Methodology Validation Report for
United Technologies Corporation

Voluntary Carbon Standard 2007.1

April 2011

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1 Introduction

This report is provided to United Technologies Corporation (UTC) as a deliverable of the first Voluntary Carbon Standard 2007.1 (VCS) methodology validation assessment process for the proposed VCS methodology titled *Baseline and monitoring methodology for the reduction of jet engine emissions through the use of engine washing technology*. This report provides a description of the steps involved in conducting the first validation assessment and summarizes the findings of the first validation assessment performed on the basis of the VCS 2007.1 and the VCS Program Normative Guidance Document: Double Approval Process, Version 1.0 (VCS Program Document).

The Audit Team was provided the original proposed methodology on September 30, 2009. Based on this documentation, a document review and desktop audit took place, which resulted in Corrective Action Requests (discussed later in this report) and revisions to the proposed methodology. The final version, dated May 10, 2010, serves as the basis of the final conclusions presented herewith.

1.1 Objective

The purpose of the methodology validation assessment is to have an independent third party assess the proposed methodology's conformance with VCS requirements.

1.2 Scope and Criteria

The validation assessment scope is defined as an independent and objective review of the proposed methodology. The validation assessment is conducted using the Voluntary Carbon Standard 2007.1 and the VCS Program Normative Guidance Document: Double Approval Process, Version 1.0 as the criteria. Additionally, First Environment applies its professional judgment as informed by ISO 14064-2 and 14064-3 in assessing the proposed methodology.

1.3 Assurance

First Environment, Inc. (First Environment) and UTC have agreed that a reasonable level of assurance be applied to this assessment.

2 Methodology

The following validation process was used:

- conflict of interest review;
- selection of validation team;
- kick-off meeting with UTC;
- development of the validation plan;
- desktop review of the methodology and other relevant documentation;
- follow-up discussions with UTC for supplemental information as needed;

- corrective action cycle; and
- validation report development.

The validation process was utilized to evaluate whether the methodology's approach is consistent with VCS and the VCS Program Document. A validation conformance checklist was developed for the methodology which summarizes the criteria used to evaluate the methodology, the methodology's conformance with each criterion, and the Audit Team's validation findings.

Conflict of Interest Review

Prior to beginning any validation project, First Environment conducts an evaluation to identify any potential conflicts of interest associated with the project. No potential conflicts were found for this project.

Audit Team

First Environment's audit team consisted of the following individuals who were selected based on their validation experience, as well as familiarity with combustion processes and transportation operations.

Michael Carim – Lead Auditor
Iris Caldwell – Auditor
Tod Delaney – Technical Expert
Jay Wintergreen – Internal Reviewer

Audit Kick-off

The validation process was initiated with a kick-off conference call on October 6, 2009 between First Environment and the primary UTC contact, Richard Love, and the primary Pratt & Whitney contacts, Colin Karsten and Chris Garrity. The communication focused on confirming the validation scope, objectives, criteria, schedule, and the information required for the validation assessment.

Development of the Validation Plan

Based on the information discussed during the kick-off conference call, the Audit Team formally documented its validation plan and provided the validation plan to UTC.

Corrective Actions and Supplemental Information

The Audit Team issued requests for corrective action and clarification during the validation assessment process. The corrective action and clarification requests and the responses provided are summarized in Section 2.3.

Validation Reporting

Validation reporting, represented by this report for UTC, documents the validation assessment process and identifies its findings and results.

2.1 Review of Documents

Eligibility requirements, baseline approach, additionality, project boundary, emissions, leakage, monitoring, data and parameters, and other pertinent criteria were assessed to evaluate the proposed methodology against VCS program requirements. Discrepancies between the proposed methodology and the validation criteria were considered material and identified for corrective action.

2.2 Follow-up Interviews

The Audit Team held teleconferences with the following individuals throughout the course of the methodology assessment:

- Richard Love – UTC
- Colin Karsten – Pratt & Whitney
- Chris Garrity – Pratt & Whitney

2.3 Resolution of Any Material Discrepancy

As described above, the Audit Team requested corrective actions, clarification, and supplemental information during the validation process. The corrective action and clarification requests and the responses are summarized in the tables below. As indicated, UTC adequately resolved all of these requests.

Requests for Corrective Actions and Clarification

ID	Corrective Action Request	Summary of Methodology Developer Response	Validation Conclusion
1	Please provide supporting evidence that the assertion that CH_4 and N_2O emissions are negligible in the baseline and project activity is consistent with 2006 IPCC Guidelines for National Greenhouse Gas Inventories.	According to 2006 IPCC Guidelines for National Greenhouse Gas Inventories, "little or no N2O emissions occur from modern gas turbines," and "methane may be emitted by gas turbines during idle and by older technology engines, but recent data suggest that little or no CH4 is emitted by modern engines."	Response is acceptable.

ID	Corrective Action Request	Summary of Methodology Developer Response	Validation Conclusion
2	Please expand on the procedures for identifying the appropriate baseline scenario – either existing level of propulsive efficiency or amount of fuel used in absence of the project activity. What are plausible alternatives to the project activity? Include a comparative assessment of the implementation barriers and net benefits faced by the project and its alternatives.	The methodology assumes that in the baseline case engines would not be washed. No plausible alternatives to the project activity need to be considered since all wash technologies are included in the assumed 5% of engines already being washed in the baseline.	Response is acceptable.
3	Please justify the assertion that TSFC declines in a linear fashion.	Pratt & Whitney's presentation of engine washing data and results from several airlines demonstrates linear decline in TSFC.	Response is acceptable.
4	Please justify the statistical sufficiency of collecting 10 cruise data points prior to the wash and 10 data points after the wash to determine $\Delta TSFC_m$ and justify the initial sample size of 20 data points.	Data and statistical evidence was provided to demonstrate that: A minimum of 10 data points ensures a level of accuracy on the calculated improvement of approximately 0.4% fuel flow and 3°C exhaust gas temperature. Across a fleet of 20 engines, representing a small fleet, this translates to accuracy greater than 0.1% on the fleet average TSFC improvement. An initial sample size of 20 data points provides a large enough statistical sample of data to identify outlying data points as well as shifts in the data, while minimizing the potential for biases that may result from normal engine operation.	Response is acceptable.
5	Please justify the default value chosen for BP.	The basis for the 5% value assigned to the parameter was explained: Pratt & Whitney sales representatives conducted an informal survey of engine washing practices amongst airlines. Based on this and known uses of Pratt & Whitney's technology, it was determined that approximately 3,500 washes were performed in 2009 out of an estimated 80,000 potential washes. A 5% value for baseline penetration is conservatively assumed.	Response is acceptable.

ID	Corrective Action Request	Summary of Methodology Developer Response	Validation Conclusion
6	Please justify the default value chosen for $ACFC_m$.	Pratt & Whitney's data on EcoPower wash effectiveness suggests that 800 cycles represents the low end of the range in which full contamination occurs, therefore serving as a conservative default value. Engine washing results from several airlines supports the claim that 800 cycles is a conservative value.	Response is acceptable.
7	The proposed methodology states that industry standard models will be used to determine fuel consumption. Please provide additional evidence regarding the reliability and consistency of modeled fuel consumption data as asserted on page 26. Please provide more thorough description of models, how are they run, etc.	The methodology employs outputs from a suite of aviation industry models which accurately represent aircraft and engine performance. Typically, each engine manufacturer maintains its own version of the model. Thermodynamic models are developed during the design and testing of engines and then customized to include airplane drag polar characteristics and engine thrust and fuel flow characteristics. The models are calibrated against airframe and engine performance data obtained by the aircraft manufacturers during flight testing. Data produced from these models are included in engine testing and performance reporting and are reviewed and approved by various technical and regulatory bodies, including the US Federal Aviation Administration. The general methodology and applicability of the models for estimation of aircraft performance is widely accepted within the aerospace industry and recognized by regulatory agencies.	Response is acceptable.
8	The parameter $NEC_{j,wc}$ is not included in Section 5.2.	Methodology was revised to include $NEC_{j,wc}$ in the monitoring methodology.	Response is acceptable.
9	Please provide further explanation supporting the claim that engine cycles are a more appropriate metric than either distance or operating hours to determine the level of engine contamination.	Contaminants known to hinder engine performance are present at ground level and in the lower atmosphere. Engine cycles correlate with engine contamination since each cycle incorporates approximately equal operating time and exposure in the lower atmosphere, as opposed to engine hours or distance which may not correlate as well due to significant operating time at higher altitudes where contaminants are not concentrated	Response is acceptable.

ID	Clarification Request	Summary of Methodology Developer Response	Validation Conclusion
1	Please confirm that the proposed methodology has not been previously rejected under any GHG programme.	The proposed methodology has not been submitted to any other GHG programme, and consequently has not been rejected.	Response is acceptable.
2	Please clarify whether engine washing results in other improvements, such as reduced maintenance requirements, and clarify whether any potential leakage scenarios were considered.	A direct correlation between engine washing and an associated reduced level of general maintenance has never been measured. What has been clearly observed is the extension of engine "time on wing" due to engine washing. Because time on wing is extended, maintenance can be foregone for a matter of months. Increased emissions from extended "time on wing" was considered as a source of leakage; however, no leakage was determined since engine washing resulted in an immediate reduction of emissions.	Response is acceptable.
3	Please clarify the process and/or criteria for demonstrating the appropriateness of models used to estimate fuel consumption and determine $\Delta TSFC_m$.	The proposed methodology encompasses models such as Pratt & Whitney's ADEM and EHM Plus, or other similar models used by major engine manufacturers as well as major airlines to monitor engine performance. Models used account for typical availability of information within an operational airline to allow for compatibility with nearly all aircraft and engine combinations.	Response is acceptable.
4	Please provide further explanation for why it is acceptable to compare engine trend data collected post-wash to engine trend data collected when the engine is fully contaminated.	Engine trend data are anticipated to remain stable and consistent in the absence of any performance-modifying activity. In the event of a known performance-modifying activity, such as an engine wash, the levels of the post-wash data can be compared to the pre-wash data to determine the direct impact of the activity on engine performance.	Response is acceptable.
5	Please clarify whether the methodology developer considered applying the additionality tests described in the VCS 2007.1 Protocol, including an explanation as to why they were or were not adopted in the methodology.	After discussion with the VCSA, the CDM *Tool for the demonstration and assessment of additionality* was selected to determine project additionality.	Response is acceptable.

ID	Clarification Request	Summary of Methodology Developer Response	Validation Conclusion
6	The methodology specifies the minimum number of cruise data points necessary to determine $\Delta TSFC_m$. Please clarify the minimum number of takeoff data points required for the same.	The minimum number of data points required at takeoff is the same as the number of data points required at cruise.	Response is acceptable.
7	Please clarify what constitutes a complete engine wash, including a technical description on the engine wash process.	Jet engine operating manuals define procedures and steps for engine washing and therefore can be referenced to determine the particular requirements for any given engine. The definition of an engine wash contained in the methodology must be consistent with wash requirements defined by the manufacturer in order for the washing of that particular engine to be eligible under the proposed methodology. See also response to Clarification Request No. 8.	Response is acceptable.
8	How do the applicability requirements of the methodology address eligible engine washes?	UTC revised the methodology to include the following applicability condition: "The engine washing was performed and completed in compliance with the wash requirements as provided in the engine's maintenance manual, or an alternative specification document as approved by a governing aviation regulatory body, such as the United States Federal Aviation Administration."	Response is acceptable.

3 Assessment Findings

The methodology validation assessment includes evaluation of elements of the proposed methodology against specific VCS program requirements. A summary of the proposed methodology's approach and First Environment's assessment is provided below.

3.1 Eligibility Criteria

The proposed methodology clearly identifies criteria by which to assess the eligibility of jet engine washing programs. Specifically, the methodology requires that eligible projects must:

- clean any or all three of the compressive components of an engine: fan, low pressure compressor, and high pressure compressor;
- only claim emission reductions related to increased propulsive efficiency due to engine washing;

- engine washing was performed and completed in compliance with the wash requirements as provided in the engine's maintenance manual, or an alternative specification document as approved by a governing aviation regulatory body, such as the United States Federal Aviation Administration;
- leave the engine on the wing during the washing and transport engine washing technology to the engine, as opposed to removing the engine from the wing and transporting it to another location;
- use a closed-loop system whereby all materials are collected and processed and all discharges meet appropriate environmental standards; and
- demonstrate that the decline in the TSFC improvement due to engine recontamination following an engine washing occurs in a linear fashion.

The proposed methodology is applicable for a 10-year crediting period and may be renewed twice.

The criteria identified provide a clear basis for determining the methodology's applicability to potential project activities. First Environment concluded that eligibility requirements are appropriate and adequate.

3.2 Baseline Approach

The proposed methodology establishes the baseline scenario as the existing level of propulsive efficiency or the quantity of fuel that would have been used by the jet engines in the absence of the project activity. Because airlines do not directly monitor fuel consumption by engines, the quantity of fuel consumed in the baseline is determined from modeled fuel consumption per engine cycle, which is defined as the operation of the engine during one takeoff and landing cycle.

The proposed methodology acknowledges that a certain number of engines may be washed in the absence of the project activity. Therefore, the proposed methodology applies a default five percent discount to overall emission reductions to account for non-additional engine washing. UTC discussed with the Audit Team internal market analyses that identified the approximate amount of engine washes that would have occurred in the baseline scenario. Baseline engine washing is estimated to occur on approximately 4.4 percent of the estimated market size of 80,000 engine washes per year. First Environment concluded that the basis for establishing the discount factor and its application result in a conservative characterization of the baseline scenario.

3.3 Additionality

The proposed methodology has adopted the most recent version of the *Tool for the demonstration and assessment of additionality* as published by the Clean Development Mechanism (CDM) Executive Board in order to evaluate project additionality. First Environment determined that this approach is appropriate and adequate.

3.4 Project Boundary

The project boundary is defined as the physical, geographical location of each engine washed by the project activity, including all flight routes. The transport and operation of equipment used to perform engine washings is also included within the project boundary.

The proposed methodology summarizes the relevant emissions sources in Table 1 and indicates whether each is included in the project boundary. Consistent with 2006 IPCC Guidelines for National Greenhouse Gas Inventories, CH_4 and N_2O emissions are considered negligible and therefore are excluded from the project boundary. First Environment determined that the proposed methodology provided sufficient criteria to establish the project boundary and that all relevant emission sources and GHGs are included.

3.5 Emissions

Baseline Emissions Quantification

Baseline emissions are assessed at the fleet level. A fleet is comprised of the set of engines of the same type, consuming the same fuel, and installed on the same type of airframe.

Baseline emissions are calculated by multiplying the total quantity of fuel consumed by all engines in a given fleet by the CO_2 emission factor for that fuel. Fuel consumption in the baseline scenario is determined per engine cycle based on modelled data. The proposed methodology requires project proponents to demonstrate the applicability of fuel consumption models during the validation process and provides basic criteria for validators to evaluate potential models. The proposed methodology also provides an equation to derive the CO_2 emission factor based on the carbon content of the fuel.

All formulae and quantification methods were reviewed for accuracy and appropriateness. First Environment concluded that the approach to calculate baseline emissions is appropriate and adequate.

Project Emissions Quantification

Project emissions are generated from fuel combustion in jet engines as well as from the engine washing process. Total project emissions are determined by summing emissions from these two activities across all fleets. Project emissions from fuel combustion are calculated by multiplying the total quantity of fuel consumed by the engines in a given fleet by the CO_2 emission factor for that fuel. The CO_2 emission factor is calculated based on the carbon content of the fuel.

As with baseline emissions, fuel consumption in the project scenario is determined per engine cycle based on modelled data. The quantity of fuel consumed is adjusted using an average thrust specific fuel consumption (TSFC) improvement factor, based on the number of engine cycles elapsed since the last engine wash. The proposed methodology requires project proponents to demonstrate the applicability of models used to determine fuel consumption and TSFC improvement.

The proposed methodology accounts for project emissions from generators used during engine washing and from the transportation of washing equipment to engines remaining on-wing. Fuel consumption from each piece of equipment is multiplied by the appropriate CO_2 emission factor based on fuel type. The proposed methodology provides equations to determine fuel consumption and the CO_2 emission factor.

All formulae and quantification methods were reviewed for accuracy and appropriateness. The Audit Team also discussed the operation and function of models used to determine TSFC with the UTC team in order to clarify their use and applicability. First Environment concluded that the methodology's approach to calculate project emissions is appropriate and adequate.

Emission Reductions Quantification

Emission reductions are calculated by multiplying the baseline penetration discount factor by the difference of baseline and project emissions. The proposed methodology specifies that the calculation should be performed for each fleet and then aggregated across all fleets. First Environment determined that this approach to calculate emission reductions is appropriate and adequate.

3.6 Leakage

The proposed methodology does not identify any sources of leakage. This is justified because no increases in greenhouse gas emissions are expected outside of the project boundary as a result of the project activity.

3.7 Monitoring

All data and parameters required for emissions quantification are described and appropriately defined in the proposed methodology. The proposed methodology requires all measurements to be taken with calibrated measurement equipment according to relevant industry standards. Additionally, the proposed methodology specifies records retention for two years after the end of the last crediting period, consistent with VCS requirements.

First Environment determined that the monitoring approach is appropriate and adequate to obtain the necessary data for emission reductions quantification.

3.8 Data and Parameters

The proposed methodology describes all data and parameters required for emissions quantification and classifies them as either monitored or not monitored. It relies primarily on modelled data to determine both baseline and project emissions. The models, however, require input data specific to each engine such as hours of operation, number of engine cycles and wash cycles, exhaust gas temperature at take off and cruise, and cruise fuel flow.

The descriptions include source of data, measurement procedures, monitoring frequencies, default values where appropriate, and other comments necessary for project implementation or validation/verification. First Environment concluded that the data and parameters included in

the proposed methodology and the associated requirements for measurement and monitoring are appropriate and sufficient to reduce uncertainty in emission reduction calculations.

3.9 Adherence to the Project-Level Principles of the VCS Program

The proposed methodology was developed in accordance with the requirements of VCS 2007.1 and adequately addresses the principles of relevance, completeness, consistency, accuracy, transparency, and conservativeness.

3.10 Comments by Stakeholders

In accordance with VCS requirement, a 30-day public stakeholder consultation was conducted from October 15, 2009 through November 15, 2009. No stakeholder comments were received for the proposed methodology.

4 Assessment Conclusion

First Environment performed the methodology validation assessment of the proposed methodology as part of the VCS double-approval process. First Environment used the Voluntary Carbon Standard 2007.1 and the VCS Program Normative Guidance Document: Double Approval Process, Version 1.0 as the assessment criteria and to guide the methodology validation assessment process.

The review of the proposed methodology and the satisfaction of corrective action and clarification requests have provided First Environment with sufficient evidence to determine the fulfillment of stated criteria.

The proposed methodology was prepared in accordance with the Voluntary Carbon Standard 2007.1 and the VCS Program Normative Guidance Document: Double Approval Process, Version 1.0. The proposed methodology belongs to Sectoral Scope 3 – Energy demand.

In summary, it is First Environment's opinion that the proposed methodology entitled *Baseline and monitoring methodology for the reduction of jet engine emissions through the use of engine washing technology*, dated May 10, 2010, meets all relevant VCS requirements.

In April 2011, First Environment was provided with a revised version of the methodology as a result of changes made during the second validation assessment. As the first validator of the methodology, we support the changes resulting from the second validation, specifically the methodology Version 1.5 dated April 4, 2011.

The validation of the Project is based on the information made available to us and the engagement conditions detailed in this report. First Environment cannot guarantee the accuracy or correctness of this information. Hence, First Environment cannot be held liable by any party for decisions made or not made based on this report or opinion.

5 Eligibility Criteria For Validator

First Environment has not completed 10 validations in the VCS Sectoral Scope 3 – Energy Demand and therefore cannot independently fulfill the requirements of 4.7.3 of the VCS Program Normative Document: Double Approval Process, Version 1.0.

6 Lead Validator Signature

Michael M. Carim
Associate

7 Internal Reviewer Signature

James T. Wintergreen
Senior Associate