INNOVATIVE ENERGY TECHNOLOGY SYSTEMS AND ENVIRONMENTAL CONCERNS: A SUSTAINABLE APPROACH
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Measuring Environmental Sustainability through Carbon Footprint

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Abstract

Sustainable development has become a global issue because of the continuous depletion of resources and its management with far-reaching consequences. There is concern everywhere about the sustainability of the present paradigm of progress. Carbon footprint being one of the most important 'climate change' environmental sustainability indicator, is used as an evaluation tool to measure the environmental impact of a purposively selected hosiery unit based in Ludhiana. Quantification of green house gases emitted from sources such as electricity, fuel, chemicals, gas leaks and so forth was found to be 141.4 tCO_2e /month. The results revealed that 83% of the emissions were from the activities going on within the hosiery unit followed by 8% from third party deliveries, 5% of emissions were by employees commuting, 3% from business travels and 2% by the company owned vehicles. Fifty seven percent of the carbon emission were due to consumption of fuel in generators, tumblers, boilers, Liquefied petroleum gas, air heater ,and so forth followed by 33% due to use of electricity and 10% by transport .Negligible amount was emitted through sources such as leak of gases and hotel stay. Dissemination of knowledge regarding carbon footprint was done through the distribution of self designed leaflets. Recommendations in the form of long and short-term strategies to reduce carbon footprint of an organization were also given with the aim to sensitize the mind of the management to follow a low carbon development pathway.

Keywords: Sustainable development, carbon footprint as environment sustainability indicator, emission sources, standards & guidelines, calculation and recommendations.

1. Introduction

"Ecological wisdom does not consist in understanding how to live in accord with nature; it consists in understanding how to get humans to agree on how to live in accord with nature. (Ken Wilber) Tell me how "global sustainable development" for the developed world can mean anything other than to learn to shrink sustainably whilst enabling the rest of the world to grow sustainably?"

—Nadia McLaren (2002) [1]

Since the early 1990s, there have been continuous international efforts to gain consensus on how to tackle global warming. This growing awareness of environmental issues has led to the development of the concept of sustainability, which is based on the interdependence between human societies and the natural environment. Sustainability is about taking what we

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need to live now without jeopardizing the potential for people in the future to meet their needs. It's about living within means of our natural systems and ensuring that our lifestyle doesn't harm other people [2].It is widely regarded as a journey, not a destination [3]. It has three distinct, but interconnected spheres - environmental, economic, and social aspects of our world or "Profit, people, and planet" as shown in Fig. 1. These interrelated spheres supports sustainability through preservation of natural resources, protection of the environment, not harming the economy, and improving or maintaining the quality of life for people [4].

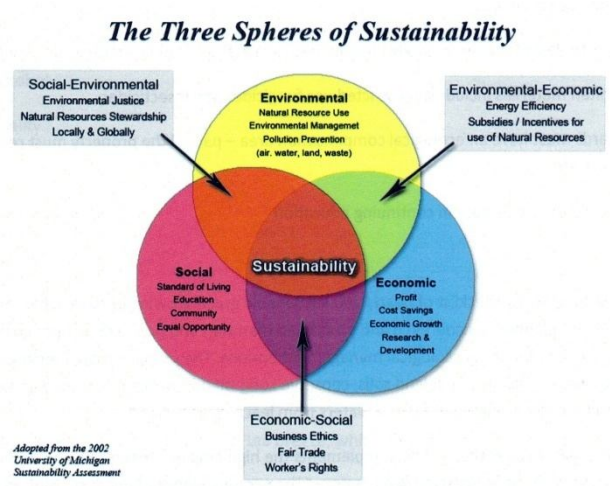

Fig. 1*:* Three spheres of sustainability [5]

Indian Hosiery industry is working towards developing different creative and thoughtful solutions in response to concerns highlighting a credible connection between the consumption of the resources and innovative approaches to replenish the resources, making the world a better place to live. To track the progress down the road to sustainable development, sustainability indicators can be used not only to define, but also to measure, the elements of sustainability in terms of environmental, social and economic systems.

Environmental, social and economic Indicators are often partitioned or integrated in some way to give a means of measuring progress towards or away from sustainability. However, in many instances, the indicators are used to assess performance in the individual dimensions of sustainability. Sometimes indicators from different dimensions are considered in combination to show the positive or negative impact of performance in one dimension on performance in the remaining dimensions. Environmental indicators aims to improve member nations' environmental performance, both collectively and individually in the area of environmental management [5]. 'Carbon emissions' and 'Emissions of Greenhouse Gases' are both important atmospheric and environmental output indicators under 'Climate change sub theme'.

In order to fully capture the dimensions of sustainability, reduced environmental footprint indicator can be used to identify climate impacts and reduce the energy consumption but also provide a calculation base to offset emissions that cannot be reduced. Accurate determination of the current carbon footprint of an organization is important by taking into account the detailed sources of emissions. Assessing carbon footprint helps in better understanding of the limitations of local resources to support social, economic, and environmental systems. Moreover, it also helps to summarize a complex array of environmental indicators into a

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single or small number of values so that they are more useful for decision-making. Fig. 2 shows various footprint categories of sustainability.

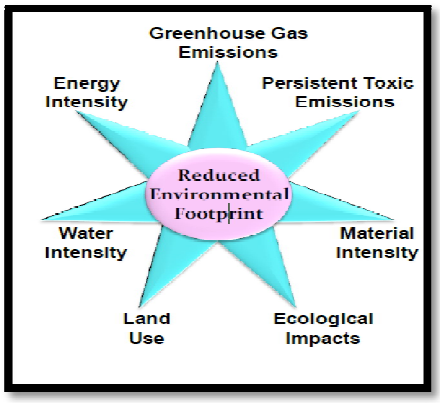

Fig. 2: Footprint category of sustainability [6].

In the words of Andreas Streubig, Director of Environmental and Social Policy, Otto Group, "The Carbon footprint now gives a transparency of the CO_2 emissions generated in the production and use of textiles". It is a measure of the severity of the impact of activities on the environment and particularly on the climate change. It measures the impact by the amount of greenhouse emissions produced through the burning of fossil for electricity, heating and so forth in our everyday lives. Activities that have a large carbon footprint, produce large amounts of greenhouse gases and therefore have a large impact on the environment[7].It is the total set of green house gas emissions caused directly and indirectly by an individual, organization, event or product. Carbon footprint is the total amount of CO_2 and other greenhouse gases emitted over the full life cycle of a process or product. Carbon footprints are typically calculated to include all green house gases and are expressed as CO_2 equivalent measured in kilograms or tonnes [8].

Most countries have acknowledged that sustainability has become a necessity rather than an option given the threat of climate change. The Indian government has also agreed to fully support the reduction of carbon footprint at the Copenhagen Meet on climate change held in December, 2009 aiming to help companies improve their competitiveness and environmental performance by identifying Best Management Practices (BMP). A Chinese proverb says that a journey of thousand miles start with a single step. Similarly the journey of reduction of carbon footprint starts with its measurement.

Keeping the importance of carbon footprint as a tool of measuring sustainability and its impact on the environment in mind, this study was planned with following aims and objectives-

1. To identify the processes contributing to greenhouse gas emissions in hosiery industry of Ludhiana.
2. To assess the impact of the activities of the hosiery unit on environment in terms of sustainability indicator "Carbon footprint".
3. To conduct an awareness drive on the concept of carbon footprint by distributing informatory leaflets in the hosiery units of Ludhiana.
4. To give recommendations regarding the reduction of carbon emissions in the hosiery industry of Ludhiana.

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Limitations of the study were-

1. The study was limited to purposively selected hosiery unit located in Ludhiana thus the findings of the study might not be applicable to the whole industry and the hosiery units in other parts of the country.
2. An attempt has been made to obtain complete data regarding consumption of fuel, electricity etc from the dealing persons, but some information might have been kept hidden by them.

2. Methodology

The study was carried out in three phases starting with understanding the basic concept of sustainability and carbon footprint by attending conferences and workshops in 1st phase. Calculation of carbon footprint of one purposively selected hosiery unit of Ludhiana was conducted in phase 2. Phase 3 included dissemination of information through distribution of leaflets and giving recommendations to reduce carbon footprint.

The selection of a hosiery unit was done on the basis of cooperation offered and the grant of permission to collect detailed information for measuring environment sustainability. Carbon footprint was selected as one of the sustainability indicator after the identification of the corresponding metrics. Calculation criteria and methods were established to acquire the data for this metric to evaluate the impact of the selected hosiery unit on the environment. As assessing and measuring something as broad as sustainability across a large area can be a major challenge, so only one indicator was chosen which was easy to communicate and understand. Moreover, a single indicator does not mean that only one source or one piece of data is used but data from various sources were collected but converted to a single common unit as carbon.

Quantification of green house gases emitted by an organization was done as per the standards of ISO- 14064-1 and guidance of World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD)-Green house gas Protocol (A corporate accounting and reporting standard) . As organizational carbon footprint include an inventory of 6 greenhouse gases identified in the Kyoto Protocol namely carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, per fluorocarbons, and hydro fluorocarbons. Hence, carbon footprint was calculated by multiplying the emissions of each greenhouse gas by their respective 100 year global warming potential. Data from various sources of green house gases emissions were collected for one month and was multiplied with emission factors sourced from Department for Environment, Food and Rural Affairs (DEFRA).All the greenhouse gas emissions other than CO_2 were converted into tonnes CO_2e Carbon foot print formula and emission factors are given in Fig. 3 and Table 1.

Fig. 3: Procedure steps of carbon footprint calculation.

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Table 1: GHG Emissions Conversion Factor.

Fuel	Activity Data Unit	CO_2	N_2O	CH_4	HFC-32	HFC-125	HFC-134A	Emission Factor Unit
Grid Electricity	kWh	0.52114	0.00025	0.00323	**0**	**0**	**0**	kgCO2e per kWh
Diesel	Ltr	2.648	0.0184	0.0012	0	0	0	kg CO2e per Ltr
LPG	Ltr	1.4884	0.0023	0.001	0	0	0	kg CO2e per Ltr
Mobil oil	Tonnes	3171.1	1.9	8.5	0	0	0	kg CO2e per Ltr
Grease	Tonnes	3171.1	1.9	8.5	0	0	0	kg CO2e per Ltr
Fire Extinguisher	Kg	1	0	0	0	0	0	kg CO2/kg
R22	Kg	0	0	0	0	0	0	kg CO2/kg
R407C	Kg	0	0	0	350.98	381.5	793.52	kg CO2/kg
R134A	Kg	0	0	0	0	0	1300	kg CO2/kg

Note. Adapted from Department for Environment, Food and Rural Affairs [DEFRA], 2012[9].

3. Results and Discussions

The study dealt with measuring sustainability of one purposively selected hosiery manufacturing unit of Ludhiana in terms of an environmental indicator that is carbon footprint.

In-depth study of the concept of carbon footprint and sustainability revealed that Carbon footprint is a more recent term for global warming potential and is often used as shorthand for the total set of Green House Gas (GHG)emissions or carbon (usually in tonnes) caused directly and indirectly by an individual, organization, event or product. Carbon means a substance which contributes to greenhouse gases emission and hence global warming, while a footprint is another way of saying the impact that someone or something has on the Earth. Together the two words represent the full impact that a person, business or thing has on the world in terms of climate change. It is possible to calculate carbon footprint of a product, organization, city, state and country.

For calculating the carbon footprint of an organization i.e. hosiery unit of Ludhiana, various sources of emissions were identified and activity data was collected. It was multiplied with respective emission factors and summed up to get the carbon footprint of the hosiery unit. Consumption of electricity, wastes, chemicals, water, fuel consumption in transportation, operations and machines were identified as the main sources of green house gas emissions. The emission sources were further classified under 5 heads that is within the premises, company owned vehicles, commuting, Business Travel and third party shipments. Under 'within premises', data for electricity consumption, fuel consumption in machines and equipments, refrigerant leaks were collected. Data was collected for the month of June, 2013.

The hosiery unit selected for Carbon Footprint calculation was using electricity generated from a Bhakra thermal power plant where coal was used as a means of generating electricity.

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Electricity was required for running of machines and equipments such as in ACs, computers, electric cutters, sewing machines, steam cutters, fusing machines, steam iron sets, fans, lights, machines, waste treatment plant, and so forth. The total electrical units consumed in the month of June,2013 were 62303 KWH which was obtained from the electric bill readings.

Fuels in form of diesel, petrol, grease, and mobile oil were used for working of machines, servicing of machines, generators, tumblers, heaters, chillers, washing of garments, boilers for steam generation, compressors, in kitchen or mess and so forth. Kerosene and wood was not used as a fuel in the unit. The details of the fuel consumption within the premises are shown in Table 2.

Table 2: Summary of Fuel Consumption in various Machines and Equipments within the Premises of the Hosiery Unit.

Type of fuel	Purpose	Capacity	Number	Amount consumed	Units
Diesel	Gen Sets	380 KVA	1	2555	**Ltr**
		125 MVA	1	971	**Ltr**
	Boiler	600Kg	1	252	**Ltr**
		200Kg	1	48	**Ltr**
		50 Kg	1	2284	**Ltr**
	Air Heater	4KW	1	1530	**Ltr**
	Tumbler	10HP	1	1172	**Ltr**
		10HP	1	942	**Ltr**
		10HP	1	463	**Ltr**
LPG	In canteen	19kg.	3	67	Kg
Grease	Lubrication of Machines	Nil	Nil	1.5	Kg
Mobil Oil	Lubrication of Machines	Nil	Nil	18	**Ltr**

Source: Records of Maintenance Department.

Leaks from refrigerators, ACs, fire extinguishers were also included in the calculation of carbon footprint as per the data obtained from maintenance department. There were 10 fire extinguishers of 5 kg and 4 were of 2kg installed in the hosiery unit. But the CO_2 gas was not refilled during June,2013 hence it was not included in the calculation. There were two ACs installed in the unit in the meeting room and managing director's room but the gas used was R22 which is considered non polluting gas, hence it was also not included in the calculation. ACs was also used in the company owned cars especially Swift, Indigo and Wagon R regularly in the month of June. The amount of the R134 A gas consumed in car ACs was found to be negligible that is 0.0042 kg. There were two refrigerators of 150 litres capacity each which also caused negligible leakage of refrigerant gas that is 0.0042 kg in the month of June. Even though the amount was too little to quantify, still the gas loss from refrigerator, cars and unit's AC was included in the quantification of the green house gases.

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Table 3: Summary of the wastes generated (Kg) in the month of June 2013.

Type of Waste	Sources	Consumption(Kg)
Recycled Waste	Cloth pieces	200
	Solid paper	60
	Cardboard	73
	Polysheets	16
	Iron	14
Land filled Waste	Kitchen waste	95
	ETP waste	55

Different processes such as cutting, sewing, and finishing in the hosiery units consumes large quantities of energy, water and different chemicals producing large volumes of wastewater and generating garbage in the form of fabric scraps, pattern papers, cardboard boxes, tapes, fusing rolls, printed papers, sheets, trims, fusing paper, damaged labels, tags, polythene bags, tickets, bar coded stickers, empty thread cones and stickers. In the unit waste such as cloth scraps, solid paper, card paper, poly sheets and iron were segregated, treated and recycled and hence was considered under the category of Recycled waste. Effluent treatment plant sludge produced in the month of June was 55kg and was not poisonous. Kitchen waste and ETP waste were sent to landfill, was considered under the category of land filled waste. Summary of wastes generated is shown in Table 3.

Usually chemicals are included in the calculation of carbon footprint as they are used extensively in stain removal, washing and finishing of the garments further leading to water pollution. But, its amount consumed was also negligible in the unit as washing of garments were outsourced by the unit.

Fuels for transportation in the form of diesel, petrol, and CNG were used in the company owned vehicles for commuting, meetings and goods transport. Table 4 shows the consumption of fuel in the company owned vehicles used in and for carrying out activities in the unit.

Table 4: Summary of Fuel Consumption in Company Owned Vehicles.

Purpose	Mode type	Name of Vehicle	Fuel Type	Number	Amount Consumed inJune,2013 (Ltr)
Commuting of Higher Management people	4-wheeler	Swift	Diesel	1	125
		Indigo	Diesel	1	83
		Wagon R	Diesel	1	63
Local work	2-wheeler	Honda shine	Petrol	1	200
		Pulsar	Petrol	1	34
Transport goods	4-wheeler	Truck	Diesel	1	421

Private and public transport such as van, bicycle, bus, motor bike, and cars were used by the employees for the daily commuting to and fro hosiery unit. Most of the employees lived nearby, hence, came to the unit on foot. The formula used for calculation is given below-

Fuel consumed=No. of Employees x Distance Travelled in Km (to & fro) x No. of working day in a month x amount of fuel consumed in 1 km of distance.

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Table 5: Summary of Fuel Consumption in Vehicles for Commuting.

Mode type	Name of Vehicle	Fuel Type	Number	Amount Consumed in June,2013(Ltr)
2-wheeler	Pulsar	Diesel	1	94
	Bicycle	Nil	32	Nil
4-wheeler	Swift	Diesel	1	125
	Figo	Diesel	1	125
	Innova	Diesel	1	375
	Honda City	Petrol	1	43
	Bus	Diesel	15	1875

Table 5 shows the consumption of fuel in the various modes of road transportation used for commuting to the unit.

Air and road transport was used by senior management staff for business meetings with buyers and suppliers, in search out for latest fashion trends, for taking inspiration from other countries or attend international exhibitions and conferences abroad and in India as shown in Table 6. For the air trip to Barcelona (to & fro), one manager travelled by business class, the distance came out to be 13558 Km (Long Haul). Nine percent uplift factor was added to the total distance, hence the total distance was 14778Km Even though train travel was also used by employees to attend meetings in Delhi; no such trip was undertaken in the month of June.

Table 6: Summary of Fuel Consumption in Air Business Travel.

No. of Persons	Class	Haul	Start place	Destination	Total Distance (Km)	To & fro journey	9% uplift factor	Total Distance (Km)
1	Business class	Long	N. Delhi	Barcelona	6779	13558	109%	14778

Note: Flights one way: Short Haul=Less than 785 km , Medium haul=785 to 3700 km , Long Haul > 3700 km.

The fuel consumption in travelling through taxi during business trips is shown in Table 7. Emissions caused by two day hotel stays were estimated to be 0.088 tCO_2e.

Table 7: Summary of Fuel Consumption in Other Vehicles used during Business Travel.

Vehicles	Start Place	Destination	Fuel Type	Distance (Km) (to & fro	Amount Consumed in June, 2013 (Ltr)
Taxi	Ludhiana	N. Delhi Airport	Diesel	700	44
	Barcelona Airport	Hotel		50	3
	Hotel	Meeting Place		47	3

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Shipment of the finished goods was done through roads, air and sea means for the sending end products to the customers. Table 8 shows the fuel consumption by trucks used for third party deliveries.

Table 8: Summary of Fuel Consumption in Third party Deliveries

Name of Vehicle	Fuel Type	Number	Amount Consumed in June,2013 (LTR) (to & fro)
Truck(Tata 407)	Diesel	1	150
Truck(Tata 407)	Diesel	1	1560
Tempo	Diesel	1	970
Tempo	Diesel	1	400
Tempo	Diesel	1	1000

Carbon footprint of the unit was calculated by multiplying the activity data with the emission factor and it was found to be 141.4 tCO_2 e per month.

Table 9: Distribution of carbon footprint as per emission sources –I

Emission sources I	Carbon Footprint	
	tCO_2 e/ month.	%
Within Premises	117	83
Company owned Vehicle	2	2
Business Travels	4	3
Commuting	7	5
Third party deliveries	11	8

Distribution of carbon footprint as shown in Table 9 and Fig. 4 pie diagram clearly depicts that 83% of the emissions were from the activities going on in the hosiery unit such as ones which consumed electricity, fuel in machines, equipments, and refrigerant leaks were collected, followed by 8% of third party deliveries, 5% by commuting, 3% from business travels and 2% by vehicles. It was revealed that majority of emissions were from the activities carried out within premises of the hosiery unit.

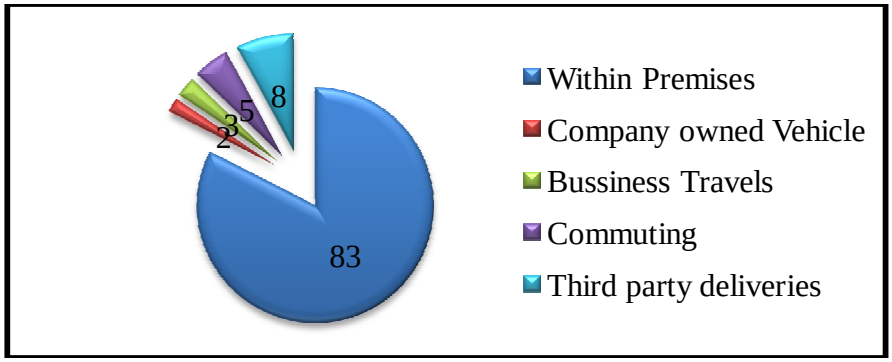

Fig. 4: Pie diagram showing distribution of carbon footprint as per emission sources –I

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Table 10: Distribution of Carbon Footprint as Per Emission Sources –II

Emissions sources II	Carbon Footprint	
	t CO_2 e/ Month.	%
Transport	23.8	10
Machines	85	57
Leak of gases	0	0
Hotel stay	0.1	0.2
Electricity consumption	33	33

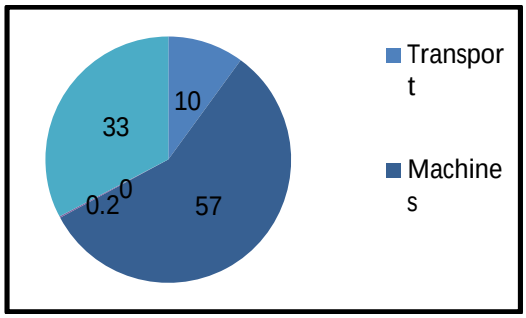

Fig. 5: Pie diagram showing distribution of carbon footprint as per emission sources -II

Table 10 and Fig. 5 revealed that 57% of the carbon emission were due to consumption of fuel in generators, tumblers, boilers, liquefied petroleum gas(LPG), air heater ,and so forth followed by 33% due to use of electricity,10% by transport. Negligible amount was emitted through sources such as leak of gases and hotel stay. It was highlighted that majority of the emission was taking place through fuel consumption.

In 3rd phase, Information regarding the concept of carbon foot print and its importance was disseminated through distribution of a designed leaflet including all relevant information on carbon footprint.

Various recommendations suggested by the researcher to reduce the carbon footprint included forming eco friendly company-wide travel policy, wide use of internet and online facilities, use of natural organic and sustainable fibers, efficient energy practices, use of eco friendly materials, and use of local raw material under short term strategies. Long term strategies included use of renewable energies, promotion of alternative or non-conventional fuels technology, fuel substitution, adoption of management systems and programmes, use of energy efficient products, use of energy efficient products, reused and recycled of waste, and recycling of fibres. Combined short and long term strategies included conducting training workshops and seminars, tree plantation programmes, company should be made carbon neutral by reducing, development of green buildings, and designing of clean development mechanism (CDM). These recommendations were highly appreciated by the management of the hosiery unit. They were highly motivated to identify the sources of carbon emissions and quantify them.

4. Conclusion

Promoting green manufacturing in the hosiery industry which is a part of a continuous improvement strategy will help manufacturers improve their productivity, profitability and

competitiveness. Carbon footprint accounting is the only one step of the carbon reduction challenge. Once accounted, the real value is in the degree of improvements that can be made and their ability to devise a better carbon-reduced pathway for the future and transform themselves into a climate responsive organization.

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