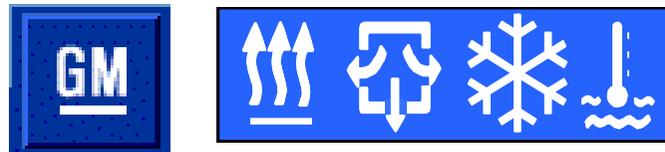


1234yf System Evaluation



June 10, 2008

Ken Porrett / Eric Scarlett
General Motors Corporation

Introduction

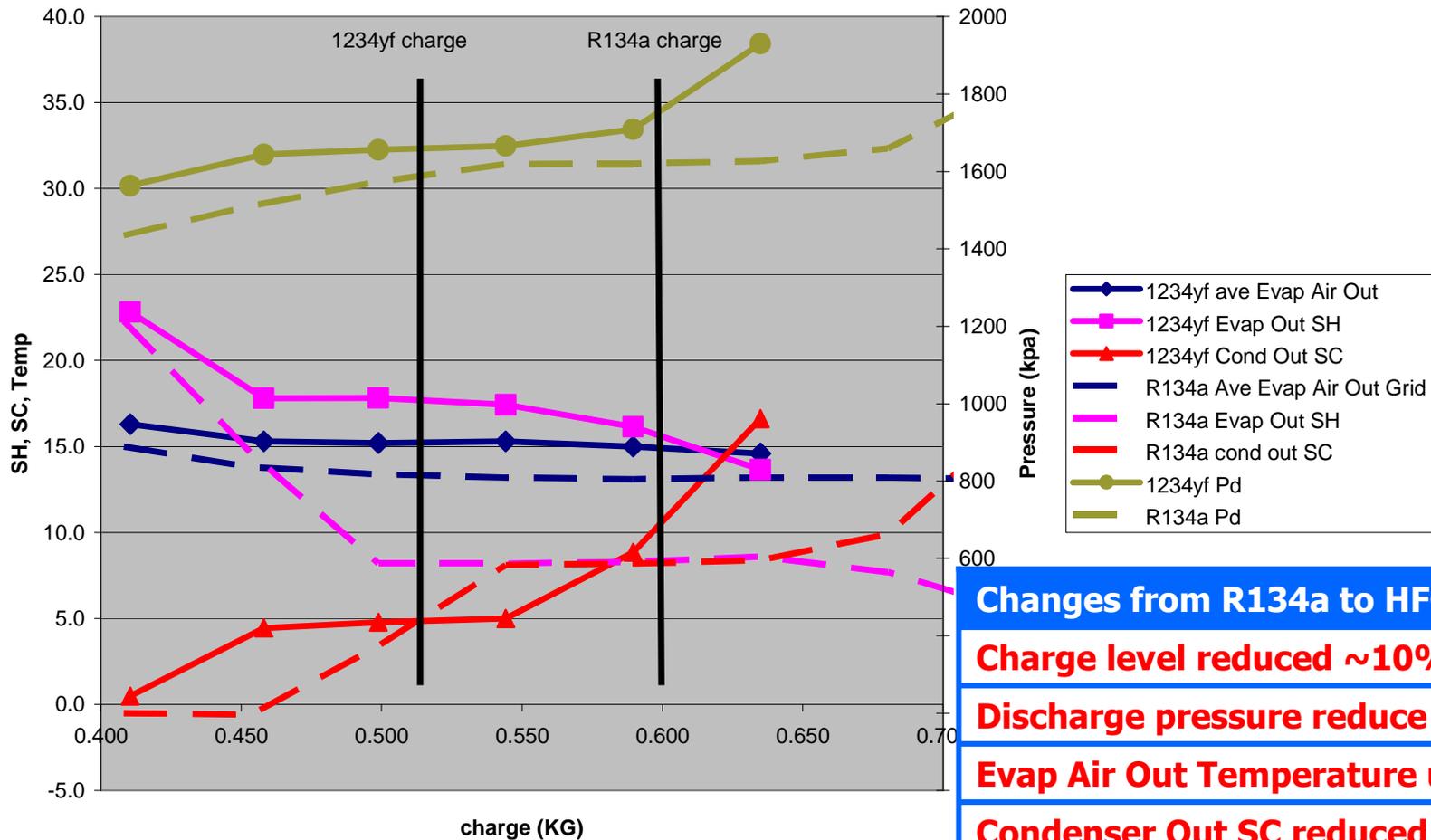
- Objective: evaluate performance impact of the HFO 1234yf refrigerant versus the production R134a system
 - maximum air-conditioning performance and steady-state conditions for three vehicles;
 - Opel Astra, Opel Corsa, and GMC Acadia.
- Evaluation items:
 - refrigerant system modifications with the TXV
 - compressor control valve
 - refrigerant plumbing
 - coaxial heat exchanger
 - Evaporator Modifications
 - Condenser Modifications
- Fuel economy measurements are compared between the production R134a system and final 1234yf configuration at nearly equal capacity

Astra System Configuration

	<u>Astra</u>	<u>Changes</u>
Powertrain	1.6L Gasoline, 5-spd Transmission	
Compressor	Delphi 6CVC135	
Control Valve	43.6 psia	45.0 psia
Condenser	CTCi	Modified
TXV	0.210 Mpa cross charge, 2.0 ton	0.190 Mpa
Evaporator	U-channel	modified
Suction Line	19mm tube / 16mm hose	3/4" suction
		IHX
Charge Amount	600 g	525 g w/o IHX

Charge Determination – Opel Astra

Astra Charge Determination
1234yf with 3/4" suct line vs R134a with 5/8" suct line



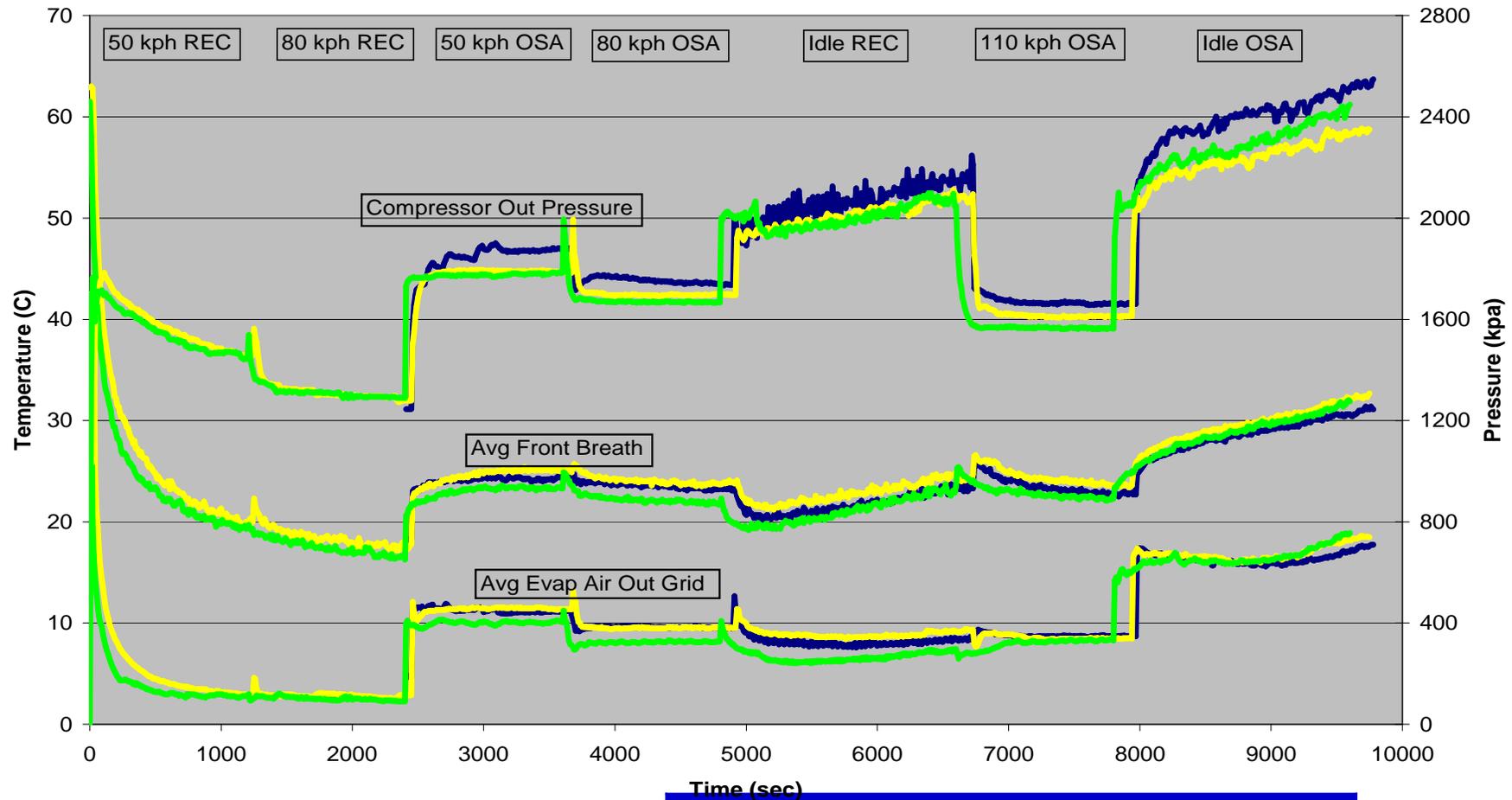
Changes from R134a to HFO1234yf

- Charge level reduced ~10%**
- Discharge pressure reduce ~50 kpa**
- Evap Air Out Temperature up ~1.5C**
- Condenser Out SC reduced ~2C**
- Evap Out SH up 7C**

Maximum A/C Performance – Opel Astra

Astra #237 (Modified Evaporator Core)- GMW3037

----- R134a Baseline - - - - 1234yf w/ 3/4" suction Line - - - - 1234yf w/ IHX



	% Capacity Change
R134a	
1234yf w/ 3/4"	0%
1234yf IHX	+2.5%

Detailed Analysis– Opel Astra

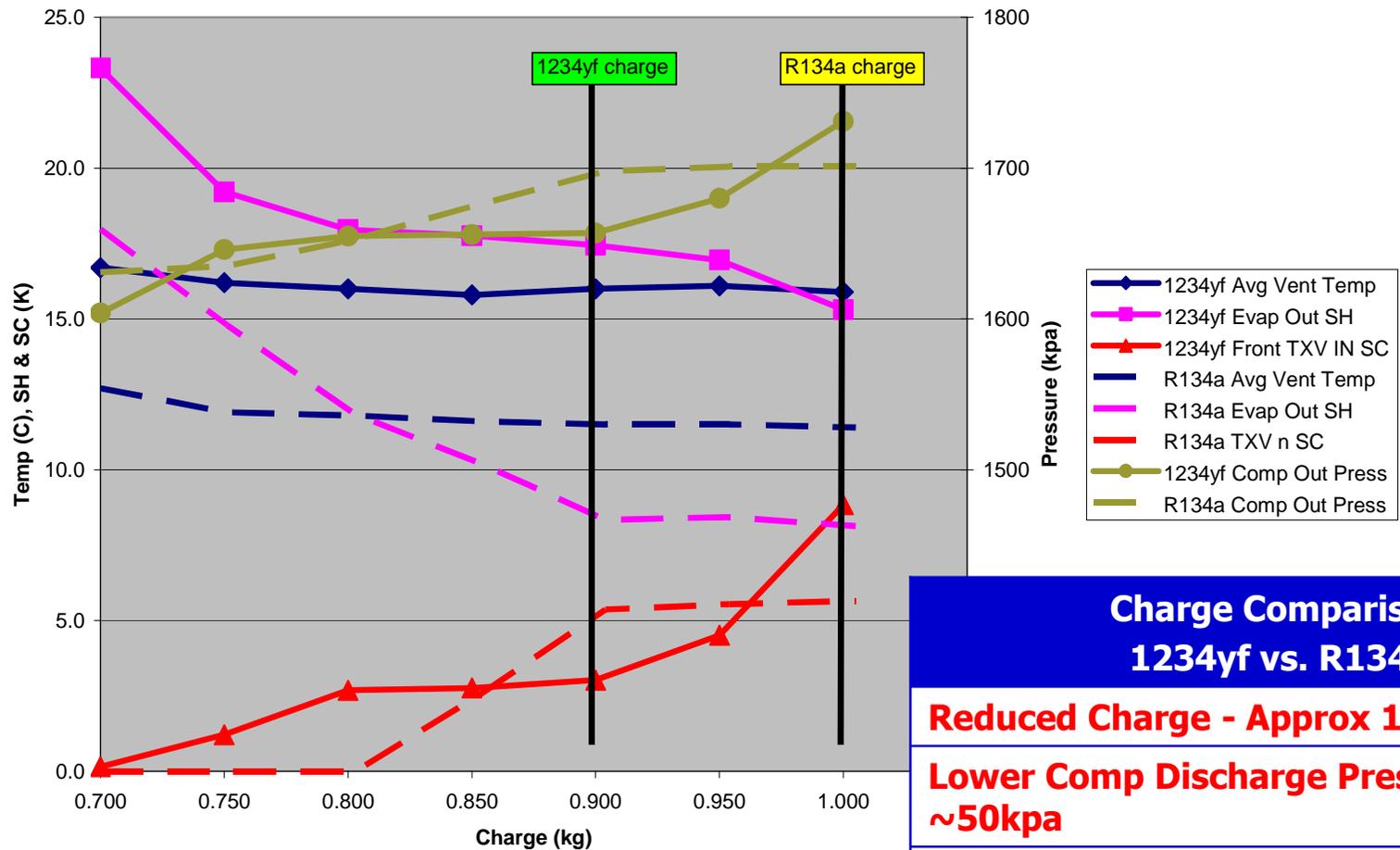
Component Change	Effect on Evap Out Air Temp	Effect on Compressor Out Pressure	Effect on Condenser Out SC
Front IHX	1-2 C colder except at OSA Idle	No effect	Increased SC at TXV in 6C
¾" Suction Line	0-1 C colder	No effect	No effect
TXV	No change	No effect	No effect
Modified Evaporator Core	0-1 C colder	No effect	No effect
Modified Condenser Core	No change	increased	+3 K SC

GMC Acadia System Configuration

	<u>Baseline</u>	<u>Changes</u>
Powertrain	3.6L Gasoline/6-spd Automatic	
Compressor	Denso 10S20	
Compressor Control	Evaporator Air Temp Sensor	
Condenser	4 Pass	Modified
TXV	Front - 0.195 Mpa Cross Charge, 2.0 T Rear - 0.140 Mpa Gas Charge, 0.6 T	
Evaporator	Front - 42 Tube, Flat Tube 6 Pass Rear - 24 Tube, Flat Tube 6 Pass	
Suction Line Dia.	19mm (3/4" inch)	Front IHX
Charge Amount	1050 g	900 g

Charge Determination – GMC Acadia

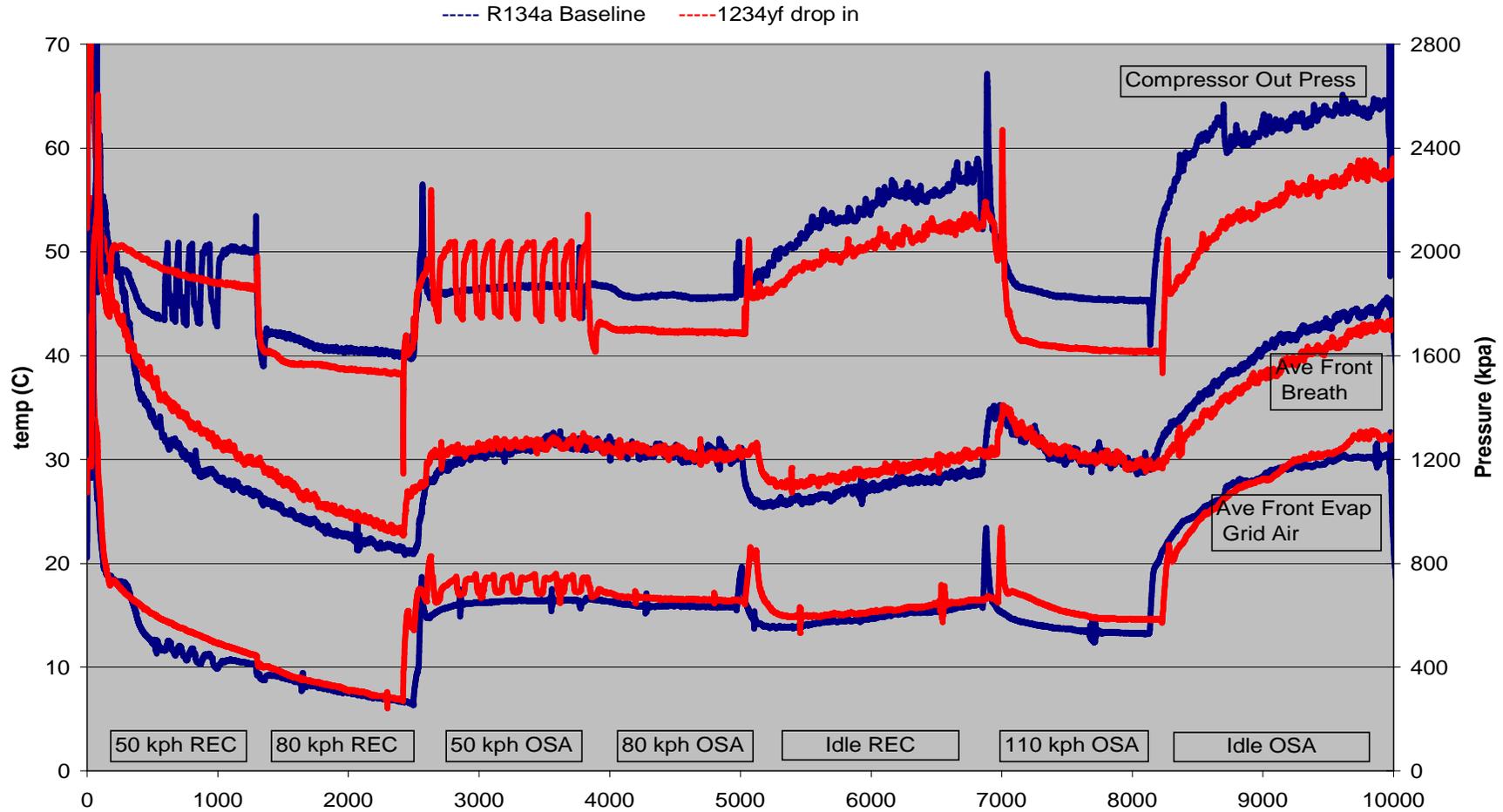
Lambda Charge Determination



Charge Comparison 1234yf vs. R134a	
Reduced Charge - Approx 10%	
Lower Comp Discharge Pressure ~50kpa	
Higher Compressor In Superheat ~8K	
Higher Average Panel Temp ~4C	
Lower Condenser Out SubCool ~2K	

Maximum A/C Performance – GMC Acadia

Lambda GMW3037 Front Vent & Breath and Compressor Out Pressure (Drop In)



time (sec)	% Capacity Change
R134a	
1234yf drop in	-3.9%

Detailed Analysis– GMC Acadia

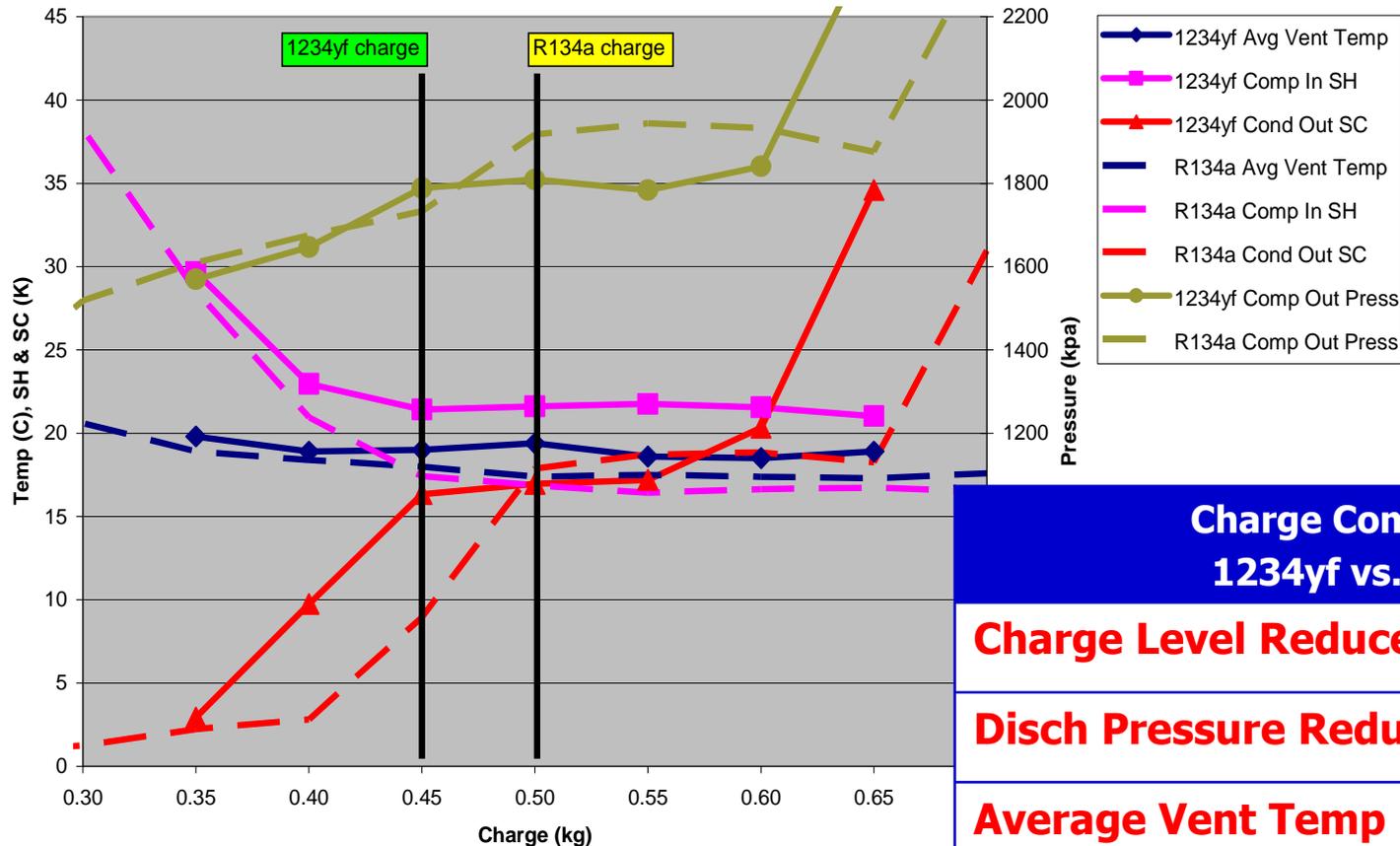
Component Change	Effect on Evap Out Air Temp	Effect on Compressor Out Pressure	Effect on Condenser Out SC
TXV	No change	No effect	No effect
Modified Evaporator Cores	NA	NA	NA
Modified Condenser Core	No change	+ 100 kpa	+ 2 K (eliminated TXV hunting)

Opel Corsa System Configuration

	<u>Corsa</u>	<u>Changes</u>
Powertrain	1.7L Turbo Diesel, 6-spd Manual	
Compressor	Denso 5SL12	
Control Valve	0.188 Mpa	
Condenser	MFIV, 248 x 647 x 16 2 Pass: 27/6 (tubes)	
TXV	0.200 MPa, Cross Charge	
Evaporator	195 x 295 x 38	
Suction Line	18mm tube / 16mm hose	Modified Suction Line
Charge Amount	470 g	450 g

Charge Determination – Opel Corsa

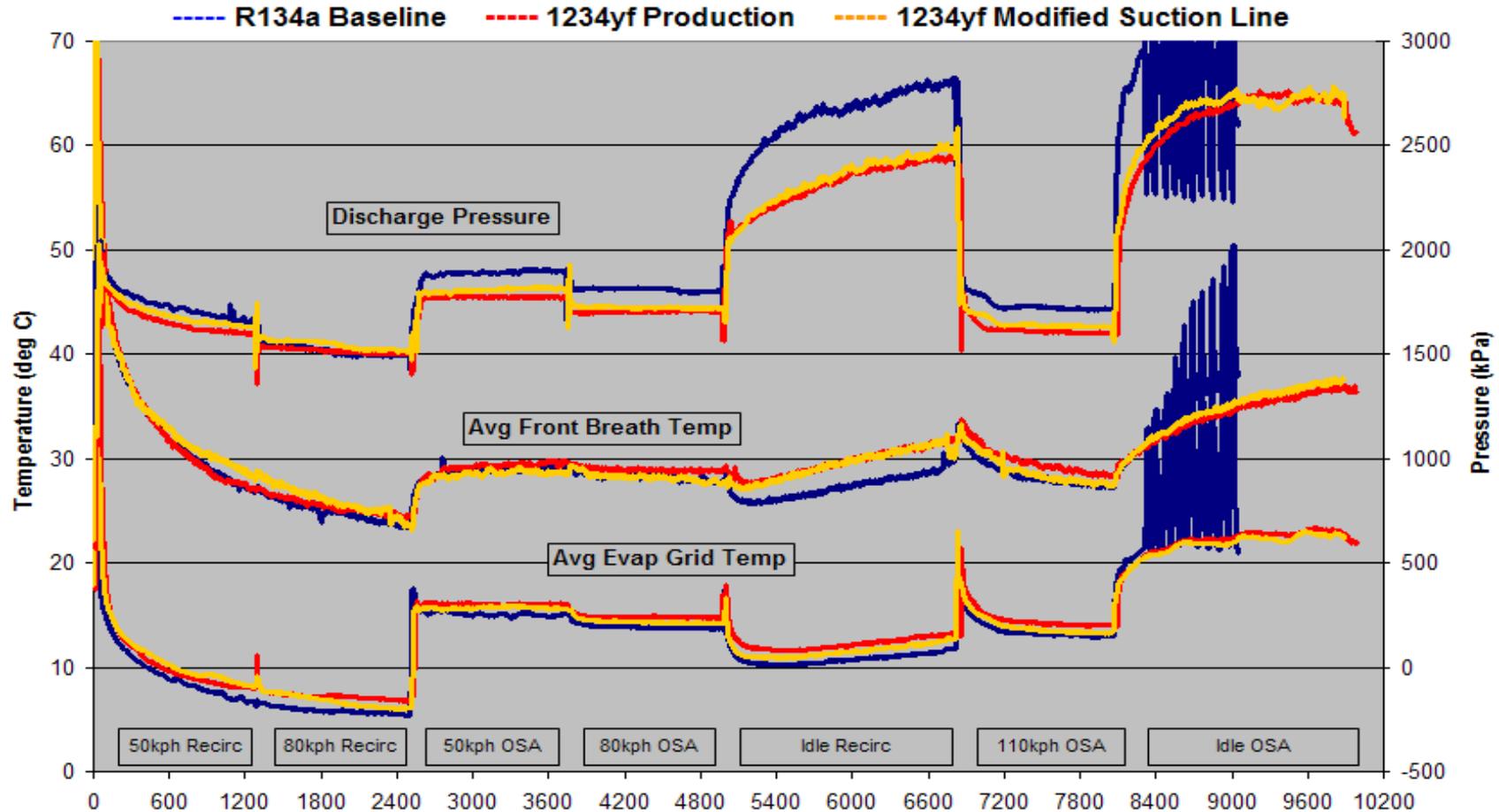
Opel Corsa Charge Determination
1234yf Drop-in versus R134a Baseline



Charge Comparison 1234yf vs. R134a	
Charge Level Reduced	~ 10%
Disch Pressure Reduced	~ 120 kpa
Average Vent Temp up	~ 1.3° K
Condenser Out SC Reduced	~ 1.5° K
Compressor In SH Increased	~ 5° K

Maximum A/C Performance – Opel Corsa

Corsa GMW3037, Evap Temp / Frt Breath / Disch Pressure



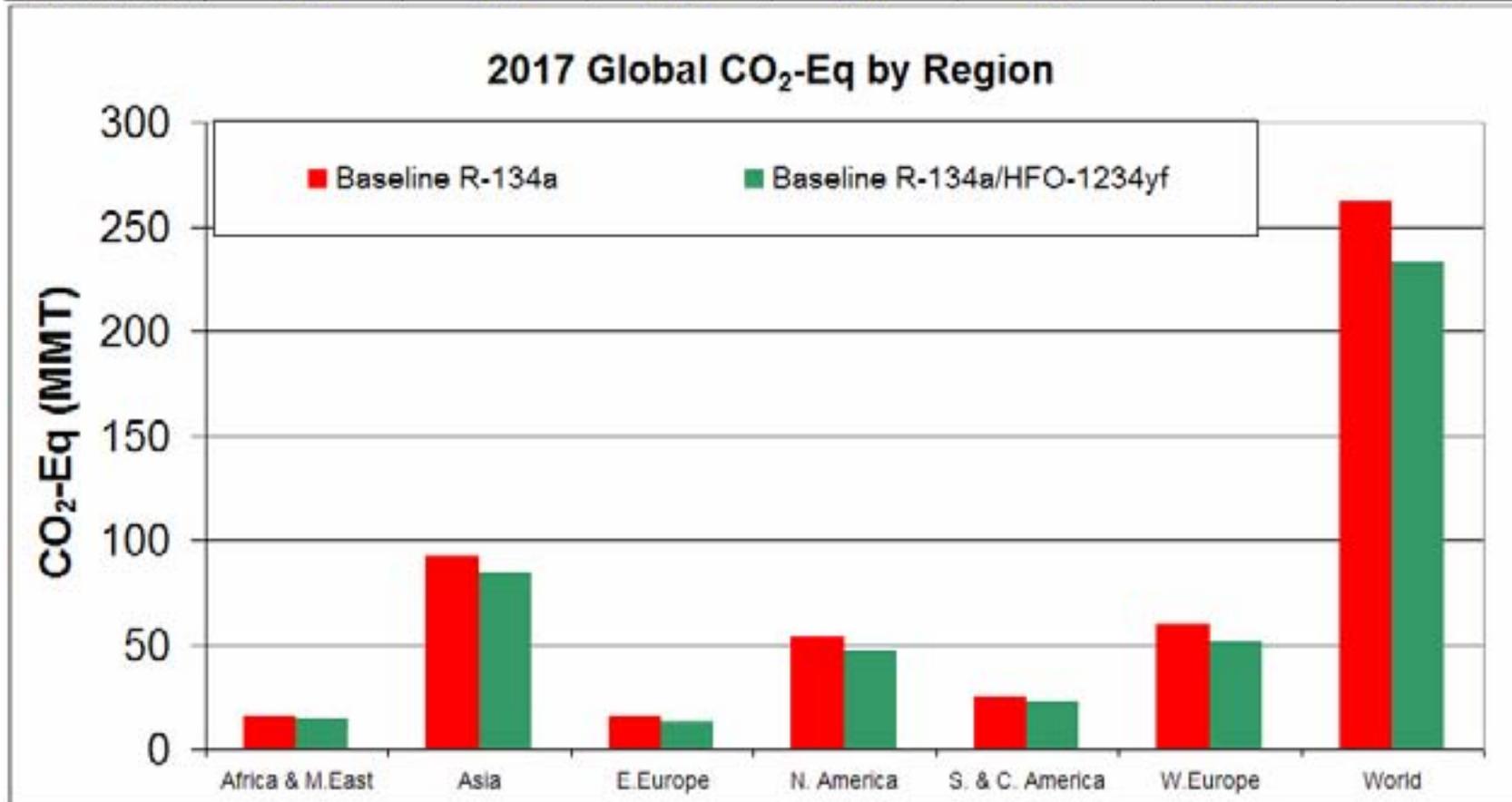
% Capacity change	
R134a	
1234yf Drop-In	- 4.1%
1234yf Mod Suction	- 2.6%

Detailed Analysis– Opel Corsa

Component Change	Effect on Evap Out Air Temp	Effect on Compressor Out Pressure	Effect on Condenser Out SC
Drop-In	+ 1.0° K	Reduced approx 120kPa @ 80kph	- 1° K SC
Modified Suction Line	+ 0.6° K	Reduced approx 80kPa @ 80kph	- 3° K SC
IHX 600mm, 25mm O.D.	Testing in Progress		

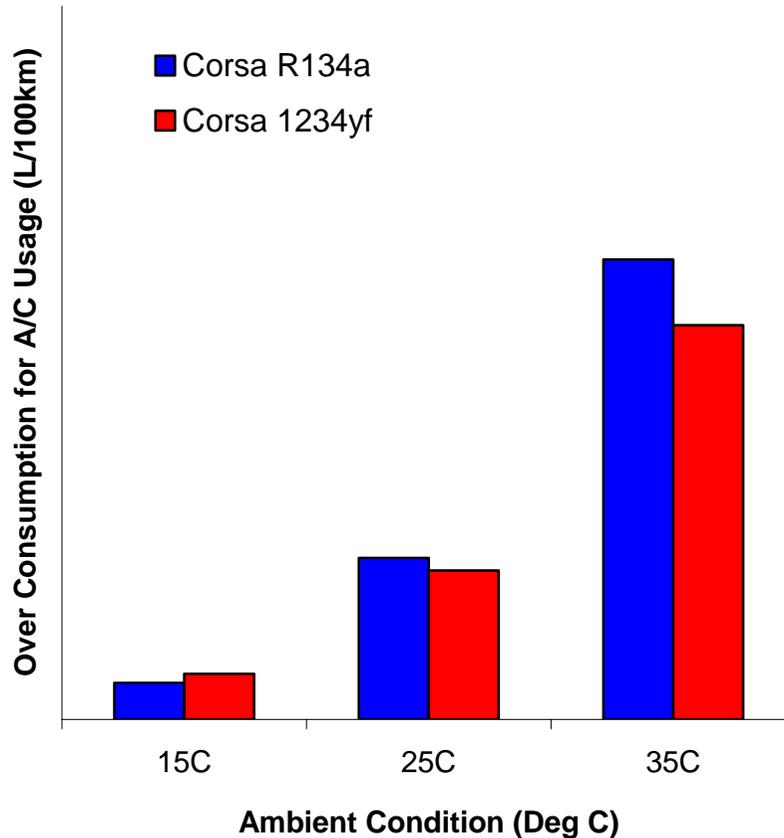
GREEN-MAC-LCCP Analysis of Corsa System

2017 Annual LCCP CO ₂ -Eq attributed to combined fleet of Baseline R-134a and Alternative Refrigerant							
	Africa & M.East	Asia	E.Europe	N. America	S. & C. America	W.Europe	World
Baseline R-134a	16.1	92.7	15.7	53.1	25.0	59.3	262.0
Baseline R-134a/HFO-1234yf	14.4	84.4	13.3	47.1	22.9	51.0	233.1



Fuel Economy Analysis – Opel Corsa

Fuel Consumption for A/C Usage
Combined SCO3 and FTP Highway

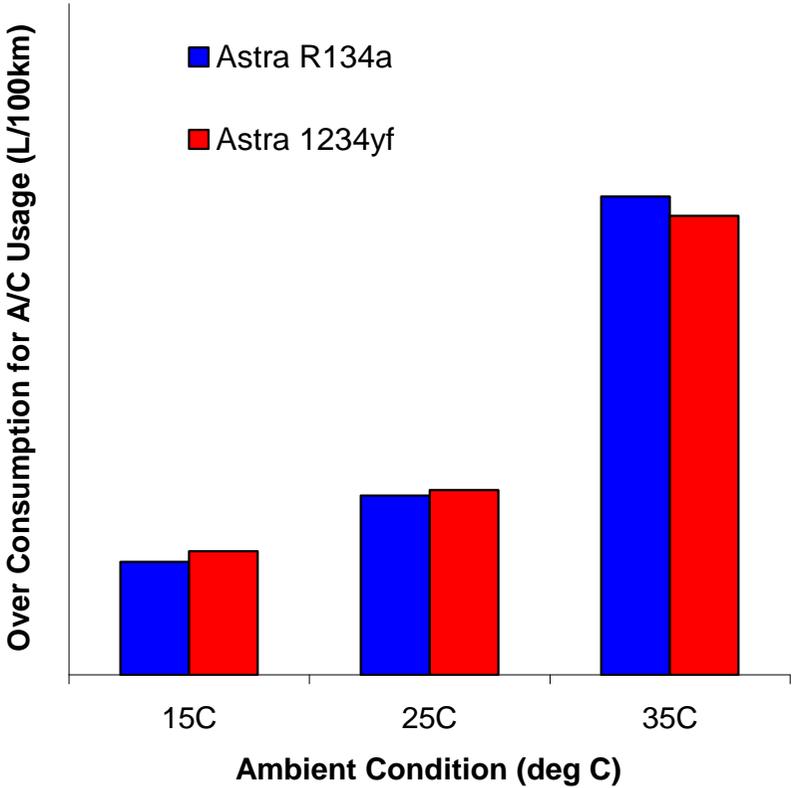


Annualized Fuel Consumption (Based on Time in Ambient)		
	R134a	1234yf
Frankfurt	3.0%	3.1%
Phoenix	14.0%	13.1%

Evaporator Capacity 35°C x 40%RH, 850 w/m2		
	R134a	1234yf
SCO3	~ Equal	
Highway	~ Equal	

Fuel Economy Analysis – Opel Astra

Fuel Consumption for A/C Usage
Combined SCO3 and FTP Highway

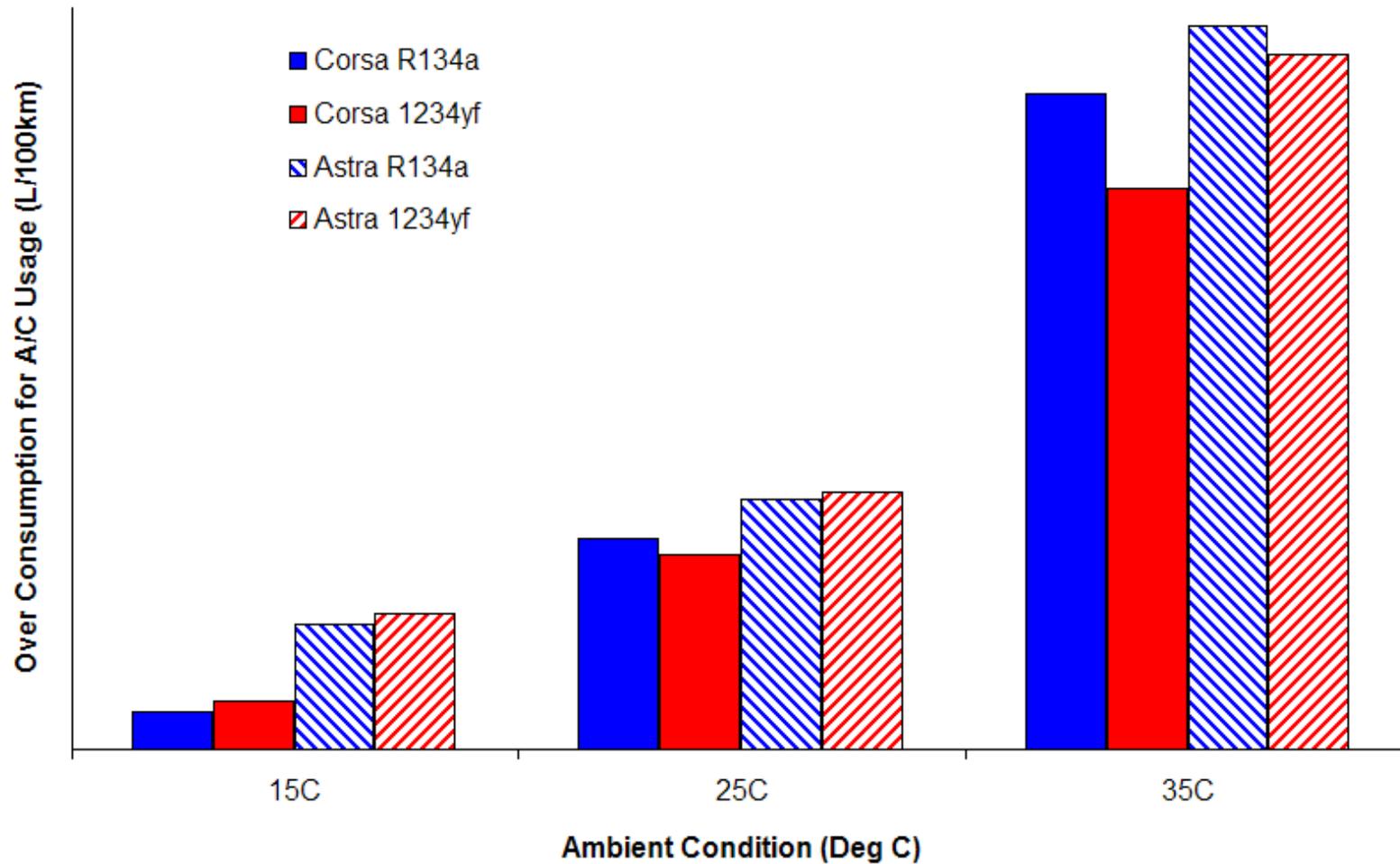


Annualized Fuel Consumption (Based on Time in Ambient)		
	R134a	1234yf
Frankfurt	3.8%	4.0%
Phoenix	12.4%	12.2%

Evaporator Capacity 35°C x 40%RH, 850 w/m2		
	R134a	1234yf
SCO3	~ Equal	
Highway	~ Equal	

NEDC Fuel Economy Estimate – Corsa/Astra

Estimated Fuel Consumption for NEDC Drive Cycle



System Configurations to be Considered

Opel Corsa

- 1. IHX**
- 2. TXV**
- 3. Compressor Control Valve**
- 4. Condenser**

Opel Astra

- 1. IHX**
- 2. TXV**

GMC Acadia

- 1. Front & Rear IHX**
- 2. Evaporator/TXV**
- 3. Compressor**

High Mileage Durability testing to begin July 2008.

Conclusions

- 1. Performance enhancements are required for 1234yf to equal R134a**
- 2. Best system configuration is vehicle/supplier dependent**
- 3. Fuel Consumption impact is minimal**
- 4. LCCP impact is reduced with HFO1234yf**

**Thanks to
Delphi, Denso & Behr
for their support**