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ALTERNATIVE WAY TO REDUCE VEHICLE EMISSIONS IN SUMMER WITH THE HELP OF CAR WINDOW FILMING AND CAR WINDOW FILMING'S ECONOMIC BENEFITS OVER WA, NY, NC, U.S.A. AND ISTANBUL, TURKEY

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1. INTRODUCTION

As a start, the increase in production and population also brings unavoidable emissions. Since the complete combustion is the ideal case to be achieved with internal combustion engines, emission of CO_2 is a must. Therefore each contribution to reduce the pollutant emission source carries great importance. At this point, decreasing the pollution at the source is more desirable instead of air pollution treatment since the emitted pollutants are never vanished by treatment, but separated from the air medium. Expressive emissions belong to transport by 23% of world (IPCC 2007) and 28% of U.S total energy-related of greenhouse gas (GHG) emissions (U.S.EPA 2011) with about 3/4 coming from road vehicles. Furthermore, vehicle operation produces CO_2, CO, NO_x, VOC, non-methane organic gases (NMOG), PM, formaldehyde (HCHO), SO_x, small amounts of CH_4, N_2O and fluorinated gases from mobile air conditioning (MAC). Also in heated car cabins, fuel and the refrigerant evaporate and form additional evaporative emissions (U.S.FHWA 2006). Moreover, emitted black and organic carbon may affect radiative forcing. Vehicle associated GHG_s can be reduced by decreasing vehicle loads, improving energy efficiency, using less carbon-intensive fuel and using techniques to reduce emissions of non-CO_2 GHG_s from vehicle exhaust and climate controls (IPCC 2007). When all these measures enhanced, though they lead important decrease in emissions as in European future proposed standards (Bianco; Meek 2012; EUCommission 2007), they are not sufficient to prevent GHG emissions especially not enough to neutralize the effect of increases in traffic and car size. Since 2.5 to 7.5% of total vehicle energy consumption belongs to MAC system (IPCC 2007) and total annual MAC fuel usage of 40 billion liters (Farrington; Rugh 2000), presented filming approach is found to be a profitable alternative. Besides, nanotechnology enables the production of invisible films, i.e. without dark shading, thus this type of film application would not violate visible light transmission (VLT) laws.

Presented research emphasizes the car window filming effects around the Washington (WA), New York (NY), North Carolina (NC), U.S.A. and Istanbul, Turkey over the reduction in fuel consumption, which eventually results decline of vehicle emissions and increase in economy.

2. DATA COLLECTION AND METHODOLOGY

Basics of this research's methodology are: The gained heat (Q_{gain}) per passenger car without any window filming or tinting (clear window), which is taken as a reference, with tinted windows, and three different types of filming applied on clear car window and the same three types of filming applied on tinted window (7 possibilities), in summer during 1 hour of parking at noon are estimated so that the maximum effect can be observed. For this reason, to reflect the maximum Q_{gain} in summer at noon, the data of the peak total solar irradiation on the surface of Earth (I_S) only including the latitudes of U.S.A. according to the orientation of the car windows are used. The filming application theoretically designed by considering clear windshield and minimum of the allowed shading among State VLT Regulations (IWF 2013) for only windshield, whereas all remaining windows are filmed/tinted for both cases. After calculating total heat gained by car for 1 hour of parking for clear windshield and remaining 7 possibilities, each application's Q_{gain} difference from that of the car without any filming/tinting is found and further used as saved MAC energy consumption. Moreover, the reduced energy consumption for cooling the car back to comfort temperature leads reduced fuel, reduced fuel cost and vehicle emissions. As a result, for total passenger cars in WA, NY, NC (to represent some of the significant states of U.S.A.), all around U.S.A., and city of Istanbul in Turkey, equivalent savings of the fuel consumption, cost and emissions due to reduced Q_{gain} are found. Decline

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in the air pollution sourced damages will also bring additional economic increase (VTPI 2013). As a final point, the net economic contribution left from filming cost is evaluated.

2.1 Assumptions Used in Calculations

To begin with, filming/tinting effects are only analyzed during summer while 1 hour of parking at noon, it should be noted that this implementation will bring further but less significant benefits for reducing Q_{gain} while driving. Secondly, it is assumed that 80% (Farrington; Rugh 2000) of the total 423 passenger cars (per 1000 people) in U.S. (U.S.FHWA 2013) are in traffic every day in summer, while the total number of cars in traffic is published as 1.7-1.8 million for Istanbul so the average of 1.75 million is used (Şensoy; Ertaş 2012). The populations of WA, NY, NC and U.S. are gathered on Sep 25, 2013 as 6,984,900; 19,570,261; 9,752,073; and 316,743,785, respectively (CENSUS 2013). It is considered as if all the cars possess MAC and use MAC to cool the car cabin every day in summer. Again from World Bank statistics, although the types of consumed fuel vary, the mainly used ones are diesel and gasoline in U.S. Hence, under the consideration of only diesel and gasoline is consumed in U.S. and by taking the ratio of diesel and gasoline, 26.3% and 73.7% (Worldbank 2013) are used for diesel and gasoline, respectfully. However, since the diesel consumption in Istanbul is not as wide as U.S., calculations are conducted only over gasoline for Istanbul. The fuel prices per liter are taken as 1.04$ for diesel and 0.96$ for gasoline around U.S. (U.S.EIA 2013a) and 2.54$ for gasoline for Istanbul (Worldbank 2013). Related with Q_{gain} calculations, it is seen that I_S values for the average of north-east/west and south-east/west orientations among the latitudes of 20° to 60°N were varying from 615 to 562 W/m^2 (ASHRAE 2009), respectfully. Hence, the average value of 597 W/m^2 is considered for all states in US, while 603 W/m^2 at 40°N (ASHRAE 2009) is taken for Istanbul due to its close latitude of 41°N. The comfort temperature of 298.15 K (Çengel; Boles 2007) is chosen for both initial and desired car cabin temperatures. According to Kirchoff's law of radiation, emissivity (ε) is confirmed to be equal to absorptivity (α) and taken as total transmitted percent. The total energy efficiency of fuel combustion through car engine to the MAC system is conservatively chosen as 40% for diesel and 30% for gasoline so that the theoretical results will not be more than that of real application. The average speed of the passenger cars is taken as 60 km/h (Benouali et al. 2003). Among listed statistics (U.S.EERE 2013), the average passenger car performance is taken as 0.01 km/m^3. Despite the fact that the maximum power can be drawn by MAC is 5-6 kW (Johnson 2002; Rugh et al. 2004), due to ambient temperature, oxygen concentration and engine speed, its range is stated as 0.4−3.4 kW, yet can reach up to 3.7 kW at 3500 rpm (Lead 2005), this value is considered as 3 kW during calculations. About MAC, the net coefficient of performance (COP) of the electrically driven air-conditioning system, including the efficiency of the compressor and the electric motor required to drive it, is used as 2 (Farrington; Rugh 2000). Medium sized car with average interior volume index of 3.3 m^3 (1977 - 2013) is taken into account for the average car in U.S. and Istanbul. It is further assumed that the car window geometries are treated as rectangle for the area calculations and the dimensions of the front and back car window are used as 1.4 m x 0.5 m, whereas for the each side windows, it is taken as 0.55 m x 0.4 m. The passenger car total emissions in kg pollutant per km for CO_2, CO, NO_x, NMOG, PM and HCHO are used as ~0.58 (VTPI 2013), 0.012, $1.4.10^{-3}$, $4.5.10^{-4}$, $1.9.10^{-4}$ and $5.1.10^{-5}$, respectively (U.S.EPA 2007-2013). For these emission values are the half of the arterial truck emission factors in 2010, to achieve the approximate value of VOC, half of the truck VOC emission is considered for passenger cars, that is $4.9.10^{-4}$ kg/km. As a remark, the film production sourced emissions are not considered. The film lifespan is assumed to be guaranteed with minimum of 5 years and implementation cost is taken as 40$ per car (Çengel; Ghajar 2010). Finally, the cost of pollutants per kg of pollutant for CO_2, NO_x, VOC and $PM_{2.5+10}$ are 0.31$ (VTPI 2013), 8.1$ (Wang et al. 1994), 2.4$ (AEATE 2005) and 238$ (RWDI 2006; Wang et al. 1994), respectively.

5.2.1 Selected car window filming, tinted and clear window properties

Improved technology provides films that reflects the sun light in summer and absorbs during winter due to the change in the incident angle of solar rays in different seasons. Three different types of filming are selected to observe the film property effects better. Each film type is selected according to the best performance among their category. Film A not only blocks 97% of infrared heat and 99.9% of UV radiation, but also it is not metallised to prevent any corrosion and mobile phone signal interference while providing advanced clarity. Film B is selected as to be an example of nanotechnology so that it will not create shading and thus will not violate any VLT law. Used nanotech based ceramics are so fine that they are invisible to both the naked eye and an ordinary microscope. However, to be able to make fair comparison, the same filming strategy is also valid for film B. Film B possesses low reflectivity, high clarity, heat reduction, tough properties, resistive to corroding and provides clear view. As the last option of film types, Film C is selected in such a way to represent old-fashion classic filming. Film A, B, C are applied on clear glass and tinted glass, resulting 6 different possibilities to investigate apart from only tinted glass option, which makes seven in total when clear glass is taken as a reference throughout calculations, see Table 1 for properties (3M 2012).

Table1. Properties of glass and film types, SC, SHGC, P, and R stand for shading and solar heat gain coefficient, possibilities, and reference respectively.

P:	R	1	2	3	4	5	6	7
Glass	**Cl**	**T**	**Clear (Cl)**			**Tinted (T)**		
Film	**-**	**-**	**A**	**B**	**C**	**A**	**B**	**C**
SC	.94	.69	.47	.47	.24	.43	.43	.31
SHGC	.82	.60	.41	.41	.21	.37	.38	.27
α	.88	.5	.39	.36	.09	.23	.21	.05

2.2 Calculation Procedure

First of all, estimations of the energy, fuel, and cost savings coming from window filming per diesel for U.S. and per gasoline car for U.S. and Istanbul along with the energy, fuel, and cost savings and emission reductions for the total number of passenger cars in traffic; in other words, 2,363,690; 6,622,576; 3,300,101; and 107,186,097 with respect to WA, NY, NC and U.S.A., are computed.

While in most of the articles like Rugh et al. and Johnson's, Q_{gain} by car cabin calculations are based on finding mean radiant temperature (MRT) (Johnson 2002; Rugh et al. 2004), in this research, Cengel; Ghajar and Cengel; Boles's procedures and the previously explained assumptions are applied to Kirchoff's law of radiation as follows:

$$\dot{Q}_{\text{solar, gain}} = \text{SHGC} \times \text{A}_{\text{glazing}} \times \dot{q}_{\text{solar, incident}} \quad (1)$$

$$\dot{q}_{\text{net solar, incident}} = \sum E_{absorbed} - \sum E_{emitted} = \alpha_S G_{solar} + \varepsilon\sigma\left(T_{SKY}^4 - T_S^4\right) \quad (2)$$

where $A_{glazing}$ is the glazing area of 1.58 m^2 in total for full-filming of back and side windows and 0.7 m^2 for windshield, which is analyzed separately for clear window and for 20% shading, $\dot{q}_{solar,incident}$ is the solar heat flux incident (W/m^2). A positive result for $\dot{q}_{net\ solar,incident}$ indicates a heat gain by the surface and giving $\dot{Q}_{solar\ gain}$ (W), which is the case. α_s is the surface solar absorptivity, G_{solar} is the total solar energy incident on surface, namely previously explained I_s, σ is the Stefan–Boltzmann constant of 5.67 x 10^{-8} W/m^2K^4, ε is the emissivity, T_{sky} and T_s are the effective sky temperature of 285 K for warm conditions and the surface temperature of 298.15 K at the beginning of the iteration, respectively (Çengel; Ghajar 2010).

$$Q_{\text{gain,1hr-park}} = \dot{Q}_{\text{gain,1hr-park}} \left(\frac{kJ}{\sec}\right) \times 3600 \sec \quad (3)$$

$$m_{air} = \rho_{air} V_{air} \quad (4)$$

$$Q_{\text{gain,1hr}} = Q_{\text{in car cabin}} = m_{air} c_p \left(T_{final} - 298.15\right) \quad (5)$$

where $Q_{gain-1hr}$ is the total heat gained after 1 hr of parking, m_{air} is the air mass in cabin (kg), obtained from air density ρ_{air} of 1.184 kg/m^3 at 298.15 K (Çengel; Ghajar 2010) and air volume in car that is interior volume index of 3.3 m^3. Final car temperature T_{final} is found after iterating the eq (1) to (5) with the assumption of T_{final} in car cabin will be equal to T_s and the peak error was 1.3 x 10^{-5}. The MATLAB loop is run for each possibility both for type of films/glasses full-filling side and back windows, clear and 20% shaded windshield, U.S. and Istanbul due to different G_{solar} values. Since filming/tinting reduces the total Q_{gain}, energy savings are found by subtracting from the Q_{gain} of the car with no filming or tinting at all. In order to gain the total energy saved all through summer, Q_{gain} due to 1-hr of parking per day is multiplied with 90 days of summer. This energy savings are divided by COP to represent the saved energy for cooling by MAC. After that, by using assumed efficiencies for diesel and gasoline cars, estimations conducted separately over U.S. and only gasoline car for Istanbul. Owing to the peak power can be driven by MAC is 3 kW from engine, the required time to cool the car is computed from saved energies. Next, the corresponding road length to travel for the necessary time durations representing only MAC savings are gained by using average speed of 60 km/hr. Consequently, the saved fuel volume is found from average passenger car performance of 0.01 km/m^3. In addition to separate calculations based on per diesel and per gasoline car, to observe the impact, the total saved MAC energy around WA, NY, NC and U.S. is divided into two for diesel having consumption percentage of 26% and gasoline having 74%. Therefore, the total diesel and gasoline savings over WA, NY, NC and U.S.A. are found, costs computed separately and the total economic increase from fuel is found by the summation of each. Lastly, again by using car performance of 0.01 km/m^3 the equivalent road length to be travelled of the saved fuel is found so that the reduced amount of emissions of CO_2, CO, NO_x, VOC, NMOG, PM and HCHO can be investigated. For more accurate economic analysis, the saved costs of reduced vehicle pollutants are also calculated from their reduced mass loads along with the paid car filming costs.

3. RESULTS AND DISCUSSION

Table 2. Regarding film free (FF) and 20% shaded (S) windshield options: Saved MAC cooling energies of Q_D and Q_G, corresponding fuel volumes of V_D and V_G, wrt 26% diesel and 74% gasoline consumptions for U.S. and only gasoline for Istanbul, total saved fuel costs C_{D+G} in 90 days of one summer, prevented emission loads and the net 5-year savings of $C_{D+G+P-F}$ are listed. Special attention is needed for the dots, which represents decimal points, the units and the minus sign of $C_{D+G+P-F}$.

		Q_D		Q_G		V_D		V_G		C_{D+G}		CO_2		CO		NO_x		VOC		NMOG		PM		HCHO		$C_{D+G+P-F}$	
Units		10^{10} kJ				10^7 lt				Million $		10^8 kg		10^6 kg		10^5 kg		10^5 kg		10^5 kg		10^4 kg		10^4 kg		Billion $	
	P	FF	S	FF	S	FF	S	FF	S	FF	S	FF	S	FF	S	FF	S	FF	S	FF	S	FF	S	FF	S	FF	S
Washington	**1**	.17	.3	.23	.4	.01	.17	.35	.62	4.4	7.7	.26	.46	.53	.92	.65	1.1	.22	.39	.20	.35	.87	1.5	.23	.41	-.02	.04
	2	.38	.51	.5	.67	.21	.28	.78	1.0	9.7	13	.57	.77	1.2	1.6	1.4	1.9	.49	.65	.45	.60	1.9	2.6	.51	.68	.07	.13
	3	.41	.54	.54	.72	.23	.30	.85	1.1	10	14	.62	.82	1.3	1.7	1.6	2.0	.53	.69	.48	.64	2.1	2.7	.55	.73	.09	.14
	4	1.2	.14	1.7	1.8	.69	.77	2.6	2.9	32	35	1.9	2.1	3.9	4.3	4.8	5.2	1.6	1.8	1.5	1.6	6.3	7.0	1.7	1.9	.46	.51
	5	.65	.78	.86	1.0	.36	.43	1.3	1.6	17	20	.99	1.2	2.0	2.4	2.5	3.0	.84	1.0	.77	.92	3.3	3.9	.88	1.0	.19	.25
	6	.68	.81	.9	1.1	.38	.45	1.4	1.7	17	21	1.0	1.2	2.1	2.5	2.6	3.1	.87	1.0	.80	.95	3.4	4.1	.92	1.1	.20	.26
	7	1.3	.15	1.8	1.9	.74	.81	2.8	3.0	34	38	2.0	2.2	4.1	4.5	5.1	5.6	1.7	1.9	1.6	1.7	6.8	7.4	1.8	2.0	.49	.55
New York	**1**	.48	.84	.64	1.1	.27	.47	.99	1.7	12	22	.73	1.3	1.5	2.6	1.8	3.2	.62	1.1	.57	.99	2.4	4.3	.65	1.1	-.05	.11
	2	1.1	1.4	1.4	1.9	.59	.79	2.2	2.9	27	36	1.6	2.2	3.3	4.4	4.0	5.4	1.4	1.8	1.3	1.7	5.4	7.2	1.4	1.9	.20	.36
	3	1.1	1.5	1.5	2.0	.64	.84	2.4	3.1	29	39	1.7	2.3	3.5	4.6	4.4	5.7	1.5	1.9	1.4	1.8	5.8	7.6	1.5	2.0	.24	.40
	4	3.5	3.9	4.7	5.1	1.9	2.1	7.3	8.0	90	99	5.3	5.9	11	12	13	15	4.5	5.0	4.1	4.6	18	20	4.7	5.2	1.3	1.4
	5	1.8	2.2	2.4	2.9	1	1.2	3.8	4.5	47	56	2.8	3.3	5.6	6.7	6.9	8.3	2.3	2.8	2.1	2.6	9.2	11	2.5	2.9	.54	.70
	6	1.9	2.3	2.5	3	1.1	1.3	3.9	4.7	49	58	2.9	3.4	5.9	7.0	7.2	8.6	2.4	2.9	2.2	2.7	9.6	11	2.6	3.1	.57	.73
	7	3.7	4.1	5.0	5.5	2.1	2.3	7.7	8.5	96	110	5.7	6.2	12	13	14	16	4.8	5.3	4.4	4.9	19	21	5.1	5.5	1.4	1.5
North Carolina	**1**	.24	.42	.32	.56	.13	.23	.5	.87	6.1	11	.36	.64	.74	1.3	.91	1.6	.31	.54	.28	.50	1.2	2.1	.32	.57	-.03	.05
	2	.53	.71	.7	.94	.29	.39	1.1	1.5	14	18	.8	1.1	1.6	2.2	2.0	2.7	.68	.91	.62	.84	2.7	3.6	.71	.95	.10	.18
	3	.57	.75	.76	1	.32	.42	1.2	1.6	15	19	.87	1.1	1.8	2.3	2.2	2.9	.74	.97	.68	.89	2.9	3.8	.77	1.0	.12	.20
	4	1.7	1.9	2.3	2.6	.97	1.1	3.6	4.0	45	49	2.7	2.9	5.4	5.9	6.6	7.3	2.3	2.5	2.1	2.3	8.9	9.8	2.4	2.6	.64	.72
	5	.9	1.1	1.2	1.4	.50	.60	1.9	2.2	23	28	1.4	1.6	2.8	3.3	3.4	4.1	1.2	1.4	1.1	1.3	4.6	5.5	1.2	1.5	.27	.35
	6	.95	1.1	1.3	1.5	.53	.62	2.0	2.3	24	29	1.4	1.7	2.9	3.5	3.6	4.3	1.2	1.5	1.1	1.3	4.8	5.7	1.3	1.5	.29	.36
	7	1.9	2.0	2.5	2.7	1.0	1.1	3.9	4.2	48	52	2.8	3.1	5.8	6.3	7.1	7.8	2.4	2.6	2.2	2.4	9.5	10	2.5	2.8	.69	.77
U.S.A.	**1**	7.8	14	10	18	4.3	7.5	16	28	200	350	120	210	24	42	30	52	10	18	9.2	16	39	69	11	18	-.86	1.7
	2	17	23	23	31	9.5	13	35	47	440	590	260	350	53	71	65	87	22	30	20	27	87	120	23	31	3.3	5.8
	3	19	24	25	32	10	14	38	50	480	620	280	370	57	75	71	93	24	31	22	29	94	120	25	33	3.9	6.5
	4	**57**	**62**	**76**	**83**	**31**	**35**	**120**	**130**	**1500**	**1600**	**860**	**950**	**180**	**190**	**220**	**240**	**73**	**81**	**67**	**74**	**290**	**320**	**77**	**85**	**21**	**23**
	5	29	35	39	47	16	20	61	73	750	900	450	540	91	110	110	130	38	45	35	42	150	180	40	48	8.7	11
	6	31	37	41	49	17	20	64	76	790	940	470	560	95	110	120	140	40	47	36	43	160	190	42	49	9.3	12
	7	**60**	**66**	**81**	**88**	**34**	**37**	**130**	**140**	**1600**	**1700**	**920**	**1000**	**190**	**200**	**230**	**250**	**78**	**86**	**72**	**79**	**310**	**340**	**82**	**90**	**22**	**25**
Istanbul, TR	**1**	-	-	.17	.3	-	-	.72	1.3	18	32	.42	.73	.85	1.5	1.0	1.8	.36	.62	.33	.57	1.4	2.4	.37	.65	.11	.24
	2	-	-	.37	.5	-	-	1.6	2.1	40	54	.92	1.2	1.9	2.5	2.3	3.1	.78	1.0	.71	.96	3.1	4.1	.82	1.1	.32	.45
	3	-	-	.4	.53	-	-	1.7	2.3	44	57	1.0	1.3	2.0	2.7	2.5	3.3	.84	1.1	.77	1.0	3.3	4.4	.88	1.2	.35	.49
	4	-	-	1.2	1.4	-	-	5.3	5.8	130	150	3.0	3.4	6.2	6.8	7.6	8.4	2.6	2.8	2.4	2.6	10	11	2.7	3.0	1.2	1.4
	5	-	-	.64	.77	-	-	2.7	3.3	69	830	1.6	1.9	3.2	3.8	3.9	4.7	1.3	1.6	1.2	1.5	5.3	6.3	1.4	1.7	.60	.73
	6	-	-	.67	.79	-	-	2.8	3.4	72	860	1.7	2.0	3.3	4.0	4.1	4.9	1.4	1.7	1.3	1.5	5.5	6.5	1.5	1.7	.63	.76
	7	-	-	1.3	1.4	-	-	5.6	6.2	140	1600	3.3	3.6	6.6	7.2	8.1	8.9	2.8	3.0	2.5	2.8	11	12	2.9	3.2	1.3	1.4

Evaluated results following the explained methodology in *Section 2.2*. are listed in table 2. The total filming costs are 0.09, 0.26, 0.13, 4.29 and 0.07 Billion $ over WA, NY, NC, U.S.A. and Istanbul, respectively.

The impact of filming clearly appears in table 2. In order to help to visualize the maximum results of film C on tinted car back and side windows and 20% shaded windshield throughout U.S., it is better to compare as such: The total reduced CO_2 emission is 0.2% of U.S. and 0.03% of global CO_2 emissions (CDIAC 2010). The total saved power resulted from the total saved energy from 90 days of summer and 1 hr of each day is almost equal to the one-half of the average energy produced by the nuclear power plant (U.S.EIA 2013b). Nonetheless, the saved fuel resulted from 80% of the total passenger cars in U.S. road equivalent is 17.4 billion km and one can travel 435 thousand rounds around equator of Earth (Cain 2009). This same fuel saving belonging to decreased MAC loads because of filming is 4% of the total annual fuel consumption by MAC in U.S. (Farrington; Rugh 2000). Last but not least, the 5-year net saving can cover 0.15% of the current approximate active passive budget difference of 16.9 trillion $ (U.S.NDC 2013).

By getting back to resulted parameters, the range of the saved fuel amount per car is 2 - 17 lt. It is seen that saved total vehicle sourced air pollution costs are 2.4 times of the total saved fuel costs of each option and possibility. One major factor is that the fuel savings brings immediate economic contribution, while air pollution cost savings depends mainly on human health and/or global warming, thus takes longer time to contribute economy. The net saved cost $C_{D+G+P-F}$ is gained by summing the total saved fuel and decreased vehicle emission cost and subtracting listed filming costs, which is paid at the beginning of the 5 year only. The minus sign in $C_{D+G+P-F}$, belongs to the tinted window (P: 1) indicates that the tinted car window costs overwhelm savings. Therefore, if the customer is cost specific, only the first option will not be suitable. On the other hand, film implementation is beneficial for both fuel consumption, decreased emissions, and 5-yr net cost saved without any exception for each possibility (from 2 to 7). However, unlike 5-yr net cost savings, the net saved cost of the first summer right after the car film implementation results indicated that only the film C (P: 4 and 7) saves money while all other options cost more for WA, NY, NV and U.S.A. Still, this is not the case for Istanbul because the gasoline price in Turkey is almost 2.6 times of U.S. Parallel to the $C_{D+G+P-F}$ results, for Istanbul, based on net costs, all types of filming possibility is beneficial for each single case, whereas tinting is not. Furthermore, the best film option for each case and throughout all areas is film C on tinted glass (P: 7) and this option is followed again by C yet on clear glass (P: 4). Film C owns much greater potential among other types due to its denser color. This property may cause problems for the customers and the traffic polices. At this point, second most efficient nano-technology product of film B can be an alternative option. Although film B cannot provide the peak savings of film C, invisible nature and clear view properties may result film B to be also preferable especially when compared to film A. All in all, each possibility has great potential to prevent significant amount of vehicle source emissions. In spite the film production industries will surely contribute air pollution due to industry source emissions; at least the air treatment is applicable at the source, whereas treatment of the vehicle sourced air pollutions is not so suitable and even filtering the exhaust gas is an additional factor for engine to consume more fuel. As last point, it is important to keep in mind that the economic contribution cases of CO, NMOG, and HCHO pollution costs are missing and the reduced Q_{gain} during driving is not considered.

4. CONCLUSION

Gained results indicated that filming is necessary to cover the filming costs and the film C applied on tinted glass owns the greatest potential for MAC energy and fuel savings, emission reduction, and economic contribution. The savings belong to vehicle emission costs are 2.4 times of the total saved fuel costs for U.S., yet it is important to recall that the fuel costs are long-term comeback. On the whole, either tinting or any type of filming massively reduces the vehicle emissions. For complementary analysis, calculating the net reduced emissions after calculating film production related emissions is needed. Moreover, additional net cost savings are better to be calculated over remaining air pollutants of CO, NMOG, and HCHO. Finally, evaluation of the saved energy by MAC while driving would increase the accuracy as well as contribution to the economy even more.

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