Reducing Total Cabin Heating in EV Cars and Trucks and Improving Passenger Comfort

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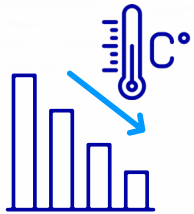
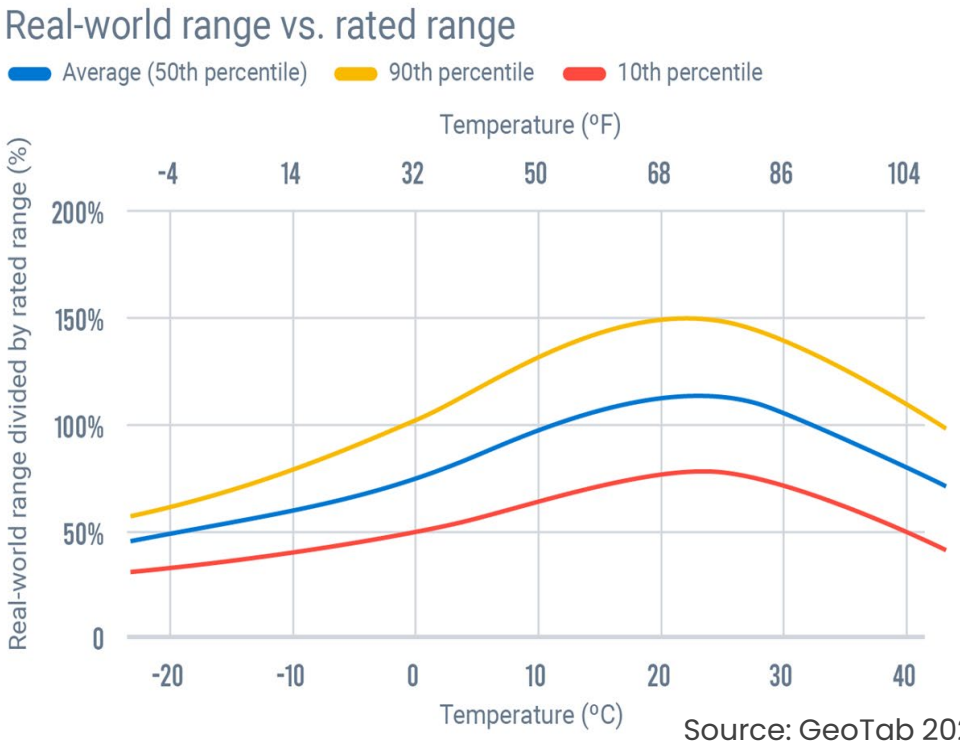
Actual EV Range Problem



Temp vs. Actual Range

Three Key Studies on actual rang

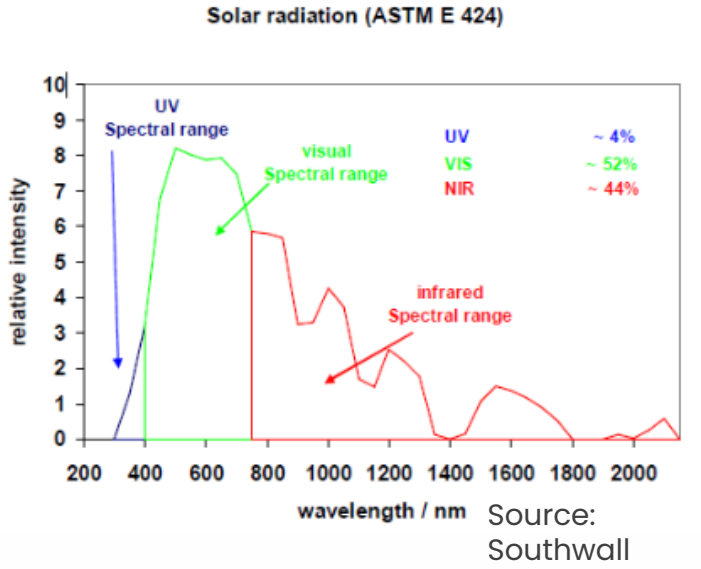
1. AAA
2. GeoTab
3. Recurrent



Source: GeoTab 2023

Low-e Windshields

Sources of Transmitted Heat



Source: Southwall

Windshield: ~41 %
Backlite: ~33 %
Sidelites: ~26 %

Source: V. Johnson, Future Car Congress, "Fuel Used for Vehicle Air Conditioning: A State-by-State Thermal Comfort-Based Approach." SAE Technical Paper 2002-01-1957

Only 52% of sun energy is in the visible range.
The goal is to eliminate non-visible sun energy entering the cabin.

Benefits of Low-e Coatings in Summer

1. Reduce energy transfer into the cabin, ~10C lower
2. Reduce surface temperatures, ~15C on the dashboard
3. Shorter time to comfort, ~30% faster
4. Potential HVAC size reduction
5. Increased driver comfort
6. Reduced fading & degradation of materials

Source: Southwall (Eastman Saflex)

In 2013, SAE presentation, “Impact of Solar Control PVB Glass… on Vehicle Range” evalutated the impact of Low E glass on EV range: based on a windshield with Tts = 55%, an 11% reduction from baseline, EV range improved about 1-1.5%

Heated Windshields for Cold Weather

Current Heated Windshields

- Small Wire Resistance Heat:
  1. Older technology
  2. No or limited IRR solar energy reduction
  3. Refracts light. More noticeable with concentrated light source
  3. Typically powered with 12V or 24V as boost defrost

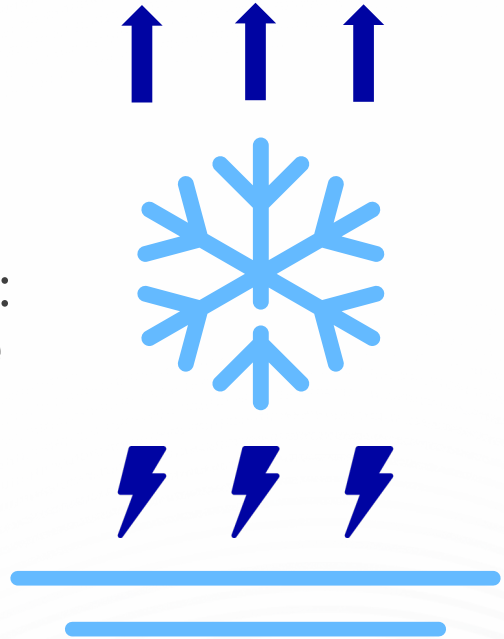
- Low-e glass
  1. Developed for flat glass market in 1980s using Ag, FTO, ITO
  2. Starting to see in EV windshields. Many class 8 trucks in NA offer Low e glass
  3. Typically, with 12 or 24V as boost defrost

Current Defrost & Defog Problems aren't solved with heated windshields

- Defrost is Energy Intensive: uses ~3-4 kWh for air defrost to flood the windshield with heat

- Defog is a larger problem in EVs than ICE:
  a. Drivers turn down heat to conserve range
  b. To reduce NVH, EVs are more tightly sealed than ICE vehicles

- Defog is also energy intensive



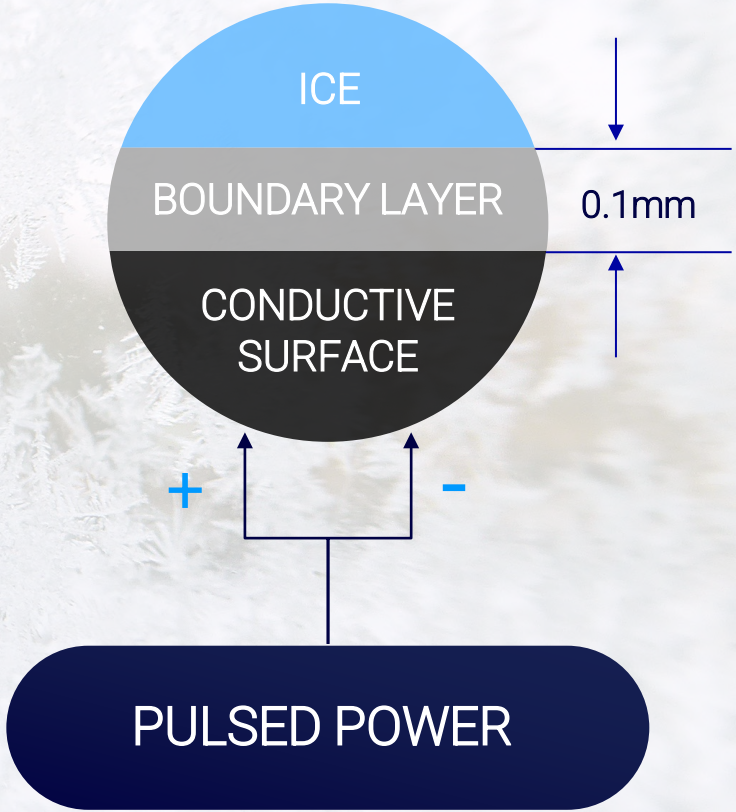
-> 12-24V heated windshields can't solve the above

Low Energy Heated Windshields with Pulsed Power

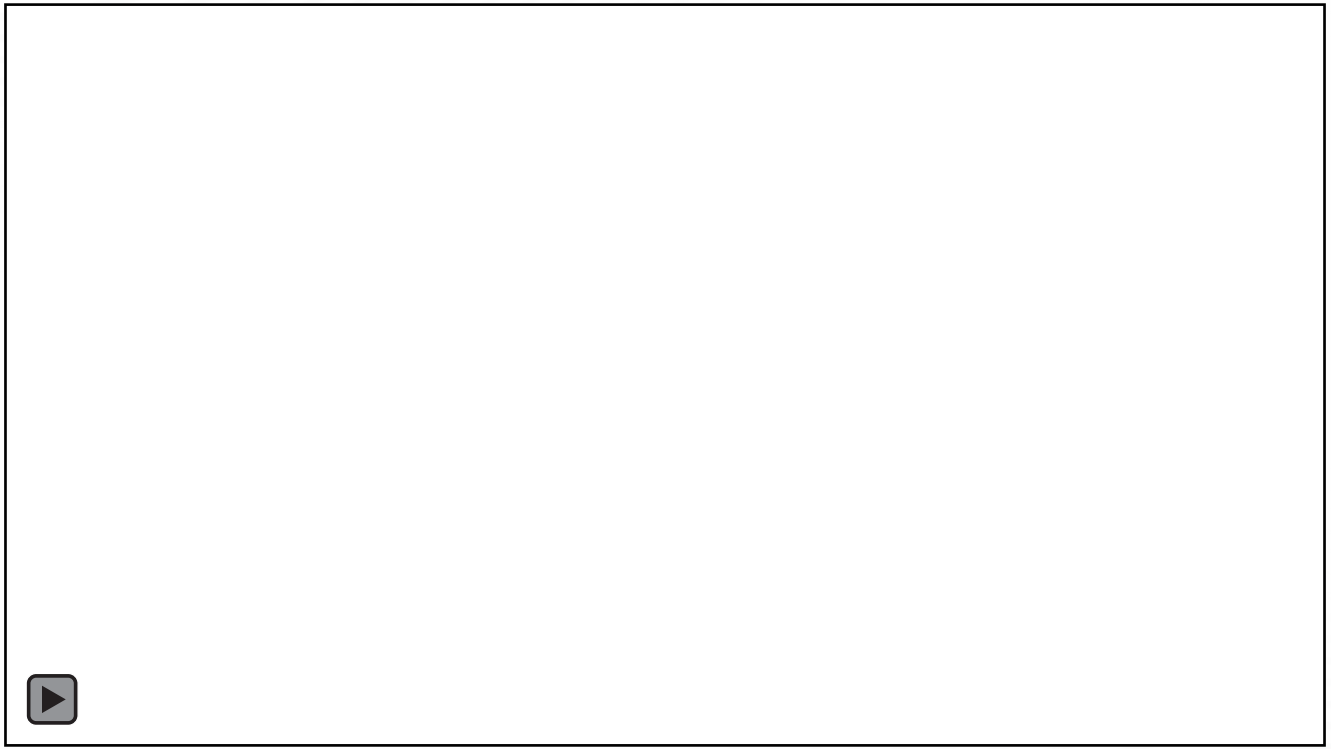
Complete Solution with Highest Thermal Efficiency

A New Approach to Surface Heating

- Pulse power to control heat penetration
- Only reaches interfacial layer of ice ~0.1mm
- Release ice from surface
- Achieve thermal efficiencies up to ~95%



Side by Side Defrost Test

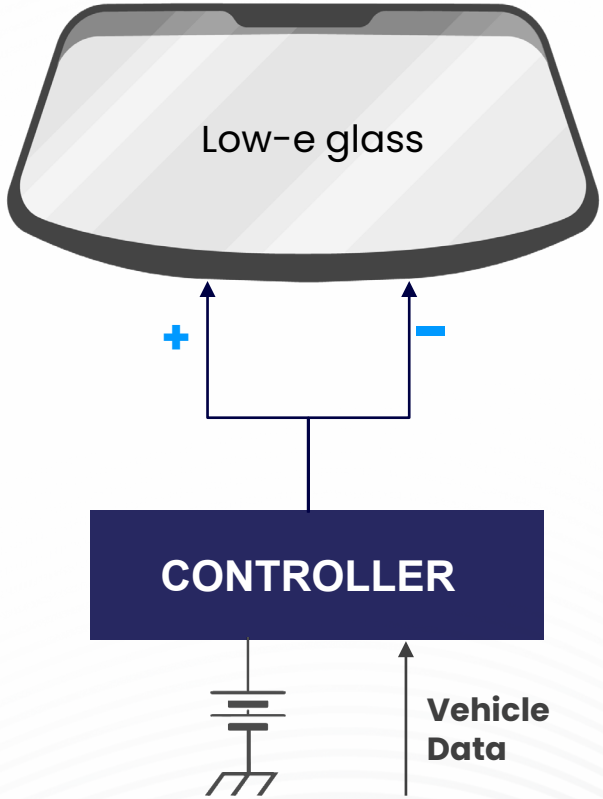


Clears in 1 min

Partial Clear in 16 mins.

Low Energy Defrost/Defog

- Controller provides high-voltage, pulsed power to conductive layer inside glass
- One algorithm for Defrost.
  One algorithm for Defog.
- 20X less energy than HVAC defrost/defog



Testing Results

Testing Vehicle

Facility:
ACE Climatic Wind Tunnel
Ontario Tech University (Oshawa, Ontario)

Vehicle:
2023 Toyota Bz4x
(with custom built windshield to work with Betterfrost System)

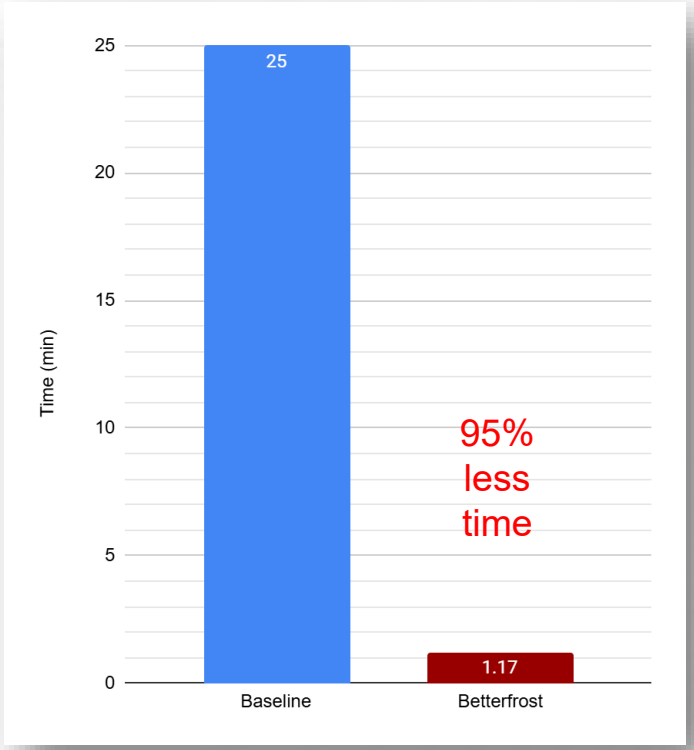
Test Objectives:

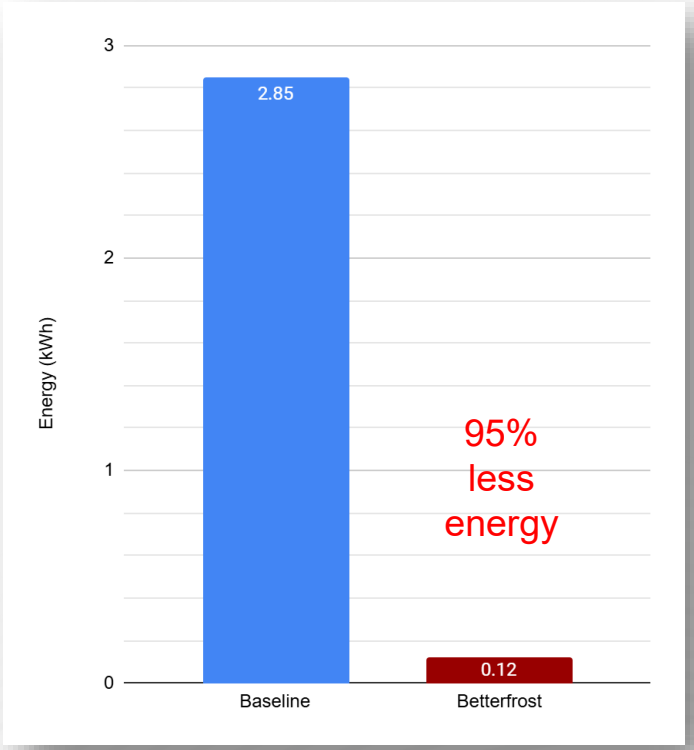
1. Compare time and energy for defrosting vehicle windshield (FMVSS103)

2. Compare cabin energy maintaining fog free windshield for steady state 100 km/h driving at -7C and -20C

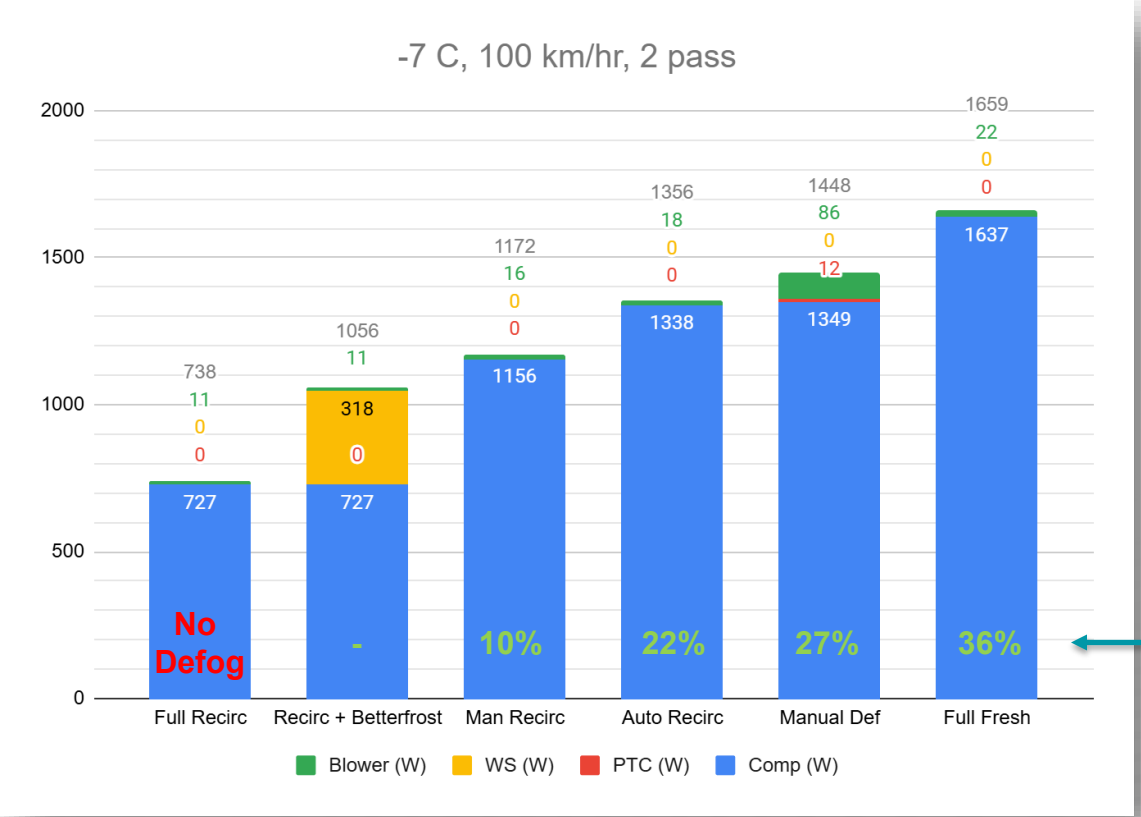
3. Compare cabin energy maintaining fog free windshield for WLTP driving at -7C

FMVSS103 Defrost Test



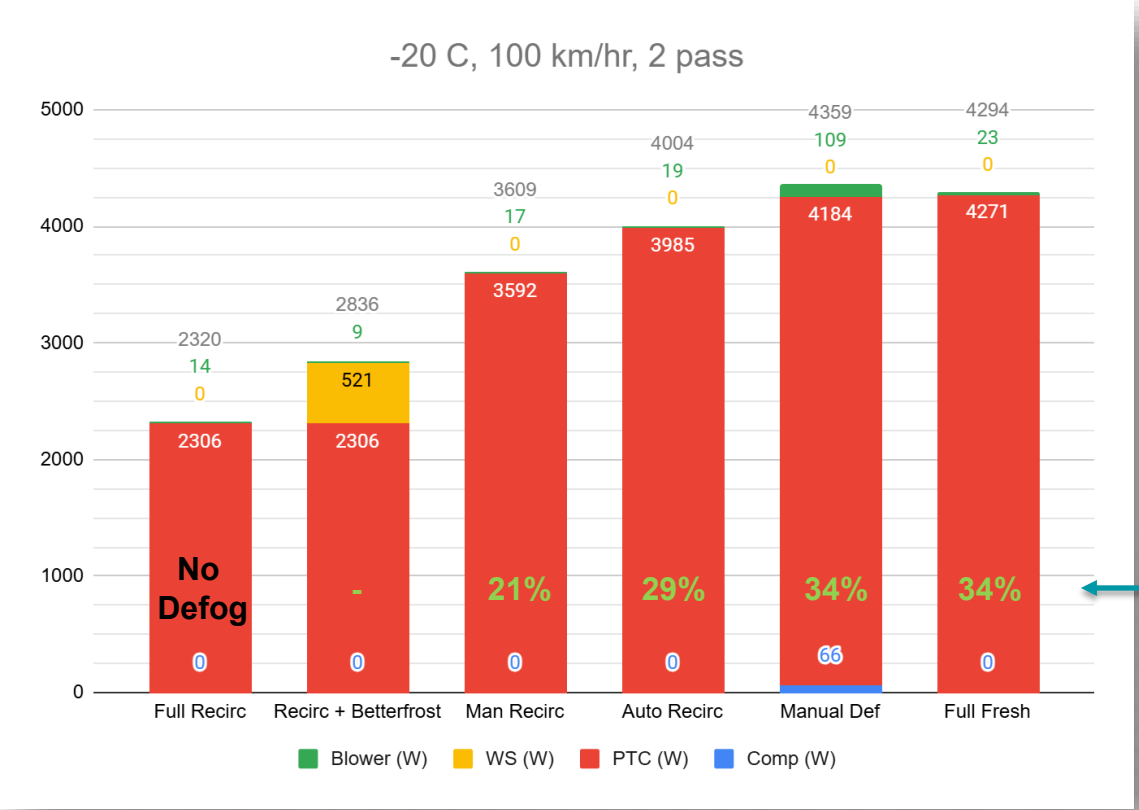


Steady State Defogging Test (-7C)



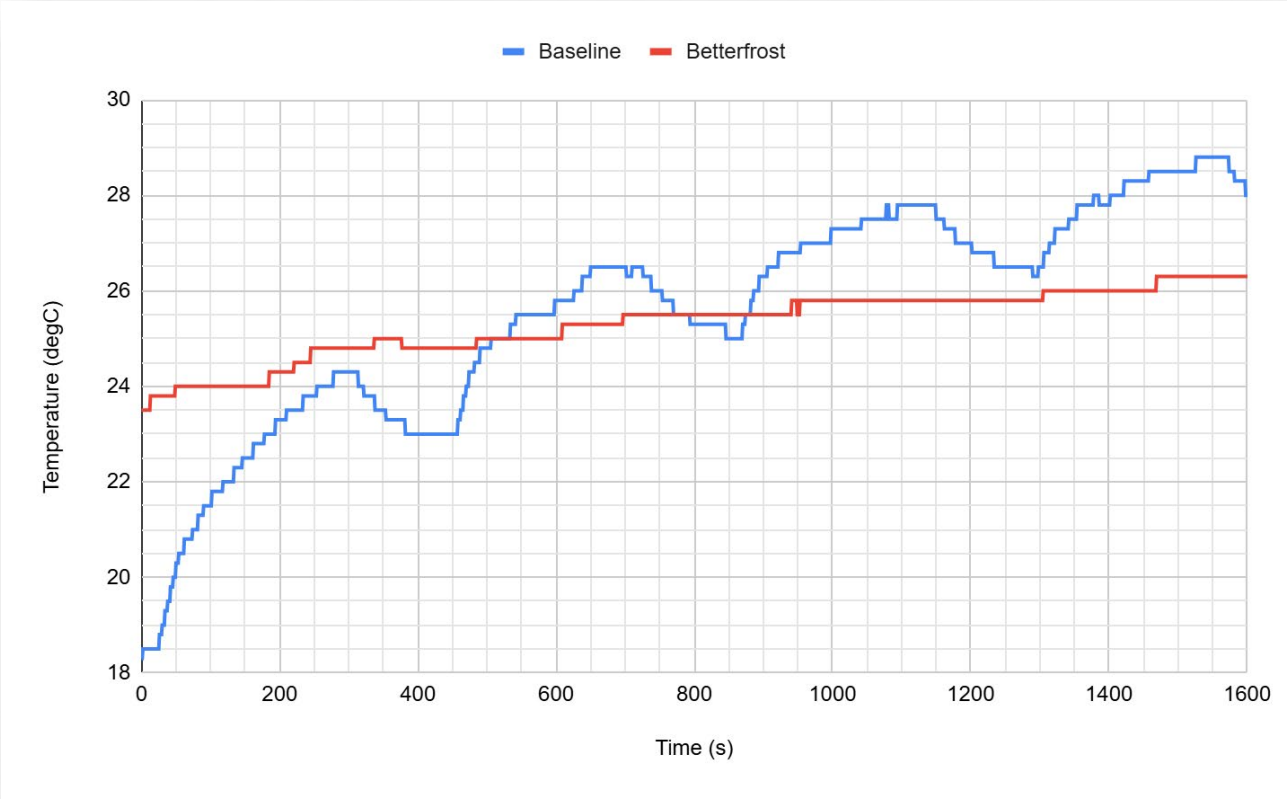
BF Energy Savings in Green

Steady State Defogging Test (-20C)



BF Energy Savings in Green

Temperature Fluctuation Reduction



WLTP Driving Test

3 consecutive WLTP test cycles of 30 minutes each (90 min total):

- Cycle 1: Cold Start
- Cycle 2: Transient
- Cycle 3: Steady State

Test Conditions:

Ambient: -7C

HVAC: Auto recirc at 22C

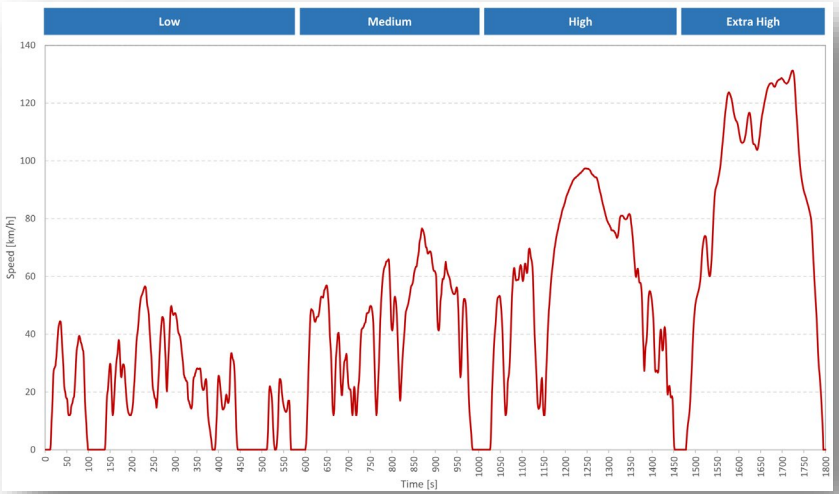
Back vents covered to prevent bleed

During Full Fresh: fresh motor disconnected

Two BF conditions tested:

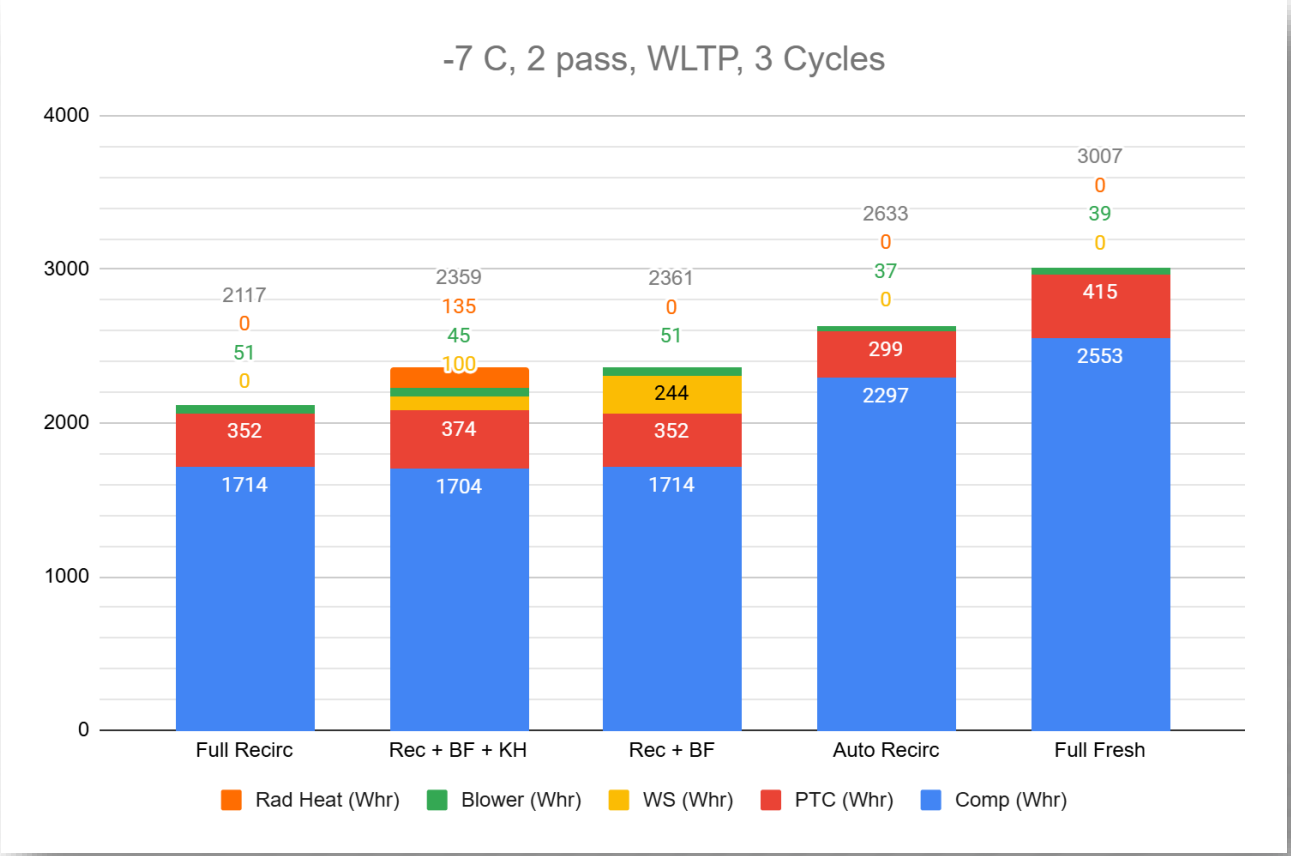
- Full Recirc + BF at 22C set point
- Full Recirc + BF at 20C set point with Knee Heaters

Full Recirc estimated from the Full Recirc + BF at 22C test



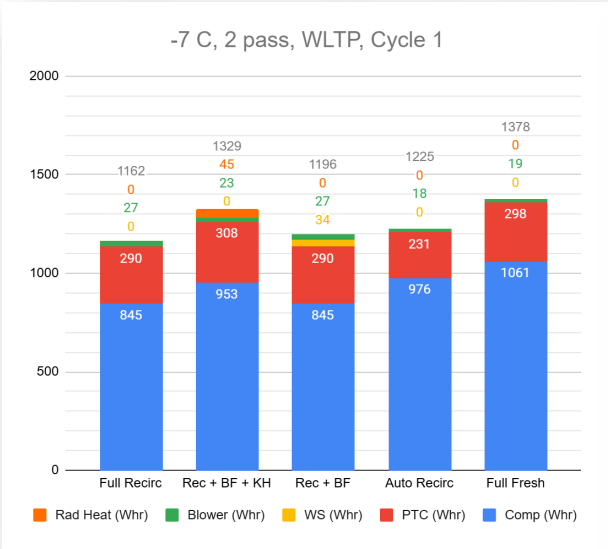
WLTC - 30 minutes
(repeated 3 consecutive times)

WLTP Testing (3 cycles - 90 minutes)

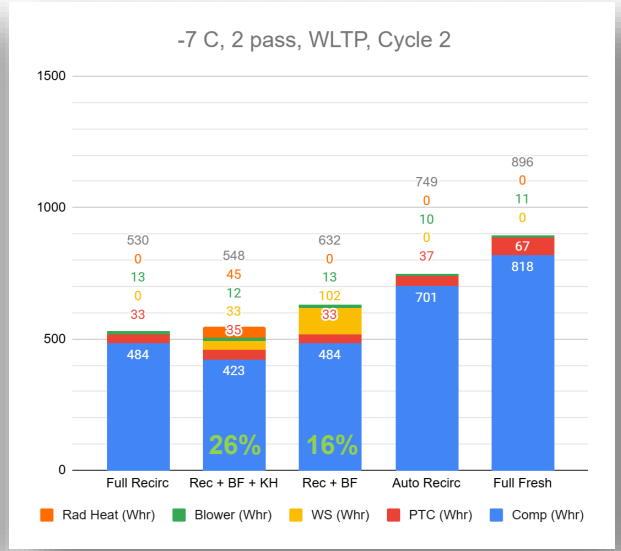


WLTP Breakdown by Cycle

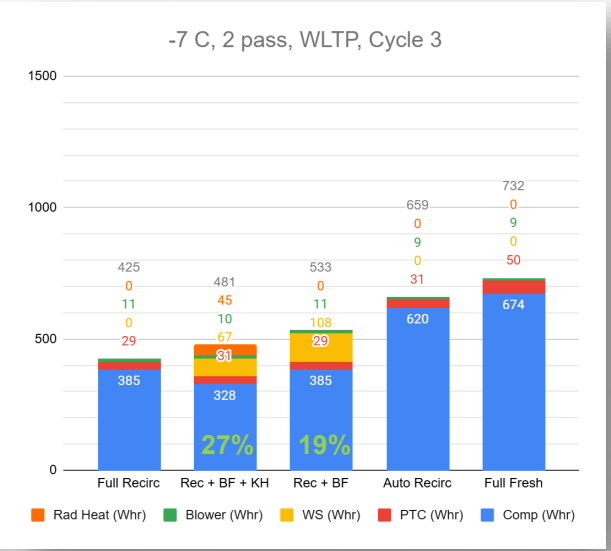
Cold Start



Transient



Steady State



- During Cold Start (Cycle 1), BF was not activated since no fog was formed.
- In Transient (Cycle 2) and Steady State (Cycle 3), BF alone saves 16-19% and BF with Knee Heater saves 26-27%.

Summary

1. On longer drives, Betterfrost delivers noticeable energy savings and superior cabin comfort
2. Energy savings increases when used with knee heaters
3. Betterfrost will keep the glass clear in extreme conditions.
4. Tested at:
   Deice: -30C and -40C
   -20C 5 person defog: 150, 200 & 250 kph
5. Less cabin noise, less temperature variation, and less hot discharge air to the face
6. Can significantly reduce HVAC heating load and reduce blower noise. Can eliminate forced heating in many conditions.

Questions?

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