

Operational Phase Life Cycle Assessment of Select NASA Ground Test Facilities

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Abstract

NASA's Aeronautics Test Program (ATP) is responsible for many large, high-energy ground test facilities that accomplish the nation's most advanced aerospace research. In order to accomplish these national objectives, significant energy and resources are consumed. A select group of facilities was analyzed using life-cycle assessment (LCA) to determine carbon footprint and environmental impacts. Most of these impacts stem from electricity and natural gas consumption, used directly at the facility and to generate support processes such as compressed air and steam. Other activities were analyzed but determined to be smaller in scale and frequency with relatively negligible environmental impacts. More specialized facilities use R-134a, R-14, jet fuels, or nitrogen gas, and these unique inputs can have a considerable effect on a facility's overall environmental impact. The results of this LCA will be useful to ATP and NASA as the nation looks to identify its top energy consumers and NASA looks to maximize research output and minimize environmental impact.

Keywords: NASA, Aeronautics, Wind tunnel, Keyword 4, Keyword 5

Introduction

NASA's Aeronautics Test Facilities

NASA's Aeronautics Test Program (ATP) manages the most comprehensive and complex portfolio of wind tunnels and propulsion test facilities in the world. As part of its management strategy, ATP's investment decisions are driven by a philosophy of "assess, decide, invest." The assessment activity employs many different techniques to determine the condition, health, capability, and liability of each facility. By fully understanding the characterization of the portfolio in total, the best decisions can be made to assure an optimized research capability for the nation. ATP has traditionally focused on

assessments that concentrate on facility productivity and research capabilities, but understands the importance of environmental impacts associated with operating and maintaining ATP's ground test facility portfolio. In order to address this need, ATP sponsored a project with the goal of estimating the carbon footprint and environmental impacts attributed to the portfolio's operation using LCA methods.

ATP's portfolio includes many different research facilities. Several of them are wind tunnels, usually either consisting of a very large motor or compressor with a circular air path or a blow-down configuration with high pressure storage and venting systems to atmosphere. Both designs have a test

section in which models are mounted and numerous complex support systems. Physical and aerodynamic properties are measured by test instruments including strain gauges, balances, and scales. The most common inputs are electricity, natural gas, steam, cooling water, and compressed air. Other facilities also use specific inputs for specialized research. These include refrigerants like R-134a and R-14, jet fuels, and cryogenic fluids. A flow diagram of the inputs of a typical ATP test facility is included in Figure 1 (figures are included at the end of the paper). Table 1 contains a list of the facilities in the ATP ground test portfolio discussed in this report.

Table 1 – ATP Ground Test Facilities

NASA Center and Location	Facility
Ames Research Center (Ames) <i>Mountain View, CA</i>	Unitary Plan Wind Tunnel Complex (Ames UPWT)
Langley Research Center (LaRC) <i>Hampton, VA</i>	National Transonic Facility (NTF)
	Transonic Dynamics Tunnel (TDT)
	Unitary Plan Wind Tunnel (Unitary)
	Langley Aerothermodynamics Laboratory (LAL)
	14 x 22 Foot Subsonic Wind Tunnel (14 x 22)
	20-Foot Vertical Spin Tunnel (VST)
Glenn Research Center (Glenn) <i>Cleveland, OH</i>	8 Foot High Temperature Tunnel (8-Foot)
	Propulsion Systems Laboratory (PSL)
	Icing Research Tunnel (IRT)
	9 x 15 Foot Low Speed Wind Tunnel and 8 x 6 Foot Supersonic Wind Tunnel (9 x 15/8 x 6)
	10 x 10 Foot Supersonic Wind Tunnel (10 x 10)

Goal and Scope

The goal of this project was to determine the carbon footprint and environmental impact of the operation of ATP’s ground test portfolio using LCA methods. This paper focuses mostly on the climate change aspect rather than the total environmental impact. The construction and demolition phases of a facility’s life-cycle have been excluded from analysis. These government-owned test facilities are very large and unique, have been in existence for many decades, and will continue to be operated well into the future. As such, data for these stages is sparse, and the impacts are assumed to be small in comparison to the operational phase of the facilities.

In this analysis of ATP facilities, some inputs and outputs were disregarded from the start, and some were disregarded after analyzing a few facilities and getting a better feel for the relative impacts. Minor material inputs – cleaners, glues, lubricants, etc. – were excluded from the start, as well as spare and replacement part purchases. Subsequently, as the analysis of the inventory data began, some inputs and outputs were discovered to be negligible, including solid waste and recycling, gasoline for facility vehicles, hydraulic and lubricating oils, and cooling water use. The relatively low use quantities established limits on what data was required and streamlined data collection for the remaining facilities.

Inventory Data

Inventory Survey

Inventory data was collected from the facilities using an inventory survey. This survey was sent out to each individual facility manager with the expectation that they would complete and return it. However, much of the inventory data, especially the shared utilities data, was tracked separately in a Center-wide management office. In the end, compiling accurate and complete inventory data for each facility involved both facility personnel as well as the central utilities management at each Center.

Project Data

The project scope was limited to three years of data; this was felt to be a reasonably accurate representation of each facility's usage. Data for each input was collected for FY08-FY10 when available. The data for these three years was averaged to get a better idea of a "typical" year of facility operation. While the data came directly from utility managers or facility personnel, it must be remembered that these facilities are research institutions. Any average data is a rough estimate; actual consumption varies based on type and frequency of testing at any given time.

Analysis

Method

For this project, the IMPACT 2002+ method was used in the LCA software SimaPro 7.3 (PRé Consultants, 2011). This method is a combination of the features of other methods including Eco-Indicator and CML but with an expanded set of impact categories.

IMPACT 2002+ was chosen for this project because it includes a global warming impact category based on Intergovernmental Panel on Climate Change (IPCC) greenhouse gas data. The carbon footprint of the facilities is equivalent to this global warming impact category, so using the IMPACT 2002+ method allowed SimaPro to calculate the carbon footprint and total environmental impact simultaneously.

SimaPro Outputs

The total carbon footprint of operating the ATP portfolio is 137,000 metric tons of CO₂e. This represents about 9% of NASA's total carbon footprint based on NASA's FY10 greenhouse gas emission inventory (FY2010 Federal Government Greenhouse Gas Inventory by Agency, 2011). A breakdown of greenhouse gas emissions by facility is included in Table 2.

A SimaPro chart comparing the total environmental impact of the facilities is included in Figure 2. This chart uses the IMPACT 2002+ single score to compare the relative impacts of each facility.

Results

Facilities

In general, electricity is the biggest contributor to the carbon footprint and environmental impact at each facility. Natural gas is generally the second most significant input. Significant quantities of electricity and natural gas are consumed directly, but the life-cycle consumption is even greater because many other common inputs like compressed air and steam usually

Table 2 – Carbon Footprint Contribution by Facility

Facility	Annual Carbon Footprint (tonnes CO₂e)
Glenn 9 x 15/8 x 6	21,000
Ames UPWT	20,900
LaRC TDT	19,700
LaRC NTF	18,600
LaRC CF4	12,000
LaRC Unitary	11,200
Glenn 10 x 10	8,130
Glenn PSL	7,310
LaRC 31/15-Inch	6,190
Glenn IRT	5,840
LaRC 8-Foot	2,920
LaRC 14 x 22	2,780
LaRC VST	330
Total	137,000

consume electricity and natural gas to be produced.

Smaller and more specialized facilities did not follow this general trend. The impacts at facilities with smaller drive systems were sometimes dominated by other inputs such as steam for heating. In facilities that use refrigerants, loss of refrigerant gas usually dominates the carbon footprint of the facility because the refrigerants used have global warming potentials that are hundreds or thousands of times greater than that of carbon dioxide.

Portfolio

The trends in the overall portfolio carbon footprint and environmental impacts typically match those of the largest facilities. Electricity generation is the biggest contributor to the carbon footprint and

environmental impact, followed by natural gas consumption. The amount of electricity and natural gas consumed directly in the facilities is much more significant than what is used to provide other support services like steam and compressed air.

Figure 3 shows the network flow diagram of the portfolio carbon footprint with a 5% cutoff. Electricity is clearly the dominant carbon footprint driver; almost half of the portfolio’s carbon footprint comes from coal-fired electricity alone. Figure 4 shows the environmental impact network flow diagram of the portfolio. Most trends here match those in the carbon footprint diagram.

Conclusion

Both the carbon footprint and total environmental impact of operating ATP’s ground test portfolio were investigated. These environmental indicators have been modeled, providing ATP with a baseline against which to gauge future analyses and also has a more detailed understanding about the energy use and environmental impacts of its portfolio.

This work also serves as the starting point for future analyses of individual projects or potential upgrades that may have a bearing on the portfolio’s carbon footprint or environmental impact. If the causes of the biggest impacts were traced in detail, recommendations for improvement could be made for each facility and for the whole portfolio. However it is used, this work serves to continue to support and improve the nation’s aeronautics test facilities.

Figures

Figure 1 – Input Flow Diagram for a Typical ATP Test Facility

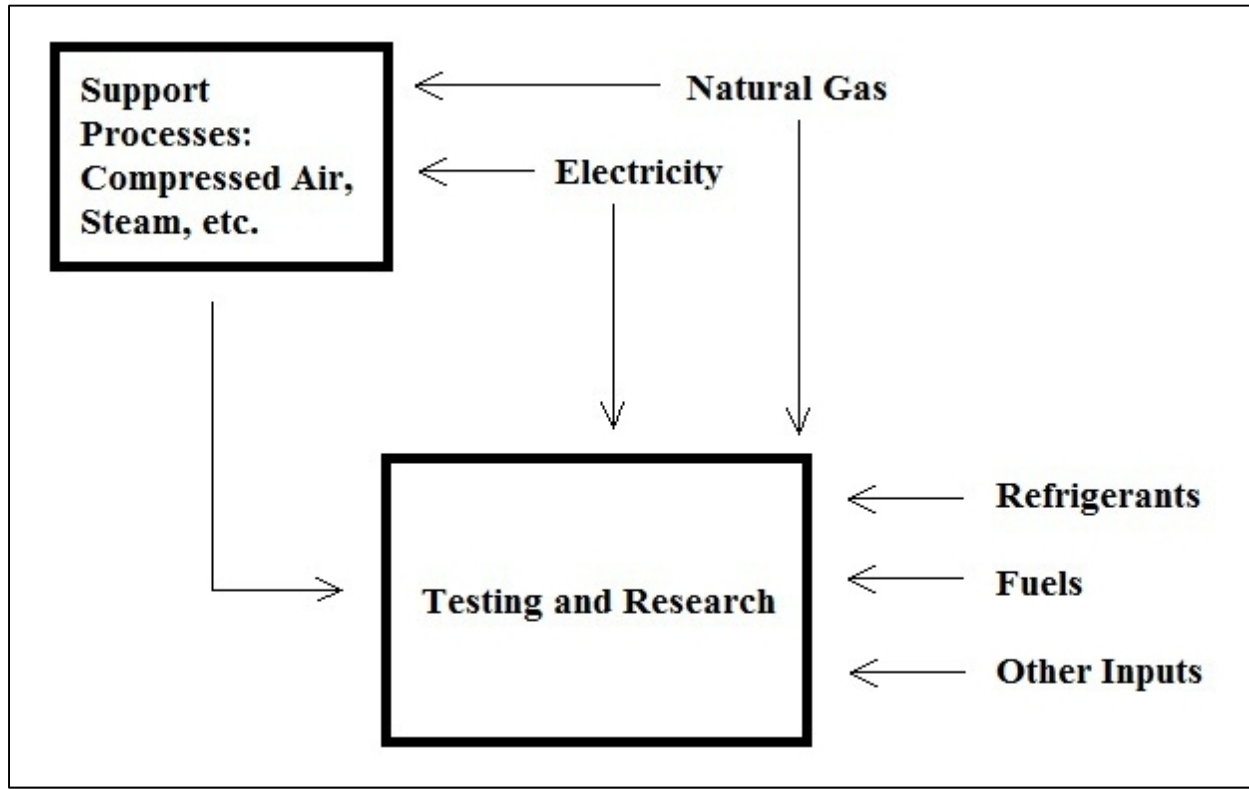


Figure 2 – Relative Environmental Impacts of ATP Facilities

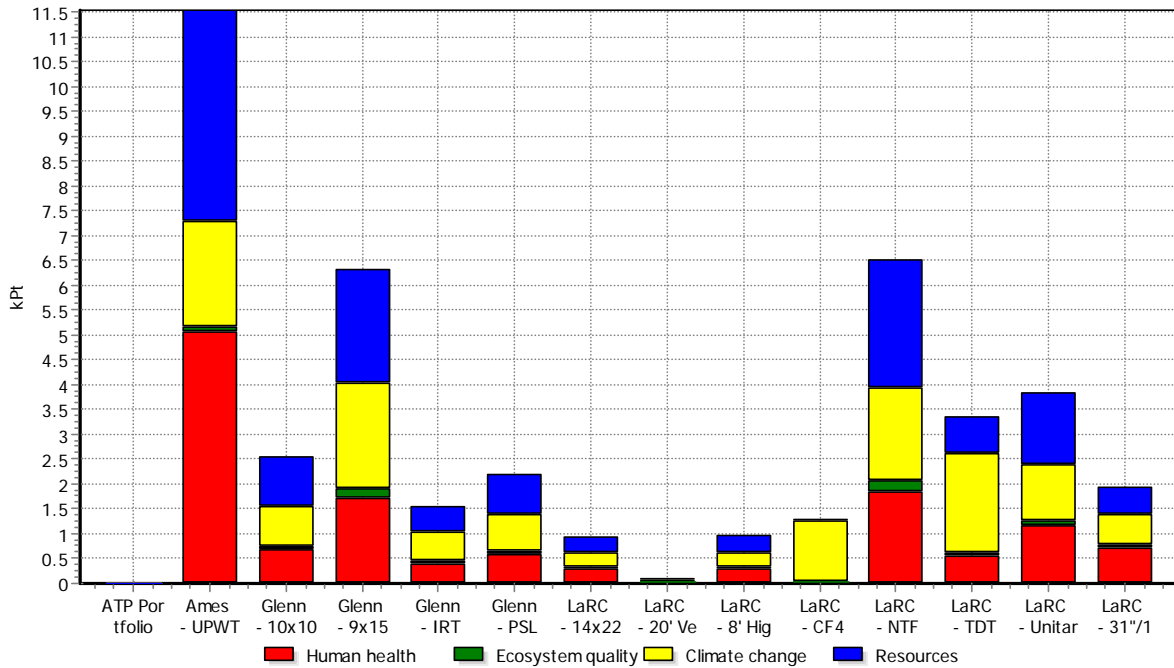


Figure 3 – Network Flow Diagram for GHG Emissions

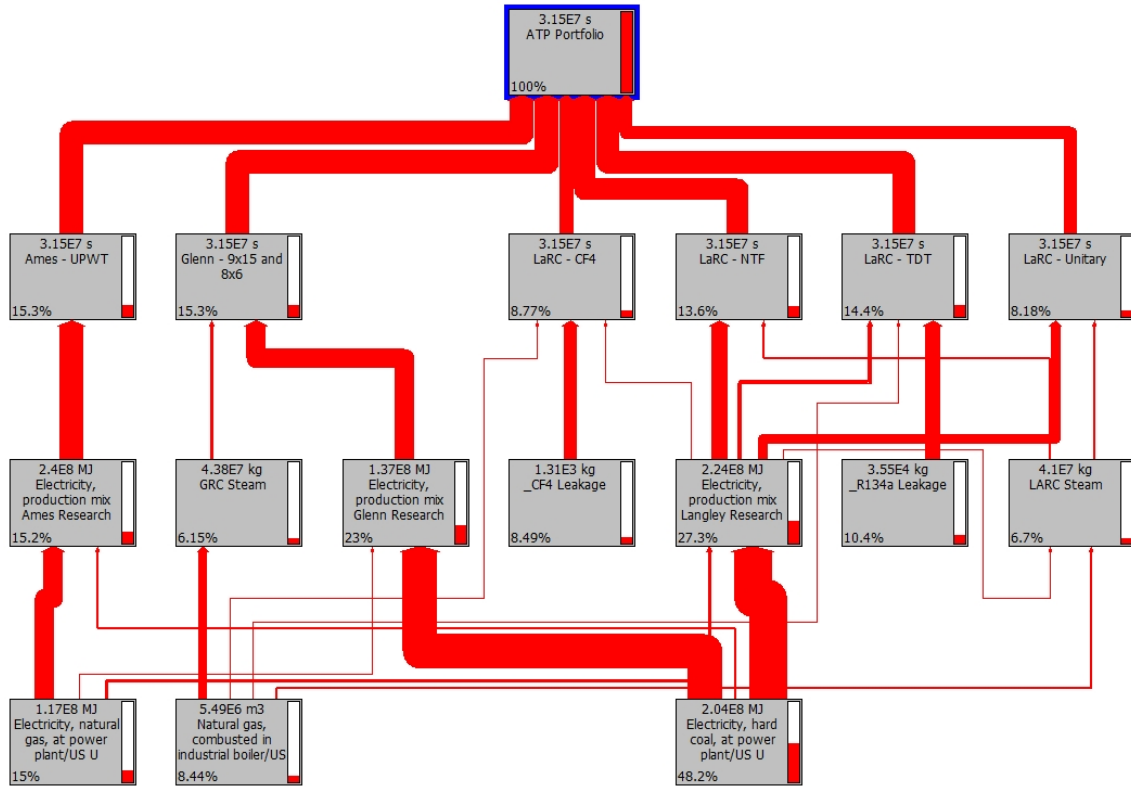
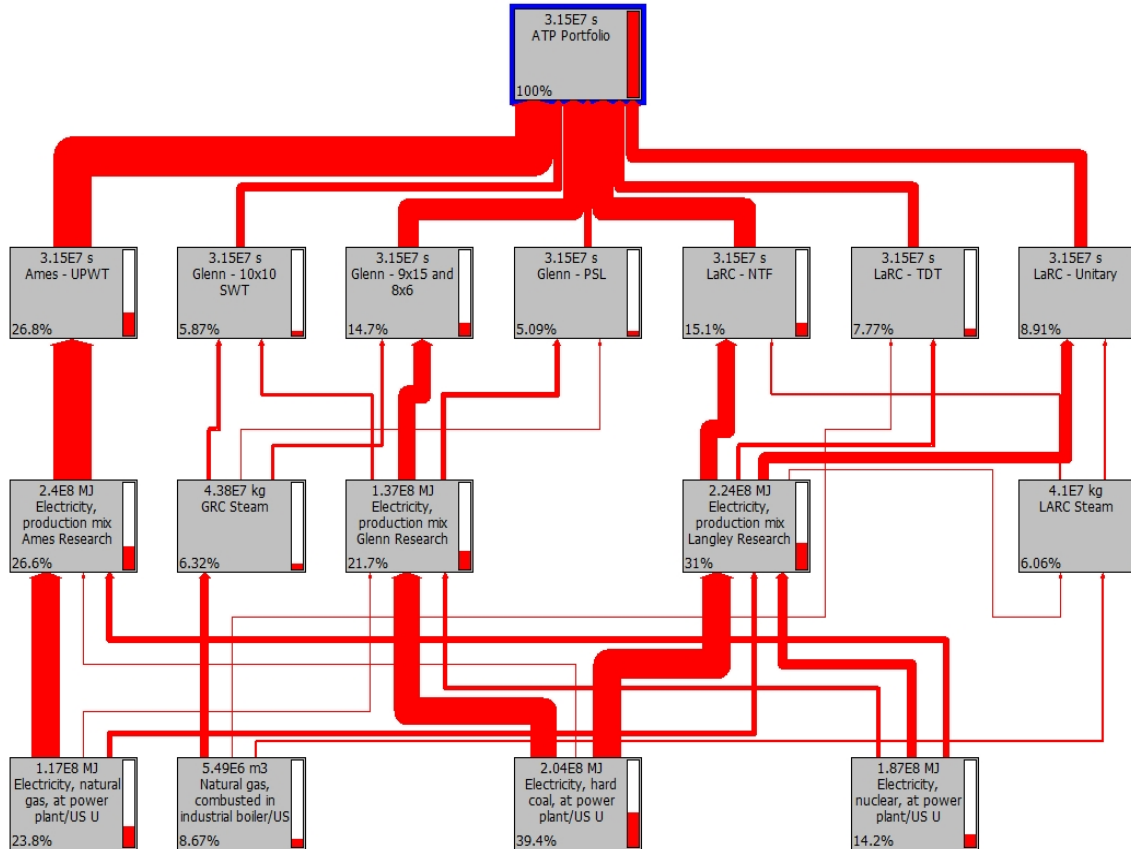


Figure 4 – Network Flow Diagram for Environmental Impacts



References

(2011): FY2010 Federal Government Greenhouse Gas Inventory by Agency. Data.gov publication, <<http://explore.data.gov/d/vzm3-edjq>>

PRé Consultants. (2011): SimaPro software.