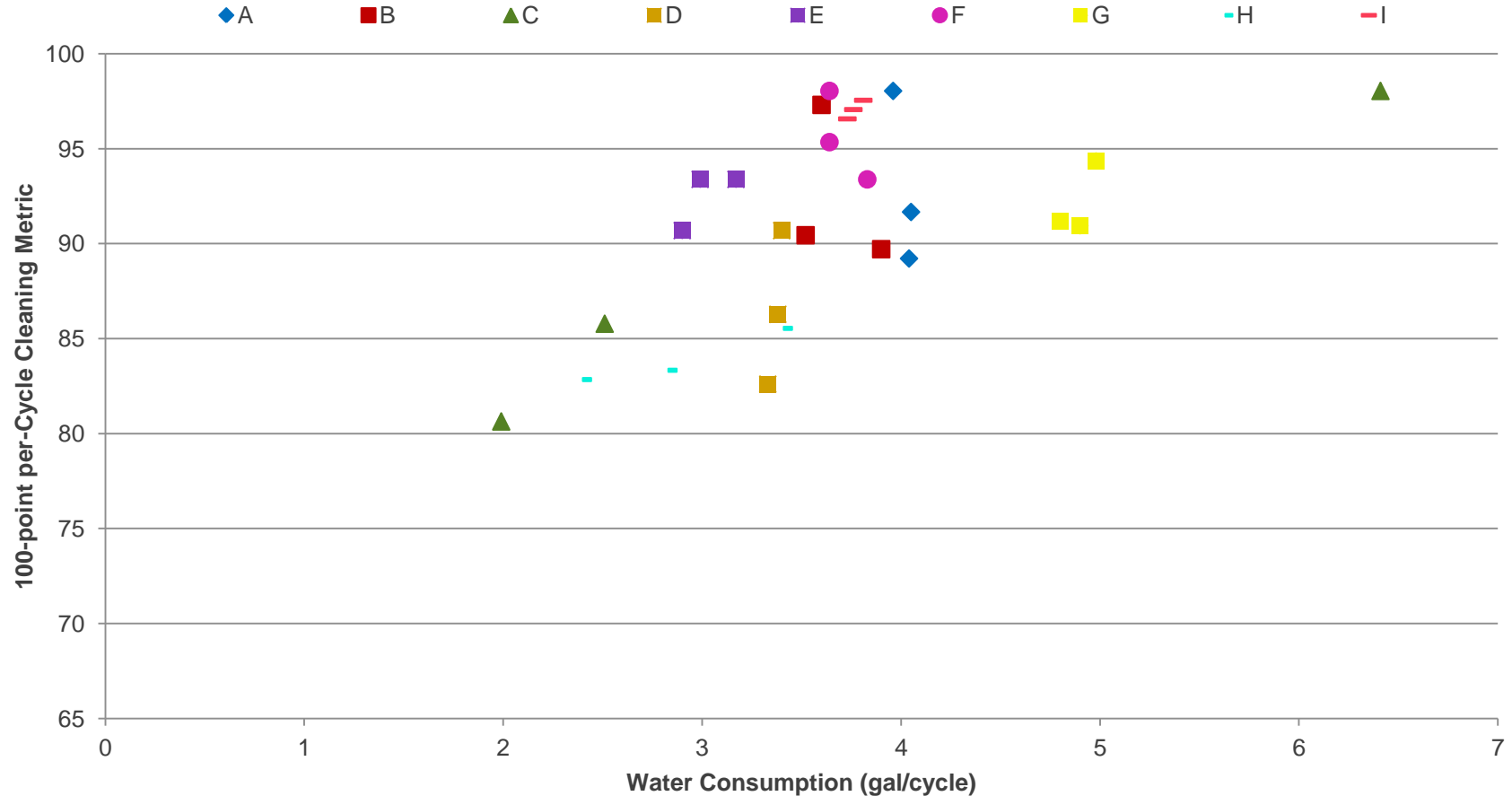
Per-Cycle Cleaning Metric vs. Energy Consumption – Heavy Load



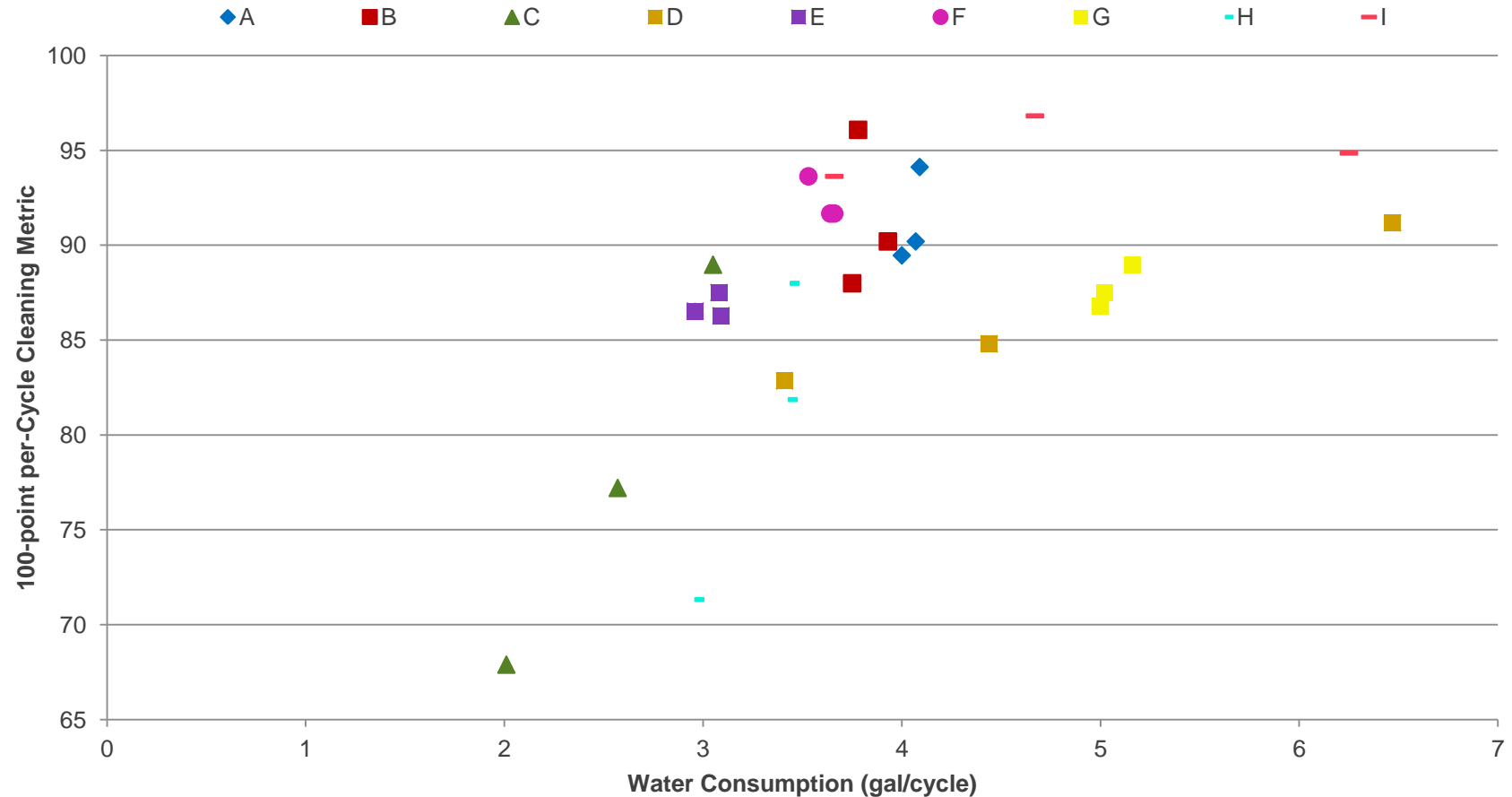
Per-Cycle Cleaning Metric vs. Water Consumption – Light Load



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



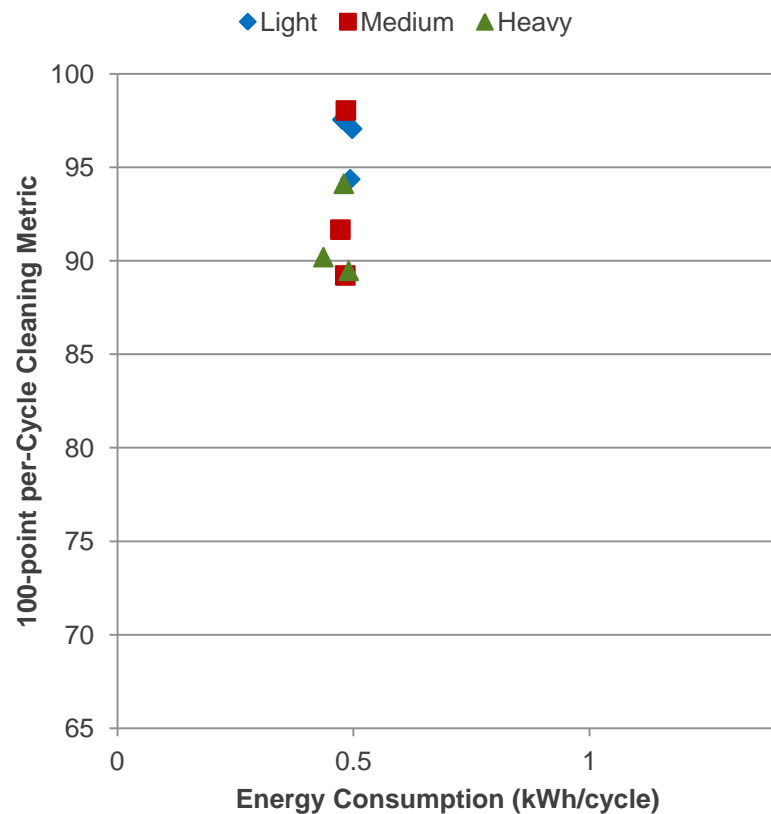
Per-Cycle Cleaning Metric vs. Water Consumption – Heavy Load



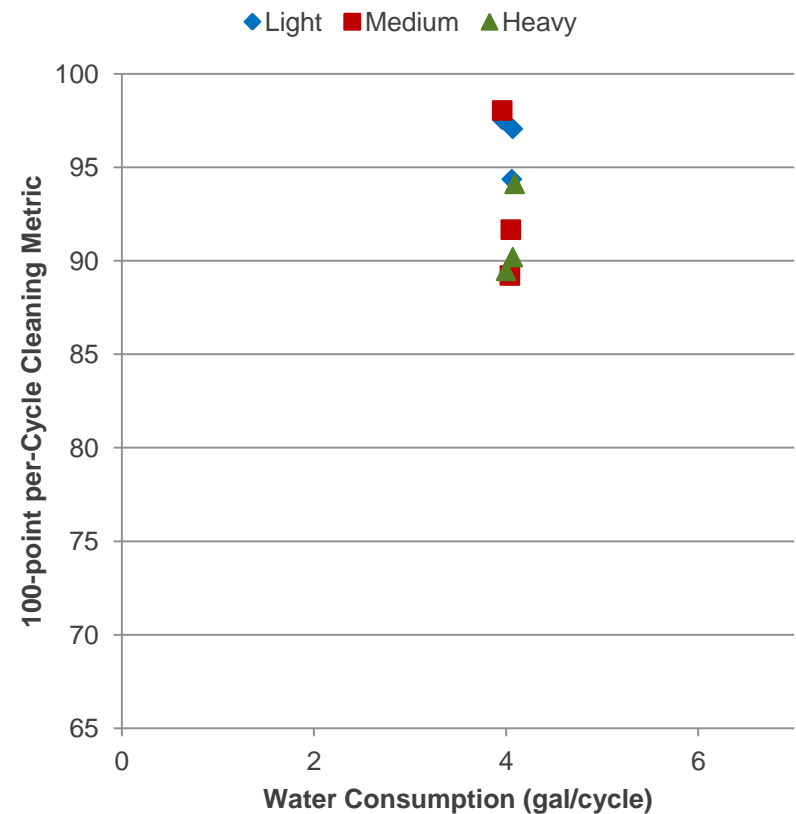
Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT A



Energy Consumption



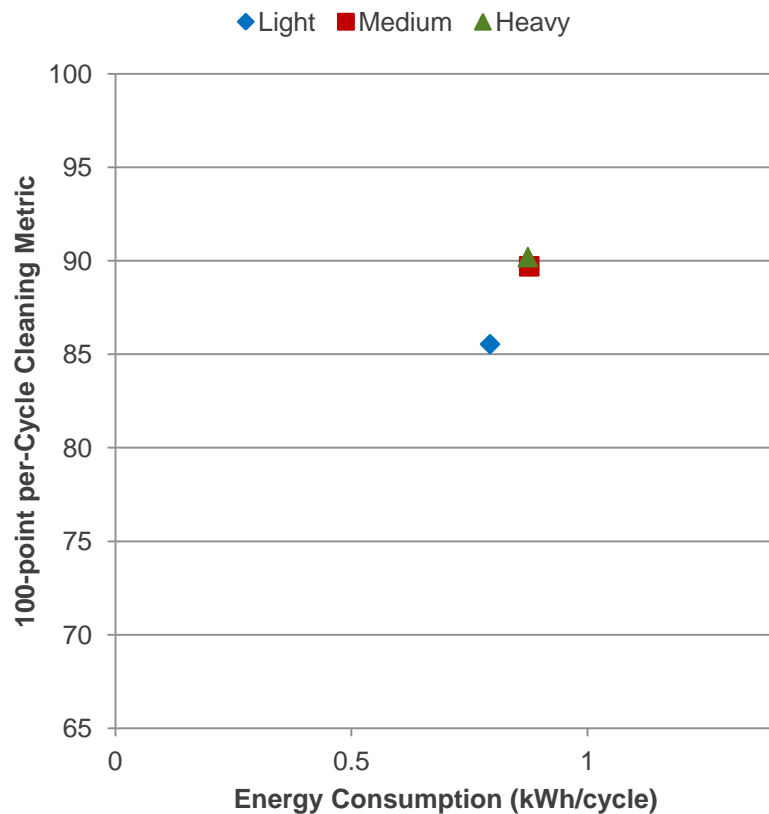
Water Consumption



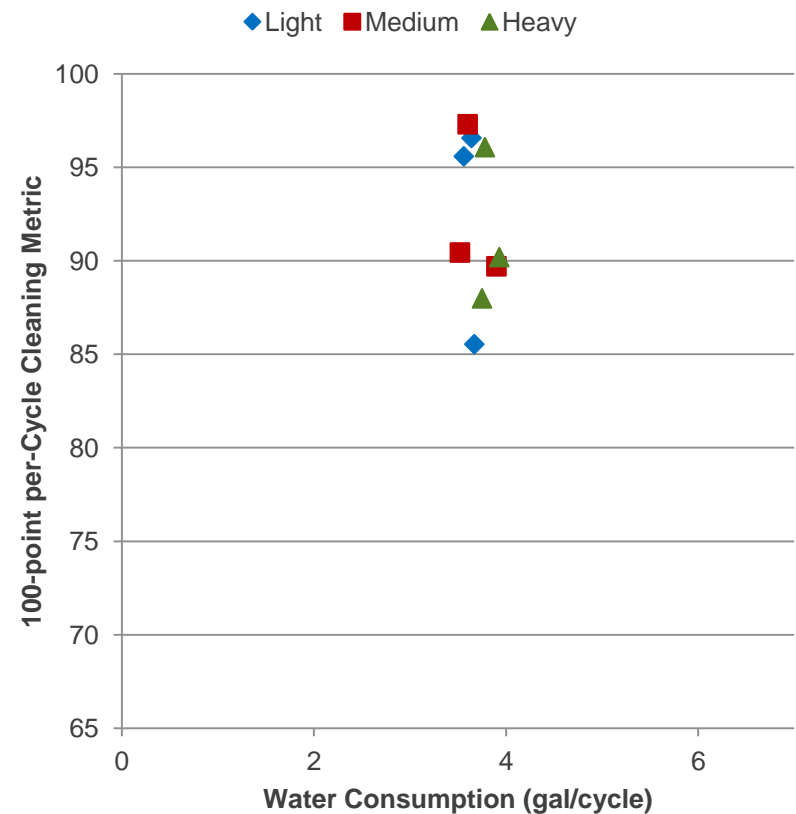
Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT B



Energy Consumption



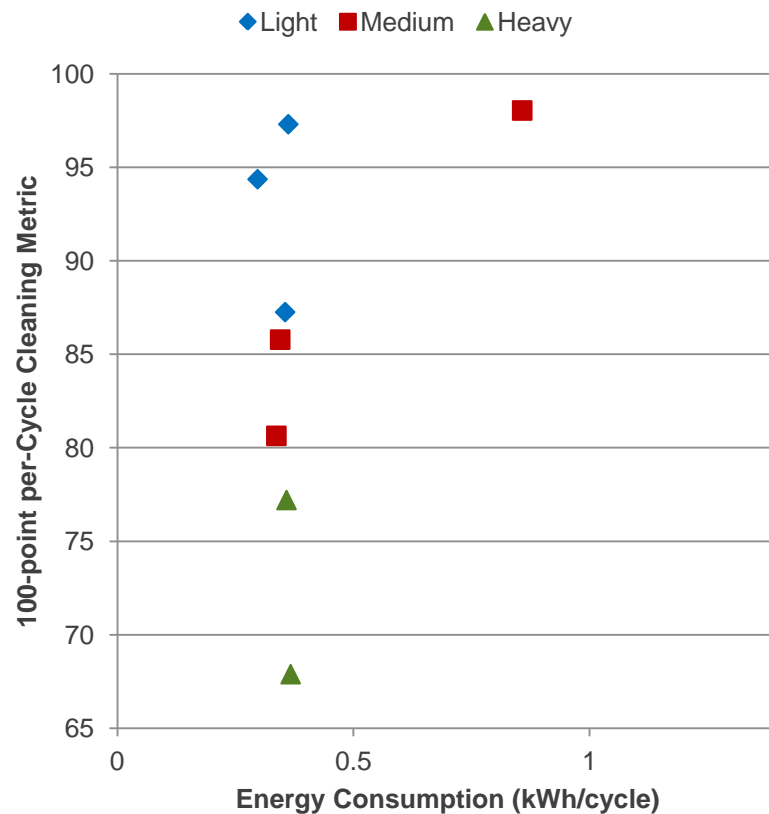
Water Consumption



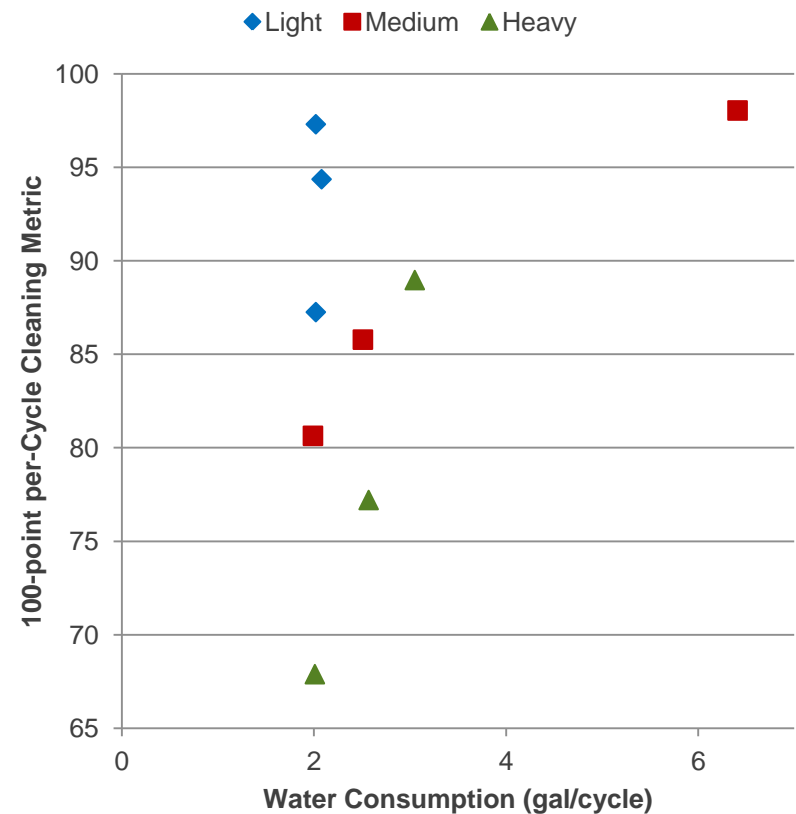
Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT C



Energy Consumption



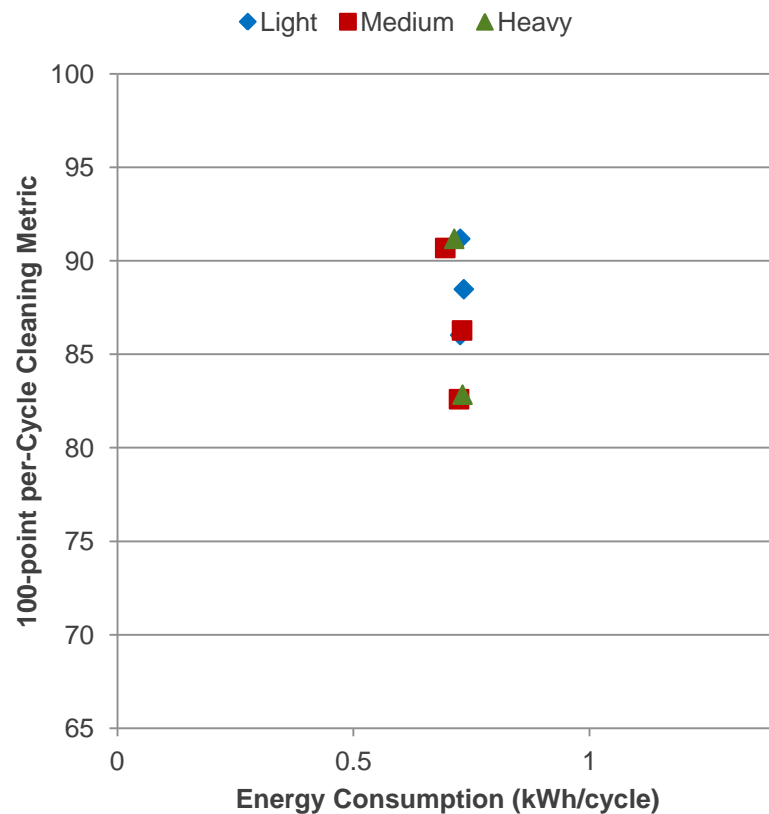
Water Consumption



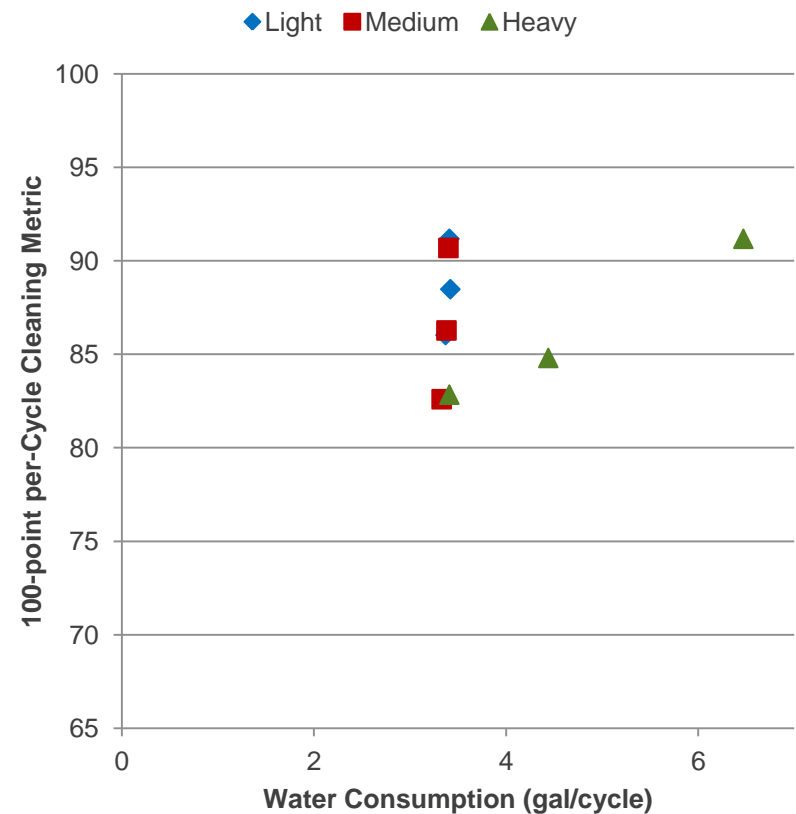
Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT D



Energy Consumption



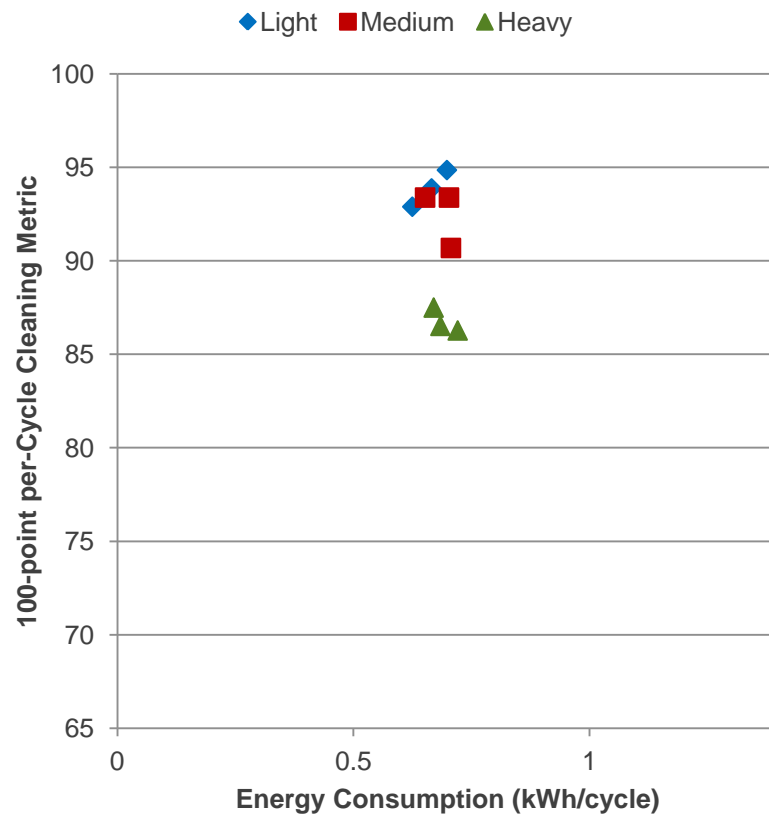
Water Consumption



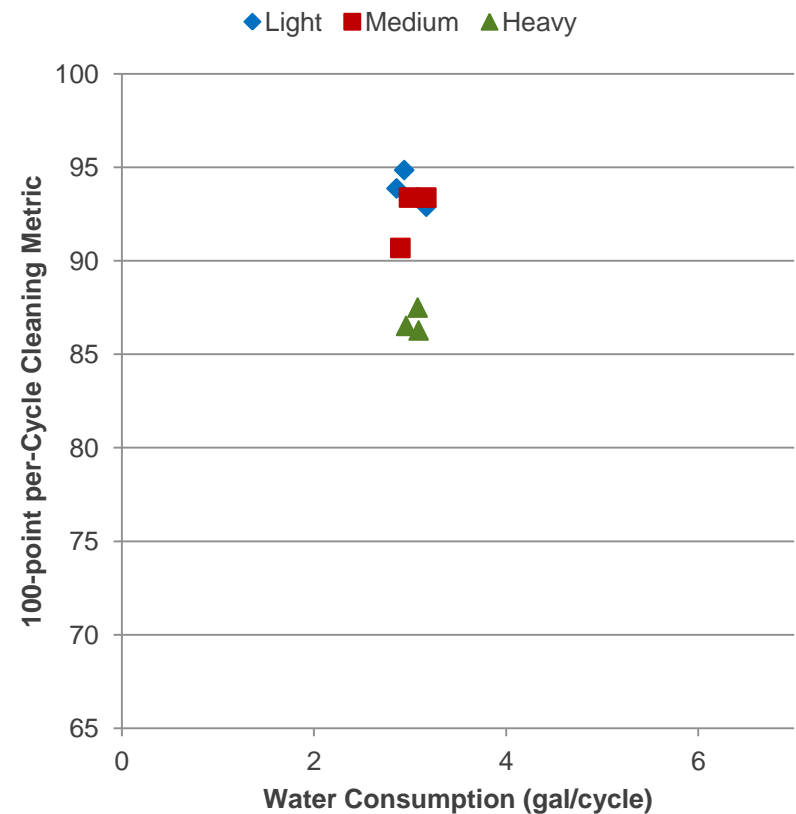
Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT E



Energy Consumption



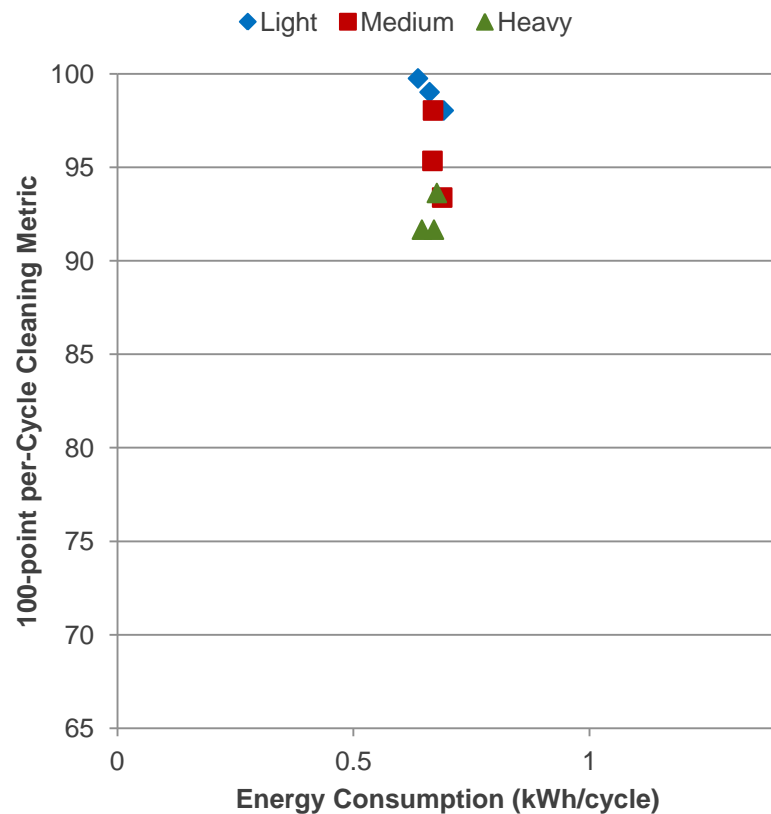
Water Consumption



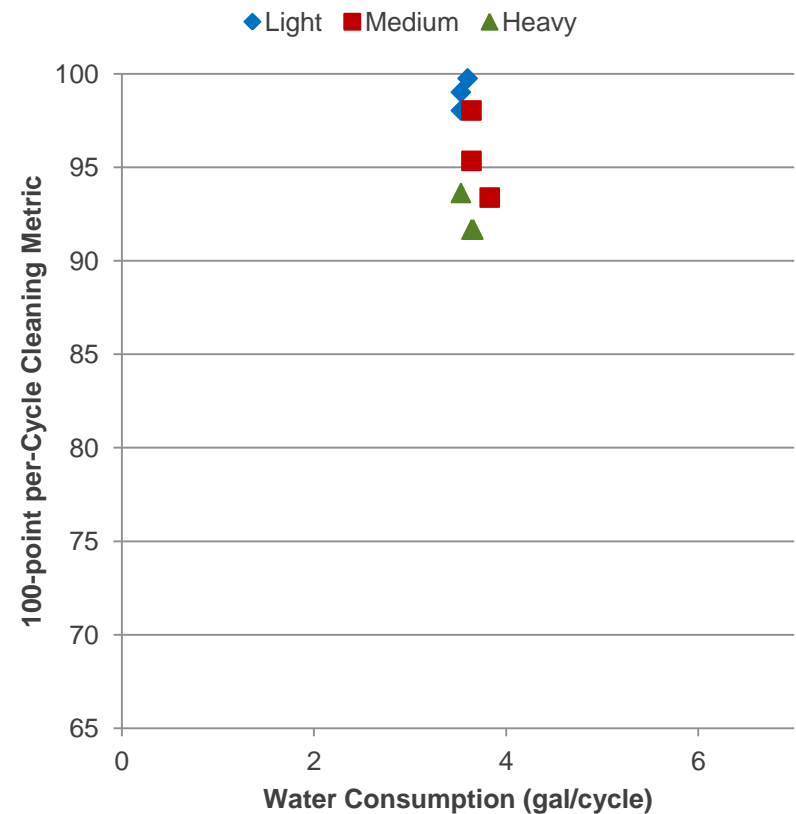
Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT F



Energy Consumption



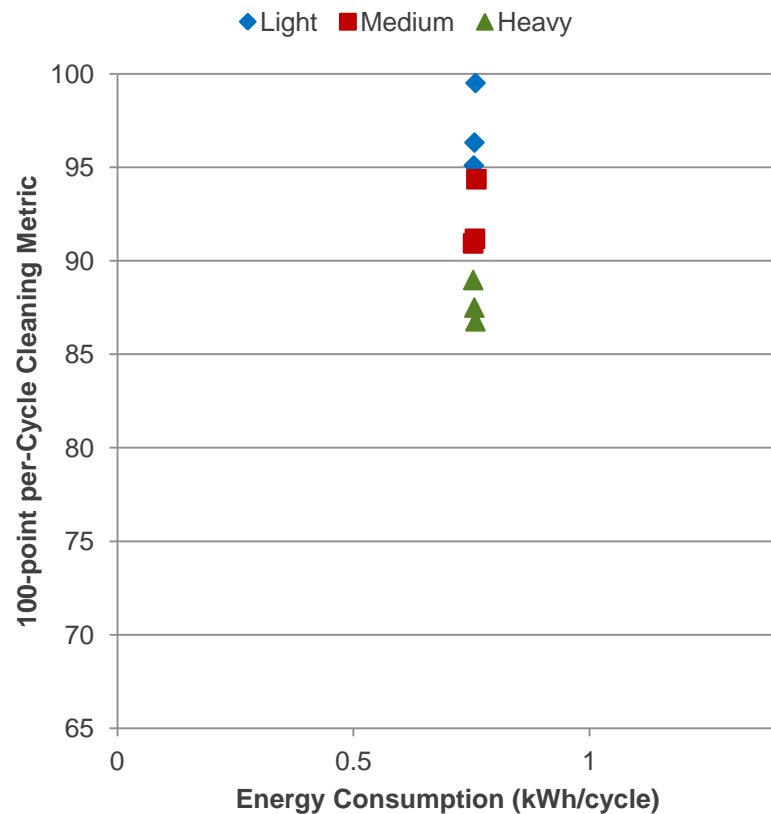
Water Consumption



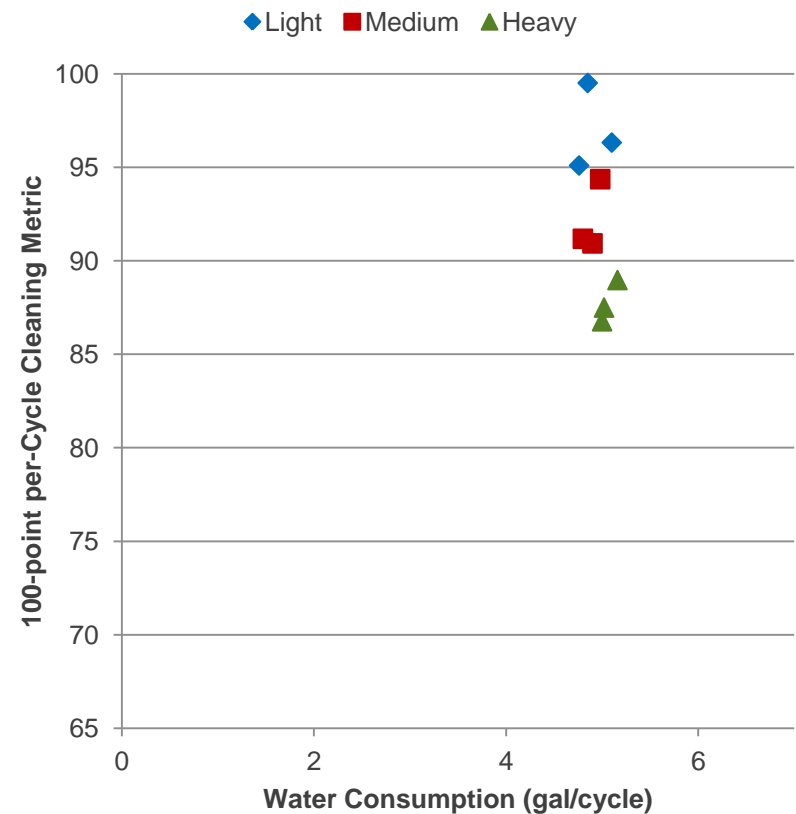
Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT G



Energy Consumption



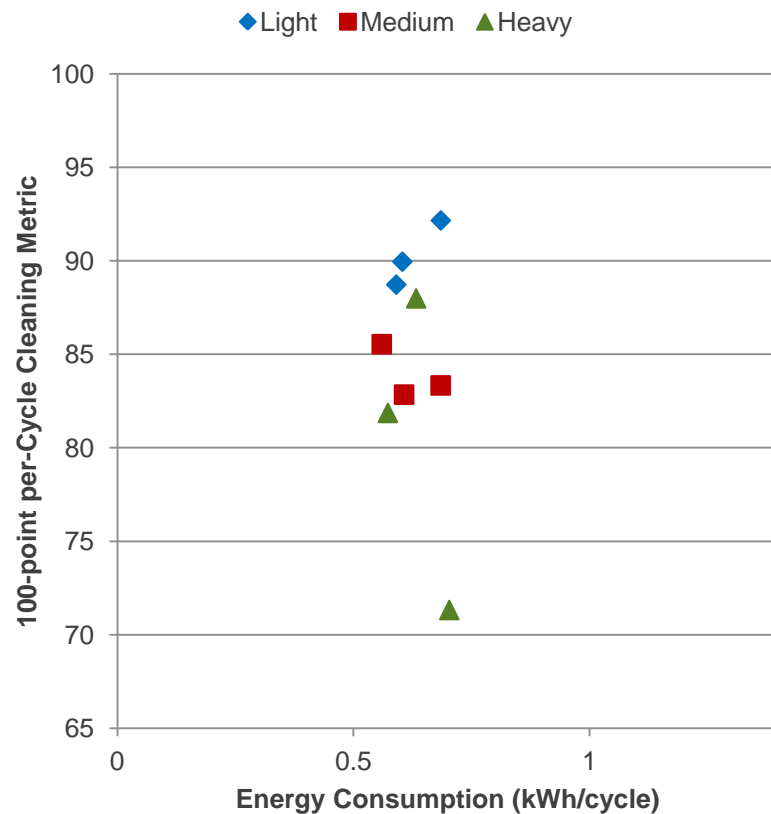
Water Consumption



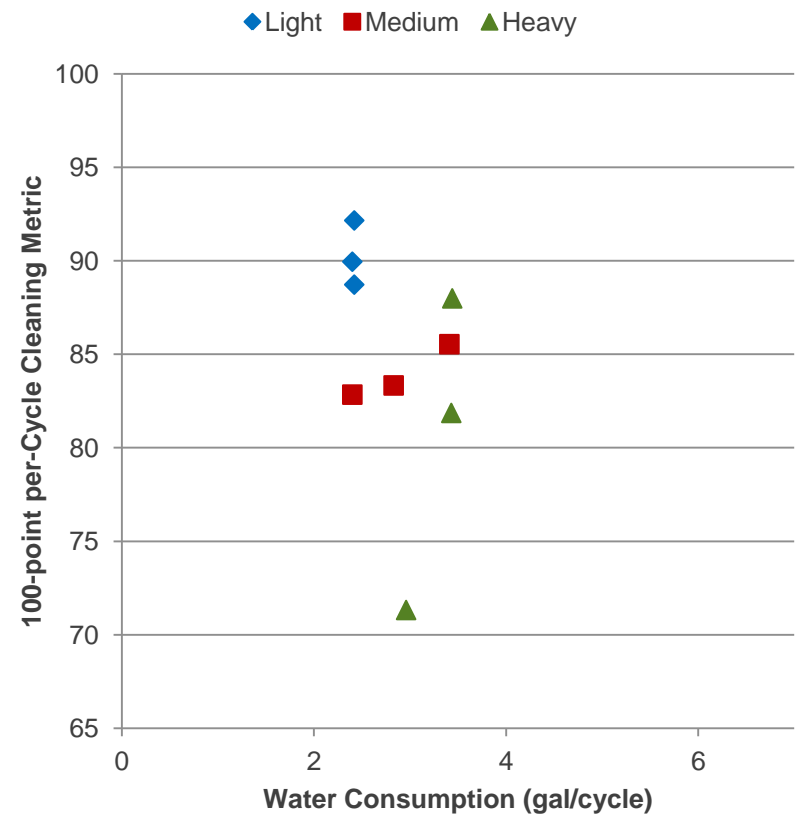
Per-Cycle Cleaning Metric vs. Energy and Water Consumption – UUT H



Energy Consumption



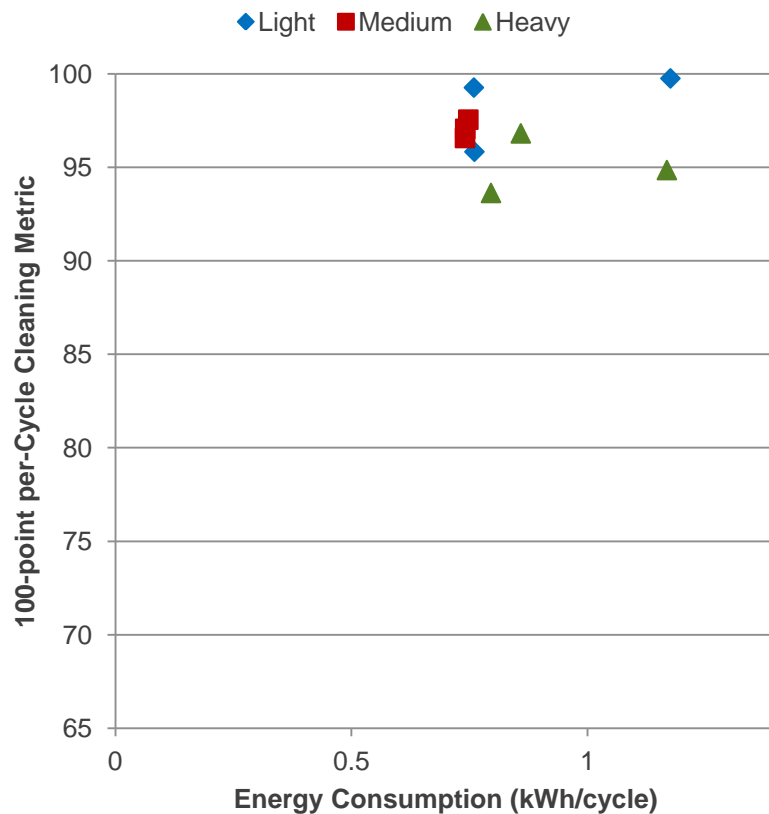
Water Consumption



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



Energy Consumption



Water Consumption

