

CO2 Emission Reductions from Tts and Weight Reductions - Sidelites and Backlite

Parameter	Units	Value	Formula	Comment / Source
<b>NREL (National Renewable Energy Laboratory - US) Study</b>				
Vehicle	–	Cadillac STS		Ref 1
Model year	–	2006		Ref 2 slide 4
Trim line	–	V6		Ref 3
Curb Weight	lbs	3960	a	OEM data
Curb Weight	kg	1796	$b = a / 2.2046$	
Fuel economy - no A/C	mpg	18.5	c	Ref 2 slide 24
Fuel use - no A/C	gpm	0.0541	$d = 1 / c$	
VMT (Vehicle Miles Traveled)	miles/yr	11998	e	Ref 1 p7 or Ref 2 slide 25
Average percent A/C use	%	26.0	f	CARB Public Workshop 12 Mar 09, p22
VMTAC (Vehicle Miles Traveled with A/C on)	miles/yr	3119	$g = e * f / 100$	
<b>Baseline Vehicle</b>				
Glazing material - all locations	–	Solargreen® glass		Special laminate for NREL study; Ref 2 slide 4, Ref 3, Ref 4
Tts - all locations	%	58	h	Ref 4
Fuel economy - with baseline A/C	mpg	15.4	i	Ref 2 slide 24
Fuel use - with baseline A/C	gpm	0.0649	$j = 1 / i$	
A/C fuel use when A/C running - baseline	gpm	0.0109	$k = j - d$	
Annual fuel use for A/C - baseline	gal/yr	33.9	$l = k * g$	
<b>Modified Vehicle - IR Glass, IR Paint, Ventilation (Config. 1 in Ref 1)</b>				
Glazing material - all locations	–	Sungate® EP		Special laminate for NREL study; Ref 2 slide 4, Ref 3, Ref 4
Tts - all locations	%	38	m	Ref 4
Fuel economy - with 70% baseline A/C	mpg	16.1	n	Ref 2 slide 24
Fuel use - with 70% baseline A/C	gpm	0.0621	$o = 1 / n$	
A/C fuel use when A/C running - modified	gpm	0.0081	$p = o - d$	
Annual fuel use for A/C - modified	gal/yr	25.1	$q = p * g$	
<b>Impact of full vehicle modification (Config. 1 in Ref 1)</b>				
Reduction in CBAST (Cabin Breath Air Soak Temperature)	C	12	r	Config. 1 in Ref 1 Tables 1 & 3
Reduction in A/C fuel use (per vehicle)	gal/yr	8.8	$s = l - q$	
Reduction in A/C fuel use (per vehicle) per degree C reduction in CBAST	gal/yr / C	0.7	$t = s / r$	
<b>Impact of IR Glass sidelites &amp; backlite (per vehicle)</b>				
Reduction in CBAST - IR Glass all locations + IR Paint (Config. 2)	C	9.7	u	Config. 2 in Ref 1 Tables 1 & 3
Reduction in CBAST - IR Glass windshield + IR Paint (Config. 4)	C	6.7	v	Config. 4 in Ref 1 Tables 1 & 3
Reduction in CBAST due to IR Glass sidelites & backlite	C	3.0	$w = u - v$	
Annual fuel saving due to IR Glass sidelites & backlite	gal/yr	2.2	$x = t * w$	
Reduction in Tts %	–	20.0	$y = h - m$	
Annual fuel saving due to IR Glass sidelites & backlite / unit Tts reduction	gal/yr / Tts	0.11	$z = x / y$	

CO2 Emission Reductions from Tts and Weight Reductions - Sidelites and Backlite

Parameter	Units	Value	Formula	Comment / Source
Exatec Calculations				
Impact of PC sidelites & backlite (per vehicle)				
Density - Glass	kg/m3	2500	aa	Ref 5 slide 12
Density - PVB	kg/m3	1060	bb	
Density - PC (polycarbonate)	kg/m3	1200	cc	
Sidelites - Thickness - Glass (total)	mm	3.85	dd	OEM input
Sidelites - Thickness - PVB	mm	0.0	ee	
Sidelites - Thickness - PC	mm	4.0	ff	
Sidelites - Maximum depth of movable window below beltline	m	0.10	gg	From sidelites used in NREL study
Sidelites - Front - DLO area (per window)	m2	0.2814	hh	Ref 3
Sidelites - Front - Effective width of area of movable window below beltline	m	0.40	ii	Per window; From sidelites used in NREL study
Sidelites - Front - Total area (2 windows)	m2	0.64	jj = 2*(hh + gg*ii)	
Sidelites - Rear - DLO area (per window)	m2	0.256	kk	Ref 3; Includes fixed rear quarter window
Sidelites - Rear - Effective width of area of movable window below beltline	m	0.27	ll	Per window; From sidelites used in NREL study
Sidelites - Rear - Total area (2 windows)	m2	0.57	mm = 2*(kk + gg*ll)	Includes fixed rear quarter window
Sidelites - all - Weight - Glass glazing	kg	11.66	nn = (jj + mm) * (aa*dd + bb*ee) / 1000	
Sidelites - all - Weight - PC	kg	5.81	oo = (jj + mm) * (cc*ff) / 1000	
Backlite - DLO area	m2	0.8347	pp	Ref 3
Backlite - Thickness - Glass (total)	mm	4.2	qq	OEM input
Backlite - Thickness - PVB	mm	0.0	rr	
Backlite - Weight - Glass glazing	kg	8.76	ss = pp * (aa*qq + bb*rr) / 1000	
Backlite - Thickness - PC	mm	4.0	tt	
Backlite - Weight - PC	kg	4.01	uu = pp * (cc*tt) / 1000	
Weight reduction - sidelites & backlites - Glass → PC	kg	10.60	ww = (nn + ss) - (oo + uu)	
Weight reduction - collateral from lighter sidelite hardware/motor	%	0	xx	% of ww; non-zero value would increase PC weight benefit
Weight reduction - total - Glass → PC	kg	10.60	yy = ww * (1 + xx / 100)	
Weight reduction - % of curb weight	%	0.59	zz = 100 * yy / b	
mpg improvement (%) / Weight reduction (%)	% / %	0.7	aaa	Ref 6
Fuel economy - with baseline A/C + PC sidelites & backlite	mpg	15.4636	bbb = i * (1 + zz*aaa / 100)	
Fuel use - with baseline A/C	gpm	0.0647	ccc = 1 / bbb	
Fuel use reduction from weight reduction	gpm	0.0003	ddd = j - ccc	
Annual fuel saving from replacing only sidelites & backlite with PC	gal/yr	3.21	eee = e * ddd	Assumes baseline A/C usage with PC to isolate weight effect
Equivalent reduction in Tts % - sidelites & backlite	–	29.1	fff = eee / z	
Tts for PC producing same CO2 lbs/yr as IR Glass per CARB Std.				
Tts - IR Glass just meeting CARB Std. for AS2 sidelites & backlite	%	60	ggg	CARB 8 May 09 posting, page A-3, paragraph a-5
Tts - PC - AS2 sidelites & backlite	%	89.1	hhh = fff + ggg	PC equivalent (lower actual Tts improves CO2 reduction)
CO2 (lbs) produced by fuel consumption (gal)	lbs/gal	20	iii	Ref 7
CO2 reduction per vehicle from weight benefit of PC sidelites & backlite	lbs/yr	64.1	jjj = eee * iii	

CO2 Emission Reductions from Tts and Weight Reductions - Sidelites and Backlite

Parameter	Units	Value	Formula	Comment / Source
References				
(1) J Rugh (NREL) et al, Paper # 2007-01-1194 in Proceedings of SAE 2007 World Congress, April 16-19, 2007, Detroit, Michigan				
(2) J Rugh (NREL) et al, presentation of Paper # 2007-01-1194 at SAE 2007 World Congress, April 16-19, 2007, Detroit, Michigan; also presented at CARB Public Workshop, May 15, 2008				
(3) J Rugh (NREL), private communication, 13 Apr 09				
(4) J Rugh (NREL), private communication, 27 Apr 09				
(5) <a href="http://www.saint-gobain-sekurit.com/EN/downloads/glazing_manual.pdf">http://www.saint-gobain-sekurit.com/EN/downloads/glazing_manual.pdf</a>				
(6) <a href="http://web.mit.edu/sloan-auto-lab/research/beforeh2/files/cheah_factorTwo.pdf">http://web.mit.edu/sloan-auto-lab/research/beforeh2/files/cheah_factorTwo.pdf</a> , page 19; also, <a href="http://www.fueleconomy.gov/feg/lightweight.shtml">http://www.fueleconomy.gov/feg/lightweight.shtml</a>				
(7) <a href="http://www.fueleconomy.gov/Feg/co2.shtml">http://www.fueleconomy.gov/Feg/co2.shtml</a>				