

# Designing of Solar Air Conditioning for Four Wheeler

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**How to cite this paper:** Basavraja K. T | M. Rajes | M. Krishnaven | P. Sachin "Designing of Solar Air Conditioning for Four Wheeler" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-3 | Issue-3, April 2019, pp.1216-1219, URL: <https://www.ijtsrd.com/papers/ijtsrd23281.pdf>



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## 1. INTRODUCTION

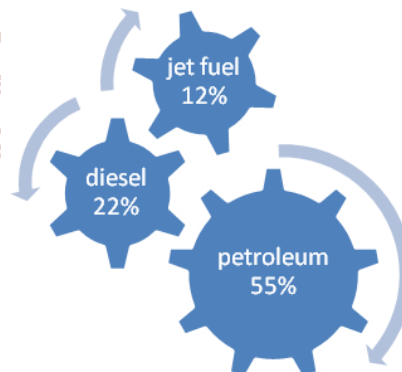
As a kind renewable energy solar energy is paid more and more in the world. Solar system can be classified into two categories; those are thermal systems which convert solar energy to thermal energy and photovoltaic systems which convert solar energy to electrical energy. However more solar radiation which falling on photovoltaic cells is not converted to electricity, but either reflected or converted to thermal energy. This method leads to a drop of electricity conversion efficiency due to an increase in photovoltaic cells working temperature[1]. In the past century, scientific community has devoted much effort to procure energy sustainability of housing in two main direction; those are reducing external energy supply and using renewable energy for the remaining. In both ways, solar resources are gaining popularity because they increase energy independence and sustainability at the same time offering nearly zero impact to the environment [1]. The earth's surface receives a daily solar dose of 10E+8KW-hr, which is equivalent to 500,000 billion oil barrels that is one thousand times any oil reserve known to man. And the solar energy is collector area dependent, and is a diluted form of energy and is available for only a fraction of the day[6]. A lot of research is being conducted where there is high availability of solar energy just like in India. Solar energy is abundant in summer months where there is no heating load, but instead of cooling is required. But the today's energy sources as shown in Fig. (1.1)

## ABSTRACT

In present day scenario natural resources like fuel, coal are used extremely and in the coming years the availability of these resources would fall down drastically. So it's high time for the people all over the world to find the alternative other than these resources. Electrical vehicles operated with batteries is one example to say that technology is progressing at a brisk phase. Another example of the natural source of energy is sun, and in this project solar energy is used as a remedy to optimize its fullest.

To use solar energy and convert it further into electrical energy requires some components and their functions are to be well understood. A PV solar cell is used to directly change solar energy into electrical energy, a battery for storage of collected solar energy and a single phase DC motor which is run by battery power. The purpose of the motor is to transfer power to compressor to move and start the process.

By the functioning of these components, making a note of dimension of the vehicle, material used for preparing vehicle (outer body and glass) heat load calculations are calculated and a result is not favorable for designing solar air conditioning system In future solar energy is going to be one of the predominant sources of energy in coming the days due to its abundant availability.



Renewable Energy considers the primary energy from recurring and non-depleting indigenous resources. The reference scenario is projecting the world primary energy demand expands by almost 60% from 2002 to 2030, and the average annual increase percentage is 1.7% per year. The demand will be reaching 16.5 billion tons of oil equivalents compared to 10.3 billion tons in 2002. There is the projected rate of growth, but it is slower than over the past three decades when it grew by 2% per year [3]. On the other hand, the fossil fuels will keep monopolizing the global energy use. They will take up around 85% of the increase in world primary demand over 2002–2030. Furthermore, the share in total demand will increase slightly from 80% in 2002 to 82% in 2030. The share of renewable energy sources will remain

the same which is at around 14% while the nuclear power will drop from 7% to 5%[3]. Hence, the negative effects of fossil fuel combustion on the environment with limited stock can force many countries seeking environmentally friendly alternatives to sustain the increasing energy demand. In this condition, the improvement in the quality of life is raising with the indigenous energy resources. The growth of scarcity in fossil fuels has raised the global interest in the harnessing of solar energy[3]. Solar power is a renewable energy while currently covering and assisting in merely a small portion of global energy demands. However, Photovoltaic (PV) power generates less than 1% of total electricity supplies since solar power has been considered as one of the most expensive sources of renewable energies [3].

## 2. Design and calculations

Calculations can be done for and designed vehicle in CATIA

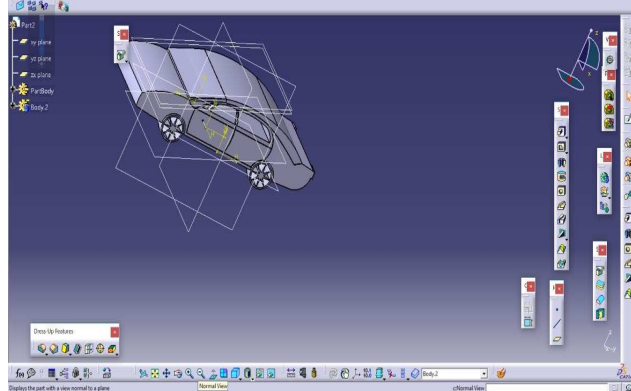


Fig 1 Car model

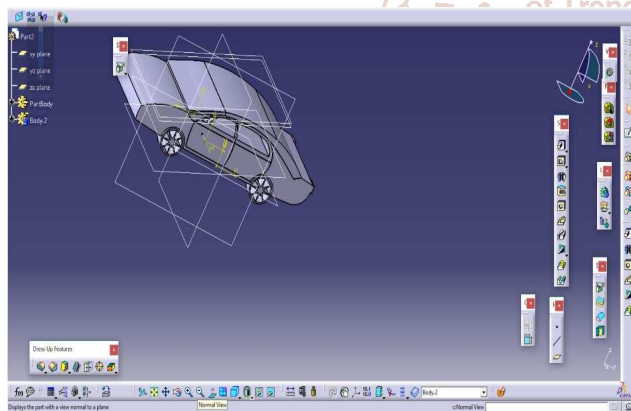


Fig 2 wire frame model

### Calculations

#### 1. Metabolic Load

The metabolic activities inside human body constantly create heat and humidity (*i.e.* perspiration). This heat passes through the body tissues and is finally released to the cabin air. This metabolic load can be calculated by

$$Q_{Met} = \sum MA_{Du}$$

Where M=Passenger metabolic heat production rate

=85 W/m<sup>2</sup> for driver

=55 W/m<sup>2</sup> for passenger

M=85+55\*4 (No. of passengers)

=305 W/m<sup>2</sup>

A<sub>Du</sub>=Body surface area

A<sub>Du</sub>=0.202W<sup>0.425</sup>H<sup>0.725</sup> where W and H are the passenger weight and height

$$=0.202*65^{0.425}*1.70^{0.725}$$

$$=1.749504 \text{ m}^2$$

$$Q_{Met} = 305*1.749504$$

$$= 533.5988112 \text{ W}$$

#### 2. Radiation Load

The heat gain due to solar radiation is a significant part of the cooling loads encountered in vehicles. According to ASHRAE, solar radiation heat load can be categorized into direct, diffuse, and reflected radiation loads.

Direct radiation is that part of the incident solar radiation which directly strikes a surface of the vehicle body, which is calculated from

$$Q_{Dir} = \sum S \tau i_{Dir} \cos \theta$$

According to ASHRAE 2007 chapter 33 Table no. 20

$$\text{Peak load} = 1417 \text{ W/m}^2$$

$$i_{Dir} = 1417 \text{ W/m}^2$$

$$\text{Glass surface area } S = 2 \text{ m}^2$$

$$\tau = 0.5$$

$$\theta = 60^\circ$$

$$Q_{Dir} = 2*0.5*1417*\cos(60^\circ)$$

$$= 708.5 \text{ W}$$

On cloudy days, most of the solar radiation is received from this diffuse radiation. This can be calculated by

$$Q_{Dif} = \sum S \tau i_{Dif}$$

$$i_{Dif} = C i_{Dir} (1 + \cos \Sigma) / 2$$

$$= 0.103 * 1417 * (1 + \cos 30^\circ) / 2$$

$$= 136.174 \text{ W/m}^2$$

$$Q_{Dif} = 2 * 0.5 * 136.174$$

$$= 136.174 \text{ W}$$

Reflected radiation refers to the part of radiation heat gain that is reflected from the ground and strikes the body surfaces of the vehicle. The reflected radiation is calculated by

$$Q_{Ref} = \sum S \tau i_{Ref}$$

$$i_{Ref} = (i_{Dir} + i_{Dif}) * \rho_g * (1 - \cos \Sigma) / 2$$

$$= (1417 + 136.174) * 0.2 * (1 - \cos 30^\circ) / 2$$

$$= 20.808 \text{ W/m}^2$$

$$Q_{Ref} = 2 * 0.5 * 20.808$$

$$= 20.808 \text{ W}$$

The net absorbed heat of each surface element due to radiation can thus be written as

$$Q_{S, Rad} = S \alpha (i_{Dir} \cos \theta + i_{Dif} + i_{Ref})$$

$$= 2 * 0.3 (1417 * \cos 60^\circ + 136.174 + 20.808) \text{ for glass}$$

$$= 519.6208 \text{ W}$$

$$Q_{S, Rad} = 3.02 * 0.4 (1417 * \cos 60^\circ + 136.174 + 20.808) \text{ for surface}$$

$$= 1045.5022 \text{ W}$$

$$Q_{S, Rad} = 519.6208 + 1045.505$$

$$= 1565.12 \text{ W}$$

#### 3. Ambient Load

The ambient load is the contribution of the thermal load transferred to the cabin air due to temperature difference between the ambient and cabin air.

$$Q_{Amb} = \sum SU(T_s - T_i)$$

For glass  $S = 2 \text{ m}^2$   
 Speed = 60 kmph  
 $V = 60 * 5 / 18 = 16.66 \text{ m/s}$

Where U is the overall heat transfer coefficient of the surface element

$$U = 1/R$$

$$\text{Where } R = 1/h_o + \chi/k + 1/h_i$$

R is the net thermal resistance for a unit surface area.  $h_o$  and  $h_i$  are the outside and inside convection coefficients, k is the surface thermal conductivity, and  $\lambda$  is the thickness of the surface element.

$$h = 0.6 + 6.64(V)^{0.5}$$

Where h is the convection heat transfer coefficient in  $W/m^2K$  and V is the vehicle speed in m/s.

$$h_i = 0.6$$

$$h_o = 0.6 + 6.64(16.66)^{0.5}$$

$$= 27.70$$

For glass  $k = 1.05$ ,  $\chi = 0.003 \text{ m}$

$$R = 1/27.70 + 0.003/1.05 + 1/0.6$$

$$R = 1.705 \text{ m/W/m.K}$$

$$U = 1/1.705 = 0.586 \text{ W/m}^2.K$$

$$Q_{Amb} = 2 * 0.586 * (60 - 30)$$

$$= 35.16 \text{ W}$$

For surface  $k = 0.2$ ,  $\chi = 10$ ,  $S = 3.02 \text{ m}^2$

$$R = 1/27.70 + 0.01/0.2 + 1/0.6$$

$$= 1.753 \text{ m/W/m.K}$$

$$U = 1/1.753 = 0.570 \text{ W/m}^2.K$$

$$Q_{Amb} = 3.02 * 0.570 * (60 - 30)$$

$$= 52.155 \text{ W}$$

$$Q_{Amb} = \text{Glass} + \text{Surface}$$

$$= 35.16 + 52.155$$

$$= 87.315 \text{ W}$$

#### 4. Exhaust Load

Conventional and hybrid electric vehicles have an Internal Combustion Engine (ICE) that creates exhaust gases. The Exhaust Gas Temperature (EGT) can reach as high as  $1000^\circ\text{C}$ .

Because of the high temperature of the exhaust gas, some of its heat can be transferred to the cabin through the cabin floor. Considering  $S_{Exh}$  as the area of the bottom surface in contact with the exhaust pipe, the exhaust heat load entering the cabin can be written as

The exhaust heat load entering the cabin can be written as

$$Q_{Exh} = S_{Exh}U(T_{Exh} - T_i)$$

$$T_{Exh} = 0.138RPM - 17$$

$$= 0.138 * 6000 - 17$$

$$= 811 \text{ K}$$

$$Q_{Exh} = 0.035 * 0.570 * (811 - 30)$$

$$= 15.88 \text{ W}$$

#### 5 Engine Load

Like the exhaust load above, the high temperature engine of a conventional or hybrid car can also contribute to the thermal gain of the cabin

$$Q_{Eng} = S_{Eng}U(T_{Eng} - T_i)$$

$$T_{Eng} = -2 * 10^{-6} * RPM^2 + 0.0355 * RPM + 77.5$$

$$= -2 * 10^{-6} * 6000^2 + 0.0355 * 6000 + 77.5$$

$$= 218.5 \text{ K}$$

$$Q_{Eng} = 0.77 * 0.570 * (218.5 - 30)$$

$$= 82.73 \text{ W}$$

#### 6 Ventilation Load

According to psychrometric calculations, ventilation heat gain consists of both sensible and latent loads. To account for both these terms, assuming a known flow rate of fresh air entering the cabin, the amount of thermal heat gain can be calculated from

$$Q_{Ven} = m_{Ven}(e_o - e_i)$$

Where  $m_{Ven}$  is the ventilation mass flow rate and  $e_o$  and  $e_i$  are the ambient and cabin enthalpies, respectively. Enthalpies are calculated from

$$e = 1006 * T + (2.501 * 10^6 + 1770T)X$$

$$e_o = 1006 * 40 + (2.501 * 10^6 + 1770 * 40)0.3 \quad (T_o = 40, X = 0.3)$$

$$= 811780 \text{ J/kg}$$

$$e_i = 1307230 \text{ J/kg} \quad (T_i = 30, X = 0.5)$$

Where T is air temperature and X is humidity ratio in gram of water per gram of dry air.

$$m_{Ven} = 0.02 \text{ kg/s}$$

$$Q_{Ven} = 0.02(811780 - 1307230)$$

$$= -9909 \text{ W}$$

#### 7 AC Load

The duty of the air conditioning system is to compensate for other thermal loads so that the cabin temperature remains within the acceptable comfort range. In cold weather conditions, positive AC load (heating) is required for the cabin. Inversely, in warm conditions, negative AC load (cooling) is needed for maintaining the comfort conditions. The actual load created by the AC system depends on the system parameters and working conditions. In this work, it is assumed that an AC (or heat pump) cycle is providing the thermal load calculated by<sup>[4]</sup>

$$Q_{AC} = -(Q_{Met} + Q_{Dir} + Q_{Dif} + Q_{Ref} + Q_{Amb} + Q_{S.Rad} + Q_{Exh} + Q_{Eng} + Q_{Ven}) - (m_a c_a + DTM)(T_i - T_{Comf})/t_c$$

$$\text{Here } m_a = 44.488 \text{ kg}$$

$$c_a = 1.005$$

$$DTM = 5.6 \text{ kJ/kg}$$

$$T_{Comf} = 20$$

$$T_i = 30$$

$$t_c = 600 \text{ sec}$$

$$Q_{AC} = - (6.76) - 0.8348 \text{ KW}$$

$$= 5.93 \text{ kW}$$

$$1 \text{ TR} = 3.5 \text{ kW}$$

$$Q_{AC} = 5.93/3.5$$

$$= 1.69 \text{ TR}$$

From ASHRAE standard 2007 1TR is equal to 400 CFM

#### Power Calculation

To supply 676 CFM blower should run at 890.66 rpm therefore we considered as 900 rpm

#### Blower Capacity

we are assumed that blower of company named "American fan". As per standards power required to run the blower at 900 rpm is 3/4 HP. So power required to run the blower is 559 Watts = 0.559 KW

#### Compressor Capacity

Type of Compressor = Swash Plate Type

Piston = 5 Pistons

Displacement = 117 cc

Compressor oil = Denso 8

Type of pulley = Polygroove

Pressure Range = 1.3MPa (inlet) to 2.7MPa (outlet)

Rated power(25V) = 738 W(2TR)

Therefore power required for 1.69 TR is 738 W = 0.738 KW

So total power required both blower and compressor is 1.297 KW.

**Solar Panel**

Roof area of car (top) = 0.94 m<sup>2</sup>

Due to lack of possibility of ideal angle formation between sun rays and solar panels, panels may work with less effectiveness, so a lower photovoltaic efficiency of 13% is taken for this system design calculations.

Average sunshine received in India = 5.4 kWh/m<sup>2</sup>

Power generated when panel receive whole day sunshine: = 5.4 kWh/m<sup>2</sup> × 0.94m<sup>2</sup> × 0.13 = 0.6598kWh

So power generated by solar panel of 0.94 m<sup>2</sup> is 0.6598KWh Therefore power required to drive the compressor and blower is we need the surface area of nearly 1.2 m<sup>2</sup>. Therefore power generated by solar panel is not sufficient to run the compressor and blower. So design of solar air conditioning for four wheeler does not hold good.

In order to gain such a high power of small surface area of solar panel is solar calls are made up of plasmonic solar cells. In thin-film solar cells, it becomes important to trap the solar energy that is incident on it. Hence, Plasmonic nanoparticles will prove to be effective to increase the efficiency of the solar cells

The structure of the proposed solar cell consist of four ordered layer : an 80-nm SnO<sub>2</sub>:F transparent conductive oxide layer on the front, followed by a 350-nm hydrogenated amorphous silicon (a-Si:H) active layer, afterwards a layer of Al-doped ZnO (ZnO:Al) thin film into which the Ag nanoparticles are regularly deposited, and finally a 120-nm Ag back reflector. by this type there is chance to gain required power<sup>[5]</sup>.

**RESULT**

The heat load obtained are follows

Type of load	Q(W)
Metabolic load	533.5988112
Radiation load	1565.12
Ambient load	87.315
Exhaust load	15.88
Engine load	82.73
Ventilation load	-9909
Ac load	5935.14

The TR obtained by calculating above load is 1.69 TR

Type	Power KW
Blower	0.559
Compressor	0.738
Total power	1.297

Average sunshine received in India = 5.4 kWh/m<sup>2</sup>

Power generated when panel receive whole day sunshine: = 5.4 kWh/m<sup>2</sup> × 0.94m<sup>2</sup> × 0.13 = 0.6598kWh

So power generated by solar panel of 0.94 m<sup>2</sup> is 0.6598KWh

**CONCLUSION**

The top surface area of car is 0.94 m<sup>2</sup>. By this average solar energy produced 0.6598KWh. But energy needed to run the compressor and blower is 1.297 KW. Therefore energy produced is not sufficient to supply 660 CFM of capacity 1.67 TR.

Therefore we cannot increase the dimensions of solar panel as it may damage the near by vehicle on roads or it may be difficult in parking.

So the result designing of solar air conditioning for four wheeler does not hold good. Therefore 1.69 TR = 676 CFM.

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