Project 66

Evaluation of Engine Fuel Burn and Thermal Management Benefits with Use of High Thermal Stability Fuels

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Objective:

Evaluation of Engine Fuel Burn and Thermal Management Benefits with Use of High Thermal Stability Fuels

Project Benefits:

Quantifying advantages of sustainable alternative fuel (SAF) supports argument to promote accelerated implementation.

An energy savings of a least 0.5% is predicted when superior thermal stability is leveraged by straight-forward design changes

Research Approach:

1. Fuel optimization: Leverage Project 65 models to predict fuel properties together with engine performance models to predict constraints & objectives within an optimization of fuel composition from a basis of 1128 molecules with known fuel properties.
2. Engine performance models (GE): Assess efficiency impacts of reduced air cooling made possible by SAF with high thermal stability. Develop sketch of fuel effects as a function of mission point and engine variation.

Major Accomplishments:

Development of Engine Performance Model with fuel composition sensitivity

First proof of concept paper published;

Boehm, Scholla, Heyne, Fuel, 2021. https://doi.org/10.1016/j.fuel.2021.121378.

Incorporation of thermal model into the Jet Fuel Blend Optimizer (JudO); many more additional molecules

Future Work / Schedule:

- Fuel optimization (ant colony method)
  - Need to improve computational efficiency
- Engine Performance Modeling (EPM) cooling and weight trades in process
- Engine fuel effects map in process

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 66 through FAA Award Number13-C-AJFE-UD-027 under the supervision of Anna Oldani. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

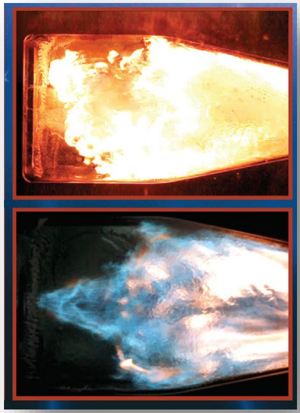
The Value Proposition

Increased Specific Energy (MJ/kg):

- Less fuel mass uplifted to aircraft
  - Greater aircraft fuel economy
  - Can be realized as a “drop-in” fuel
- May drive Energy Density (MJ/m^3) outside of experience range
  - If too high, fuel nozzle flow number may need reducing
  - If too low, fuel nozzle flow number may need increasing
- Expect ~2% energy savings is possible (~4.4% by mass)† Boeing 787-8 basis

† M Kirby R Denney, Georgia Tech

- Reduced PM emissions
  - **Reduced radiation heat load on combustor (longer life)**
  - **Reduced contrail formation**



Increased Thermal Stability:

- Enables improved thermal management of engine and/or aircraft
  - Greater aircraft / engine fuel economy
    - More energy delivered to the combustor
    - Less parasitic (air) cooling loss
  - Cannot be realized as a “drop-in” fuel
  - Aircraft / engines designed to capitalize on the high thermal stability of SAF will be committed to using fuel of similar thermal stability throughout most of its service life
- Expect ~0.5% energy savings

- Trade engine efficiency improvement for aircraft performance or efficiency
- Less maintenance (hot section)

Recent Accomplishments

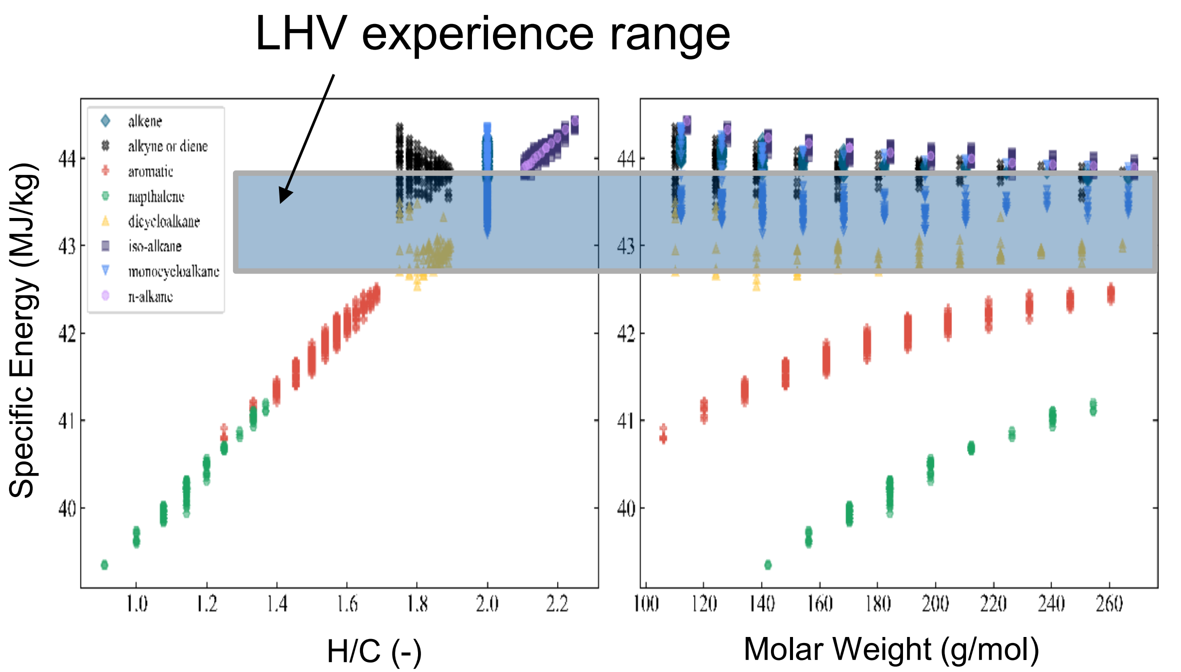
Fuel Optimization:

- Increased database of molecules (94 → 1,128)
- Added or improved filter for smoke point, T10 & IBP
- Now limiting number of molecules in trial fuels: < 30
- Confirmed addition of aromatics to HEFA increases coke deposits in QCM

Expecting Pareto-front fuels to have high fraction of cylco- and multicyclo-alkanes

Plan to evaluate:

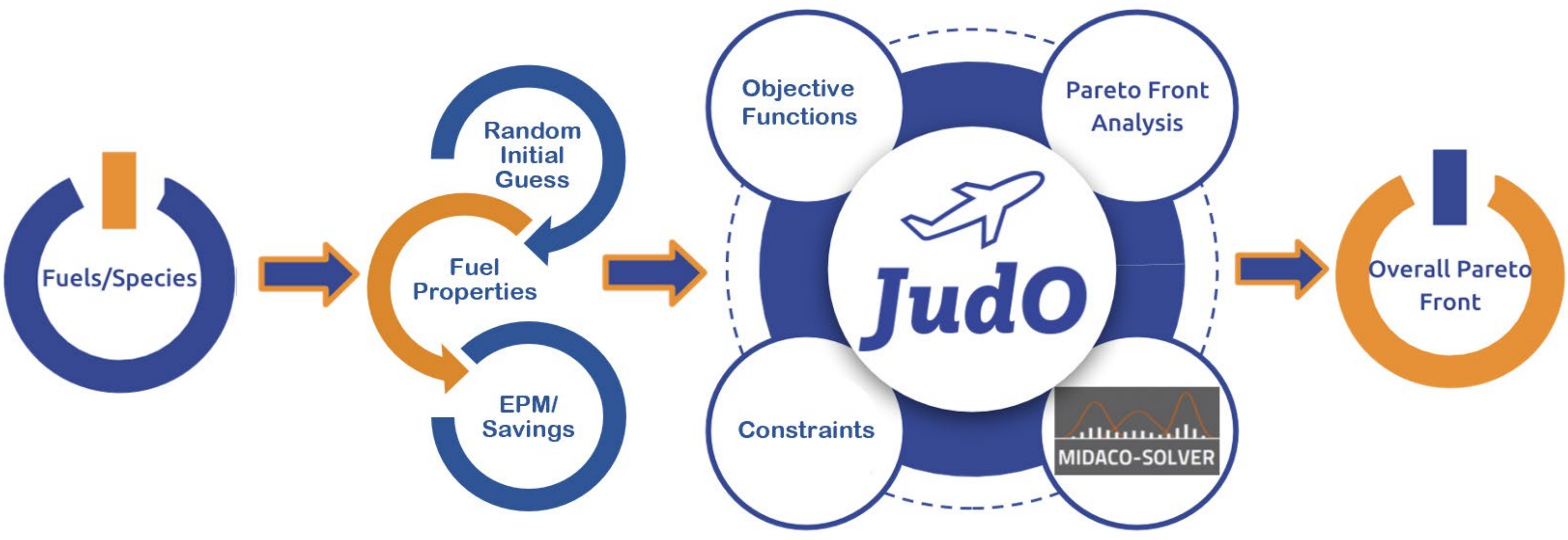
- Seal swell
- Thermal stability
- Freeze point
- T90-T10



Recent Accomplishments

Fuel Optimization:

- Fuel system thermal model, engine performance model, & energy savings calculator converted from VBA to Python for JudO compatibility
- Completed integration of converted code and revised/additional constraints into JudO framework
- Fuel optimization is in process – but slow, working toward better computational throughput and MIDACO I/O



Recent Accomplishments

Map Fuel Effects on Engine Performance

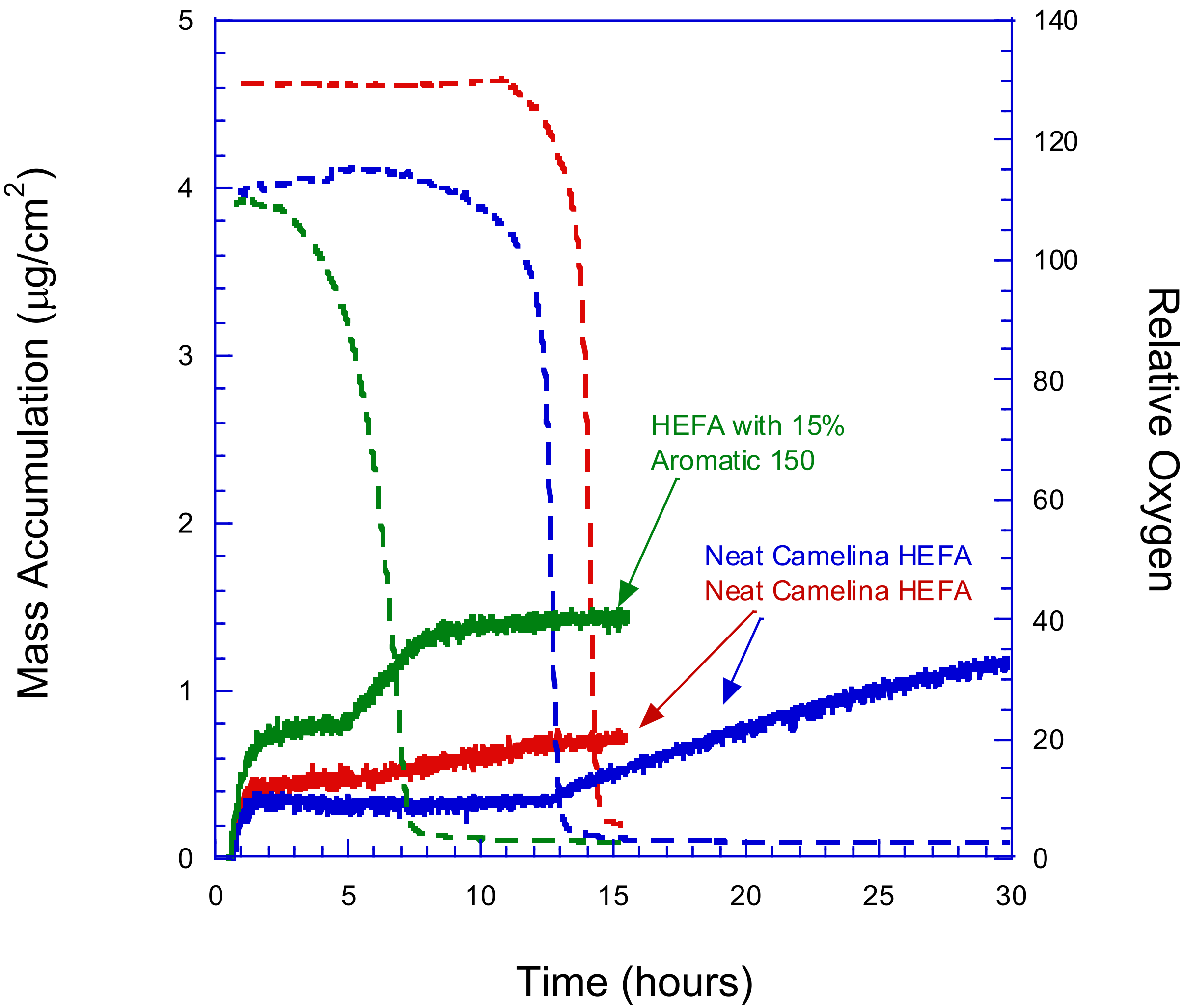
- Engine performance models identified to represent narrow-body and wide-body applications
- Generating input decks to create standard and hot day study data
- Range of fuel properties received

Engine Cooling & Weight Trades

- Investigating increased target fuel temperature (160 °C) impact on fuel-cooled oil cooler (FCOC) and air-cooled oil cooler (ACOC) heat exchangers
  - Opportunity to reduce or potentially remove ACOC weight

BACKUP SLIDES

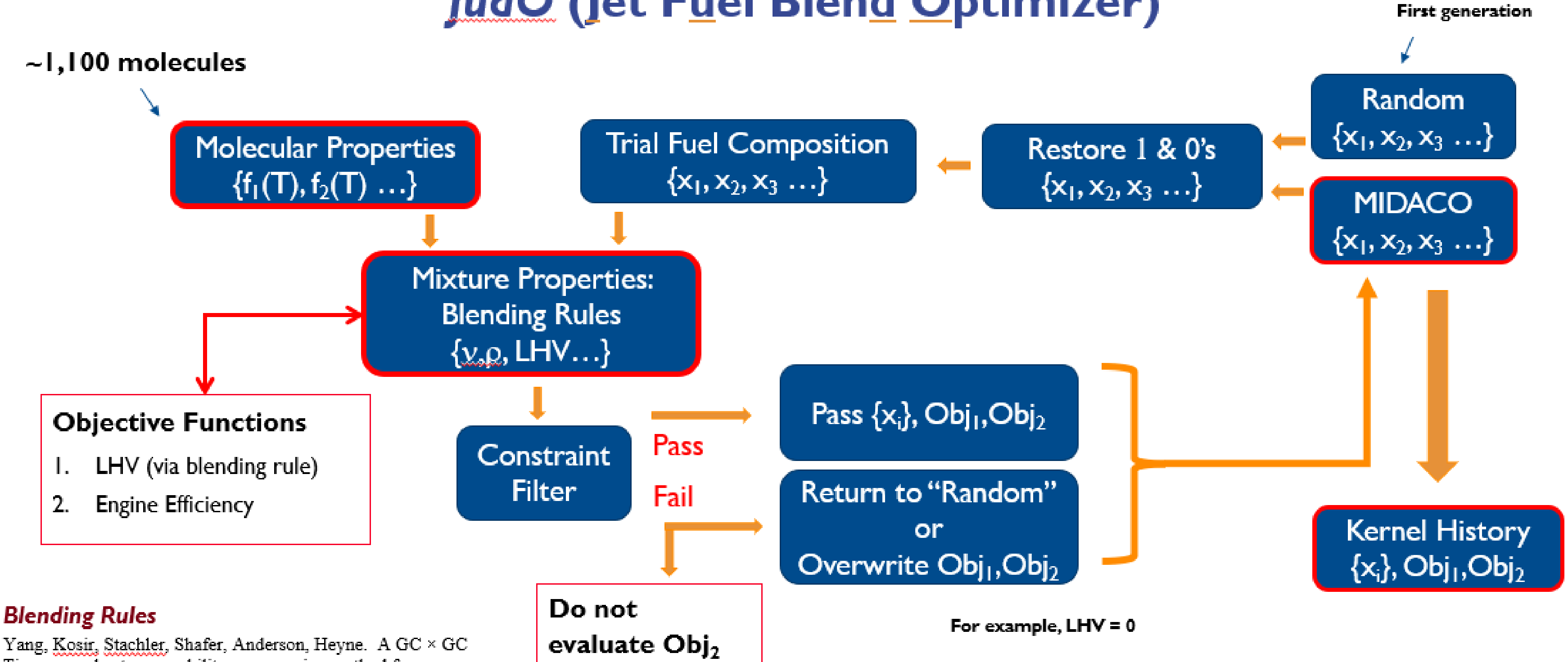
Appendix QCM Test Result



Appendix

Overview of Jet Fuel Optimization Process

JudO (Jet Fuel Blend Optimizer)



Blending Rules

Yang, Kosir, Stachler, Shafer, Anderson, Heyne. A GC × GC Tier α combustor operability prescreening method for sustainable aviation fuel candidates . Fuel 2021;292:120345. https://doi.org/10.1016/j.fuel.2021.120345

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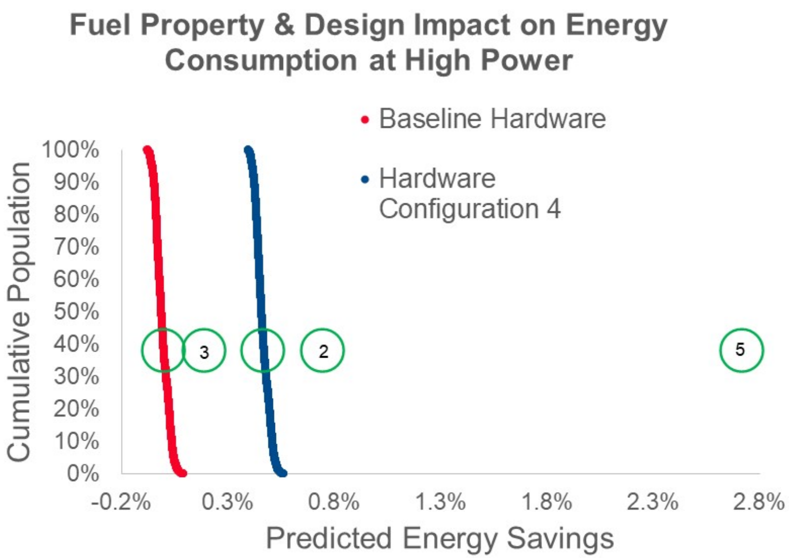
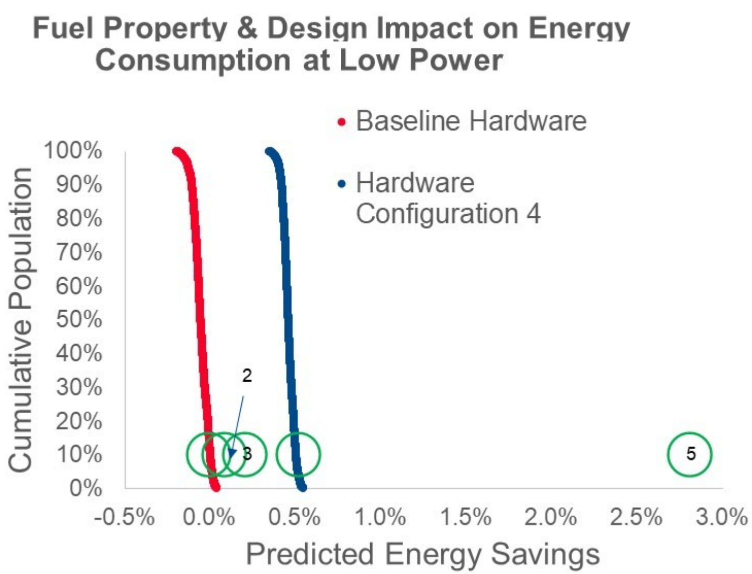
Appendix: Prior Accomplishments





Design Options Considered

1. Baseline configuration has an FCOC and an air-cooled oil cooler (ACOC), and results in a fuel temperature of 127 °C at min fuel flow (max residence time)
2. Double the size of the FCOC, remove the ACOC
3. Add an FCAC to the baseline configuration, but do not change the cooling air flow to any part of the engine
4. Add the FCAC, and reduce (globally) the turbine cooling flow such that its cooling authority at max power is conserved through the design change
5. Add the FCAC, and *notionally* re-optimize the turbine cooling air flow splits to decrease the clearance gap between the rotating and stationary parts of the turbine

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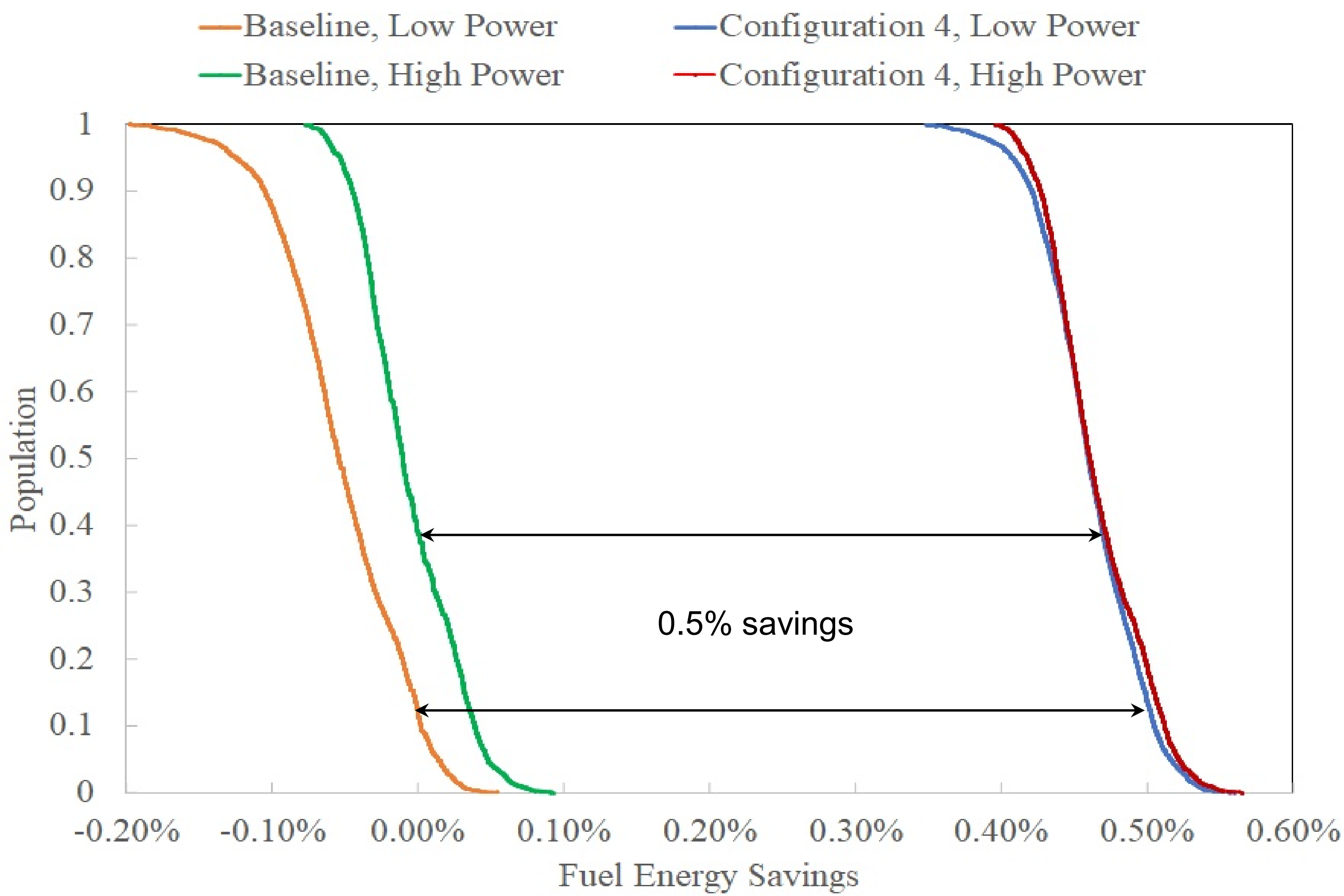

Designing to higher thermal stability fuel is the largest effect