

Continuous Lower Energy, Emissions and Noise (CLEEN) Program Benefits

The CLEEN Program is the FAA's principal environmental effort to accelerate the development of new aircraft and engine technologies. Through the CLEEN Program, the FAA has selected companies to cost-share development of technologies that reduce noise, emissions, and fuel burn. The benefits of CLEEN's investment is two-fold:

- CLEEN enables the aviation industry to expedite development and integration of these technologies into current and future aircraft to deliver benefits in operation for years to come.
- CLEEN leads to improved analysis and design tools that are improving every aircraft or engine product being made by these companies, well beyond individual technology applications.

CLEEN's acceleration of technology development has been successful. Technologies from CLEEN Phase I (2010-2015) have entered the fleet, and industry anticipates that additional technologies will enter into service in the coming years as opportunities arise for their insertion into new aircraft and engine designs. While maintaining continuous investment on advancing technologies to enter operational service, the program has also enabled development of supporting technologies with lower readiness level that may otherwise been left unsupported, such as developing viable manufacturing alternatives and advancing the state of the art for materials that can be used in various applications.

Highlighted technology benefits include:

- Boeing's Adaptive Trailing Edge and Ceramic Matrix Composite Nozzle technologies, developed under CLEEN Phase I, may provide fuel burn reductions of 2% and 1%, while reducing noise by 1.7 decibels and up to 2.3 decibels, respectively. Boeing adopted technologies from the Adaptive Trailing Edge project for use in commercial and defense products. Boeing is currently considering the Ceramic Matrix Composite Nozzle in trade studies for current development programs. Boeing's CLEEN Phase II technologies include the Structurally Efficient Wing, estimated to save 3.5% fuel burn, which has cleared testing that supports transition of many composites technologies into a broad set of current and future commercial and military applications.
- Delta Tech Ops and MDS Coating Technologies have partnered to successfully develop and begin operational test of an erosion-resistant fan blade coating. This coating, undergoing operational test on Delta flights, may provide retained efficiency equating to 0.4% to 1% fuel burn savings in different flight conditions over uncoated blades.
- GE Aviation's Twin Annular Premixing Swirler (TAPS) II combustor exceeded the NOx emission targets for CLEEN Phase I (60% target below CAEP/6 standard). The TAPS II is now in service on aircraft throughout the global fleet – installed on Airbus 320neo, Boeing 737 MAX, and COMAC C919 aircraft. GE's advanced combustor work has continued under CLEEN Phase II. The TAPS III combustion system will be implemented in the GE9X-powered Boeing 777X, expected to enter into service in 2020, and enables NOx emissions 30% below the more stringent CAEP/8 international standards.
- Honeywell's CLEEN Phase I technologies in jet engine cores achieved a 15.7% overall fuel burn reduction relative to baseline engine designs, as part of a package of complementary engine upgrades. Under CLEEN Phase II, Honeywell's engine core work has focused on turbine and combustor technologies which are targeting a combined 22% fuel burn reduction relative to their baseline engine while reducing NOx emissions 50% below CAEP/8 standards.
- Pratt & Whitney's Geared Turbofan developments under CLEEN have focused on enabling technologies for revolutionary high-bypass engine designs that provide 20% fuel burn reduction and 20 decibels noise reduction relative to current 737-800 aircraft.

- Rolls-Royce developed advanced-cooling turbine blades and ceramic matrix composite blade tracks under CLEEN Phase I, yielding 1% fuel burn reduction.

The work CLEEN has done on maturing individual environmentally beneficial technologies will propagate into greater benefits on a fleet-wide scale. According to analysis done by Georgia Institute of Technology under the Aviation Sustainability Center of Excellence (ASCENT), the technologies matured in the first phase of CLEEN will reduce U.S. fleet-wide fuel burn by 2 percent from 2025 through 2050, representing a cumulative savings of 22 billion gallons of jet fuel. The associated CO₂ savings are the equivalent of taking 1.7 million cars off of the road over the duration of this 25 year period. It will also save airlines 2.75 billion dollars per year while contributing to a 14% decrease in the land area exposed to significant noise, as defined by a day-night noise (DNL) level of 65 dB. Alternatively, this noise reduction enables a 1.4x increase in operations while maintaining current noise levels.

CLEEN Phase II technologies are expected to enter operational service by 2026, providing further benefits to fuel burn, emissions, and noise. An ongoing assessment of CLEEN Phase II's projected fleet-wide benefits is expected to yield results in Fall 2020 and will show further benefits that will change the trajectory of aviation's environmental impacts for years to come.

For more information on the CLEEN Program, please refer to <http://www.faa.gov/go/cleen>.