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The energy consumption and environmental impacts of a color TV set in China

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A B S T R A C T

The present study analyses the different processes followed during color TV set production along with the energy consumption and the environment emissions in each stage. The purpose is to identify "hot-spots", i.e. parts of the life cycle important to the total environmental impact. The analysis is performed using life cycle assessment (LCA) methodology, which is a method used to identify and quantify in the environmental performance of a process or a product from "cradle to grave". LCA methodology provides a quantitative basis for assessing potential improvements in the environmental performance of a system throughout the life cycle. The system investigated includes the production of manufacturing materials, transport of manufacturing materials, color TV set manufacturing, transport of color TV sets, use of color TV sets, discarding color TV sets and partial plastic waste energy utilization. The environmental burdens that arise from color TV sets are mainly due to air emissions derived from fossil fuel utilization.

1. Introduction

The flowering economy in China has caused a rapidly rising demand for TV sets. Since 1994, China has become the largest TV set producer all over the world. In 2001 China's color TV sales accounted for 29.6% of total global sales and China has produced 41.5 million TV sets in that year. Statistics show that the TV penetration rate has reached 99.1% in urban families; there are 139.2 TV sets for every 100 families. By the end of 1998, every 100 rural families have owned only 32.67 color TV sets. The figure has grown at an average annual rate of 27% in the last 10 years, and the market has entered into a highly growing stage. At present, about 350 million TV sets are used in the society, in accordance with the general TV set lifespan of 10–15 years, it has entered the peak period of discarding TV sets from 2003. Since then, about 10 million TV sets have been discarded every year [1]. The environmental problems of TV sets is worthy of in-depth study.

2. Methodology

The Society of Environmental Toxicology and Chemistry [2] is generally credited for the current LCA methodological framework. Recent standards by the International Organization for Standardization [3] have further formalized LCA. It defines life cycle assessment as a way to study the environmental aspects and potential impacts throughout a product's life from raw material acquisition through production, use and disposal. Life cycle inventory (LCI) analysis is the phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a given product system throughout its life cycle.

This paper uses the methodology of LCA to analyze extraction and production of raw materials, products' manufacturing, use and disposal after they are used.

2.1. Definition of goal and scope

The first phase of life cycle assessment is the goal and scope definition. The goal of this study is to trace a color TV set eco-profile that synthesizes the main energy and environmental impacts related to the whole life cycle. To fulfill this purpose, life cycle inventory analysis, including air emissions and energy requirement, was carried out for the color TV set. A traditional inventory quantifies 3 categories of environmental releases or emissions: atmospheric emissions, waterborne waste, and solid waste. This study examines atmospheric emissions such as CO_2, SO_x, waterborne waste such as BOD and COD, and solid waste.

A functional unit is a measure of the performance of the functional outputs of the product system. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results. The functional unit of this system is 10,000 general color TV sets that are 25 inches diagonally and 30 kg in mass [4].

2.2. Product system description

A product system is a collection of unit processes by flows of intermediate products which perform 1 or more defined functions [5].

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The life cycle of a color TV set includes the production and transportation of manufacturing materials and manufacturing, transportation, use and disposal of color TV sets, and partial plastic waste energy utilization. Fig. 1 shows the product system in detail.

Table 1 shows the major material composition of 10,000 TV sets by weight of components. It can be seen that glass is the main component (51 wt %), followed by steel (12 wt %), copper (8 wt %), aluminum (2 wt %), polyethylene (PE) (1.0 wt %), polyvinyl chloride (PVC) (3.5 wt %), polystyrene (PS) (6.0 wt %), circuit board (3 wt %) and others (3 wt %) [4]. In this study, only 7 species of raw materials are considered, they are glass, steel, copper, aluminum, PE, PVC and PS.

We set some general assumptions for the product system:

- The expected lifetime of a color TV set is 10 years;
- The electricity used is recalculated to primary energy, which is based on 100% coal fuels because of the fact that China's electricity is mainly from coal. It consumes 0.4 kg coal to generate 1 kWh of electricity and will release 0.05 kg dust, 1 kg CO_2, 0.005 kg NO_x, 0.008 kg SO_x into the environment [6]. The data about electricity in the form of energy will be recalculated to coal consumption and the releases from coal combustion to generate electricity will be added to the related environmental releases. The coal consumption and its releases for electricity production can be found in Table 2 in which processes 1–7 stand for 7 major processes, respectively, in color TV set life cycle. The conversion relationship between electricity and its coal consumption is as follows:

$$11,840\ \text{kJ (electricity)} \sim 1\ \text{kWh (electricity)} \sim 0.4\ \text{kg (coal)} \sim 8,373.6\ \text{kJ (coal)}$$

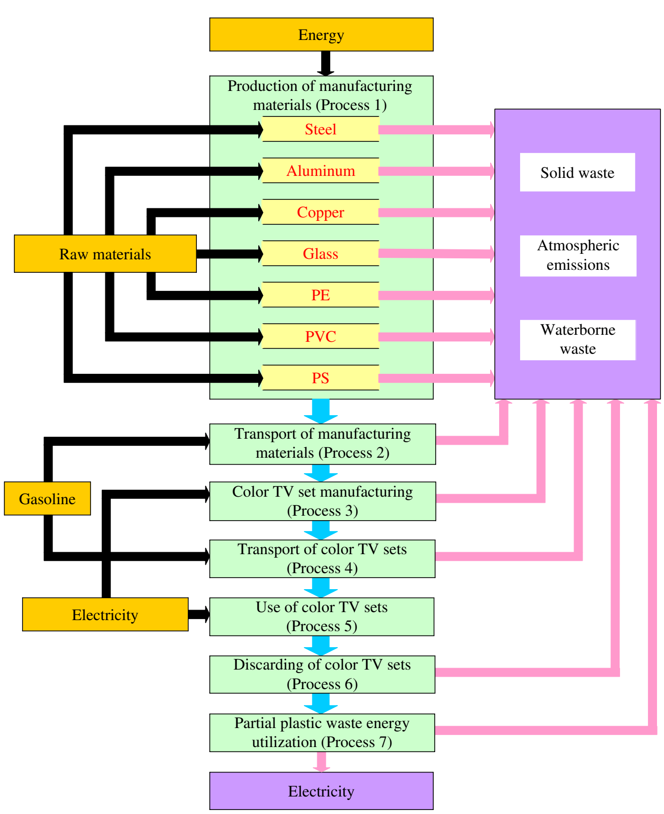

Fig. 1. A simplified life cycle of color TV sets, indicating the system boundary.

Table 1
Material composition of 10,000 color TV sets

Materials	Total/kg
Glass	1,53,000
Steel	36,000
Copper	24,000
Aluminum	6000
Polyethylene (PE)	3000
Polyvinyl chloride (PVC)	10,500
Polystyrene (PS)	18,000

- The unit net calorific value of electricity and coal can be found in Table 18. The coal consumption used to generate electricity is defined as "coal (electricity)".
- Partial plastic waste of TV sets will be utilized as energy and other materials are not reclaimed.
- The unsure-type category of energy in this paper is considered as coal.
- SO_x is treated as SO_2.
- "N" is a waterborne waste emission related to the nutrient enrichment impact and only exists in "NH_4^+" during steel production.
- All solid waste emitted during each process is added up as "Bulk waste", which will be collected and buried.
- Dust and fumes emitted to atmosphere are considered as soot and ashes, during each process.

2.3. Unit processes

Product systems are subdivided into a set of unit processes. Unit processes are linked to one another by flows of intermediate products and waste for treatment, to other product system by product flows, and to the environment by elementary flows. Fig. 1 shows the detailed system flow diagram for color TV sets. According to the method of life cycle inventory, the product system is subdivided into 7 unit processes, which are described as the following.

(1) Production of manufacturing materials (defined as process 1).
In this unit process, it includes the production of steel, aluminum, copper, glass, PE, PVC and PS.
Based on site investigation, we propose the assumption for this unit process:
- The density of fumes in standard conditions during the process of copper production is 1.293 kg/m^3, equal to air's. So 3,84,000 Nm^3 fumes' mass is 4,96,512 kg (3,84,000 × 1.293).
- The data for glass production are the same as for flat glass.
- The data for PS production are the same as for PS box.

(2) Transport of manufacturing materials (defined as process 2).
Regarding this unit process, main assumptions are as follows:
- Only the 7 major manufacturing materials are considered.
- The average transport distance was assumed to be 300 km.
- The manufacturing materials are transported to the TV set manufacturer by truck (carrying capacity: 10 tonne), so the total distance for transporting 2,50,500 kg manufacturing materials is 7500 km, as 25 truckloads (250.5 t ÷ 10 t) times as 300 km.
- Trucks consume gasoline only.
- The unit gasoline consumption is 0.07 L/(t·km).
- The density of gasoline is 0.73 g/cm^3.

So it consumes 1,31,512.5 L (250.5 × 7500 × 0.07), considered equivalent to 96,004.125 kg gasoline, to transport 2,50,500 kg

Table 2
The coal consumption and releases for electricity production

Process		Electricity consumption /MJ	/kWh	Coal consumption /MJ	Dust /kg	CO_2 /kg	NO_x /kg	SO_x /kg
1	Steel	5,50,080	46,459.46	3,89,033	2322.973	46,459.459	232.297	371.676
	Aluminum	11,16,109	94,266	7,89,346	4713.3	94,266	471.33	754.128
	Copper	3,72,000	31,418.92	2,63,090	1570.946	31,418.919	157.095	251.351
	Glass	19,77,455	1,67,014.8	13,98,515	8350.74	1,67,014.8	835.074	1336.118
	PE	0	0	0	0	0	0	0
	PVC	0	0	0	0	0	0	0
	PS	2,71,728	22,950	1,92,174	1147.5	22,950	114.75	183.6
2		0	0	0	0	0	0	0
3		9,92,310.4	83,810	7,01,791	4190.5	83,810	419.05	670.48
4		0	0	0	0	0	0	0
5		3,40,99,200	28,80,000	2,41,15,968	1,44,000	28,80,000	14,400	23,040
6		0	0	0	0	0	0	0
7		0	0	0	0	0	0	0

manufacturing materials to TV set manufactory and releases 64.5 kg CO, 21 kg NO_x, 7.5 kg HC, 1275 kg CO_2 to environment according to main airborne emissions of an internal-combustion engine shown in Table 3.

(3) Color TV set manufacturing (defined as process 3).

Based on site investigation, we propose some of the following assumptions for this unit process:

- Thirty kilograms of color TV sets' manufacturing data in this paper are be equal to 32 kg color TV sets' mentioned in Ref. [1];
- The emissions and electricity consumption in this process are from Ref. [1];
- There is no color TV set manufacturing materials' mass loss in this process.

(4) Transport of color TV sets (defined as process 4)

- The transport of 7 major manufacturing materials replaces the transport of color TV sets because this paper is on the assumption that the 7 major manufacturing materials make up of a color TV set.
- The average transport distance is 300 km.
- Manufacturing materials are transported from manufacturing factory to market by truck (10 tonne), so the total distance of transporting 2,50,500 kg manufacturing materials is 7500 km (25 trips at as 300 km per trip).
- Trucks consume gasoline only.
- The unit gasoline consumption is 0.07 L/(t·km).
- The density of gasoline is 0.73 g/cm^3.

So it consumes 96,004.125 kg gasoline to transport materials from manufacturing factory to market and releases 64.5 kg CO, 21 kg NO_x, 7.5 kg HC, 1275 kg CO_2 to environment.

(5) Use of color TV sets (defined as process 5)

- The color TV set rated power is 0.12 kW and each color TV set works 8 hours every day, 300 days every year. So 28,80,000 kWh of electricity is consumed by 10,000 color TV sets in 10 years ($0.12 \times 8 \times 300 \times 10{,}000$).

(6) Discarding color TV sets (defined as process 6)

- Only the 7 major materials used to manufacture a color TV set were considered in the discard phase.
- It is assumed that the collection ratio for the discarded TV sets is 50%. The discarded TV sets are then manually disassembled, and their parts are separated for recycling purpose [4].
- It is also assumed that the separation process, which takes advantage of differences in specific gravity [4], results in recovering 100% of plastic (includes PE, PVC and PS) derived from the discarded color TV sets which have been collected. Finally, plastic waste is incinerated for electricity production.
- Other 4 major materials (includes glass, steel, copper and aluminum) cannot be efficiently recovered and remanufactured to return for human utilization.

So 15,750 kg plastic waste can be collected for energy utilization in process 6.

(7) Partial plastic waste energy utilization (defined as process 7)

- Plastic waste (15,750 kg) will be set into an internal-combustion turbine combined cycle generator group to generate electricity.
- The electricity used in this process can be provided by the internal-combustion turbine combined cycle generator group itself. So it doesn't consume additional energy and can generate 34,453.125 kWh of electricity in this unit process.

Table 3
The emissions in gasoline combustion [7]

Fuel type	CO	NO_x	HC	CO_2
Gas (g/km)	8.6	2.8	1.0	170

2.4. Data collection and data quality

A large amount of data, such as data related to energy consumption, atmospheric emissions, waterborne waste, etc., during production and transportation of color TV set manufacturing

Table 4
Data source

Process		Item	Data source
Process 1	Steel	Energy consumption	Ref. [8]
	Aluminum	Atmospheric emissions	Ref. [9]
	Copper	Waterborne waste	Ref. [10]
	Glass	Solid waste	Ref. [11]
	PE		Ref. [12]
	PVC		Ref. [12]
	PS		Ref. [13]
Process 2		Unit gas consumption Main airborne emissions of an internal-combustion engine	Ref. [7]
Process 3		Electricity consumption Solid waste	Ref. [1]
Process 4		Unit gas consumption Main airborne emissions of internal-combustion engine	Ref. [7]
Process 5		Electricity consumption	Assumption
Process 6		Solid waste	Calculation
Process 7		Solid waste Atmospheric emissions	Ref. [1]

Table 5
Inventory results for energy consumption, emissions, waste from 36,000 kg steel production

Fuels/MJ	Coal (electricity)	3,89,033
	Fuel oil	1,21,320
	Coal	13,67,640
Atmospheric emissions/kg	Dust	3942.973
	CO	3960
	CO_2	3,41,659.46
	SO_x	2207.676
	NO_x	808.297
	Hydrocarbon	68.4
	CH_4	648.288
	H_2S	3.132
	HCl	31.464
Waterborne waste/kg	Suspended substance	4339.44
	NH_4^+	35.64
	COD	10.152
	BOD	0.18
	Phenylic acid	0.18
	Na^+	13.68
Solid waste/kg	Slag	143,280
	Mixed solid waste	31,320
	Ash	10,620

materials and manufacturing, transportation, use and disposal of color TV sets, part plastic waste energy utilization and so forth, are obtained. The data are reviewed and verified, based on the best knowledge available in China.

Most data applied in production of steel, glass, PE, PVC and PS are cited from some Chinese references, which are collected by some authors from industry yearbooks and some dominating corporations in China. So these data can represent current industrial levels in China ultimately. The data of aluminum and copper production are impossible to be collected perfectly in China, so they are cited from some international institutes about interrelated metals in some advanced countries, which may be quite different from the reality in China, and therefore detailed discussion for this difference may be important. Because the control for the environment and resource use in these countries is advanced, the relative environment releases are quite lower than in China. Therefore, the environmental releases and shown in the present study may be better than the reality. With the development of technology in China, the difference may become smaller and smaller (Table 4).

Table 6
Inventory results for energy consumption, emissions, waste from 6000 kg aluminum production

Fuels	Coal	1116 kg	23362 MJ
	Diesel oil	78.0 kg	3331 MJ
	Heavy oil	1428 kg	59788 MJ
	Natural gas	1848 m^3	65767 MJ
	Coal (Electricity)		7,89,346 MJ
Atmospheric emissions/kg	Fluoride gaseous (as F)		3.42
	Fluoride particulate (as F)		3.0
	Particulates		101.4
	CO_2		94,266
	NO_x (as NO_2)		488.13
	SO_2		902.328
	Total PAH		0.9
	BaP (Benzo-a-Pyrene)		0.031
	CF_4		1.32
	C_2F_6		0.126
	HCl (Hydrogen chloride)		0.402
	Mercury		0.0012
	Dust		4713.3
Waterborne waste	Fresh water		80.4 m^3
	Sea water		165 m^3
	Fluoride (as F)		1.2 kg
	Oil/grease		0.9 kg
	PAH (6 Borneff components)		0.023 kg
	Suspended solids		9.96 kg
	Mercury		0.0108 kg
Solid waste/kg	Bauxite residue (red mud)		11,430
	Carbon waste		42.0
	Dross-landfill		46.2
	Filter dust-landfill		2.4
	Other landfill wastes		4572
	Refractory waste-landfill		26.4
	Scrubber sludges		87
	SPL-landfill		103.8
	Waste alumina		28.2

Table 7
Inventory results for energy consumption, emissions, waste from 24,000 kg copper production

Fuels/MJ	Coal	1,51,200
	Coal (electricity)	3,72,000
Atmospheric emissions/kg	Fumes	4,96,512
	Dust	1581.146
	CO_2	64,778.919
	SO_2	365.351
	NO_x	251.415
	CO	38.88
	HC	25.56
Waterborne waste/m^3		24
Solid waste/kg	Acid mud	24
	Arsenic deposit	48
	Ash	720
	Gypsum	240

3. Inventory analysis

Detailed data of the energy inputs and emission outputs of the production system are presented in Tables 5–17.

4. Energy consumption

The net calorific values of different energy resources can be found in Table 18 to convert mass modality into energy modality, for a convenient and standard compare and calculation, in the same unit "MJ".

Partial data of the net calorific value of different energy can be found at the websites www.ntem.com.cn/hjtj/gxckxs.doc and http://stjmj.gov.cn/01/ggwj/W06163-3.doc. Regarding this unit process, main assumptions are as follows:

- The net calorific value of light oil used in PS production is equal to fuel oil because of data lack.
- The steam used in PS production is ignored because of lack of data.
- "Electricity and other" in the form of energy during copper production will be considered as electricity only.

Table 8
Inventory results for energy consumption, emissions, waste from 1,53,000 kg glass production

Fuels	Coal (electricity)		13,98,515 MJ
	Coal	66,677.4 kg	13,95,825 MJ
	Heavy oil	38,035.8 kg	15,92,483 MJ
Atmospheric emissions/kg	CO_2		1,67,282.856
	SO_2		2102.954
	NO_x		1130.67
	CO		41.31
	Dust		8568
Waterborne waste/kg	COD		76.194
	SS		709.92
	Oil		14.382
Solid waste/kg			1839.06

Table 9
Inventory results for energy consumption, emissions, waste from 3000 kg PE production

Fuels/MJ	Coal	97,640
Atmospheric emissions/kg	CO_2	19,225.5
	SO_2	127.59
	NO_x	0.516
	C_2H_4	6.051
	CH_4	39
Waterborne waste/kg		45,669
Solid waste/kg		1467.81

Table 10
Inventory results for energy consumption, emissions, waste from 10,500 kg PVC production

Fuels/MJ	Coal	5,87,402
Atmospheric emissions/kg	CO_2	91,230.248
	SO_2	778.89
	NO_x	1.806
	EDC	51.77
	CO	10.82
	VCM	3.57
	PVC	0.105
	CH_4	136.5
	Cl_2	0.001
Waterborne waste	Waste water	3,89,791.5
Solid waste		12,425.175

Table 11
Inventory results for energy consumption, emissions, waste from 18,000 kg PS production

Fuels	Heavy oil	7160 kg	2,99,775 MJ
	Light oil	1964 kg	82,229 MJ
	Coal (electricity)		1,92,174 MJ
Atmospheric emissions/kg	CO_2		84,313.636
	NO_x		278.386
	SO_x		510.873
	Dust		1147.5
Solid waste/kg			793.636

Table 12
Inventory results for energy consumption, emissions, waste from transport of color TV set manufacturing materials

Fuels	Gasoline	96,004.125 kg	41,40,082 MJ
Atmospheric emissions/kg	CO_2		1275
	NO_x		21
	CO		64.5
	HC		7.5

Table 13
Inventory results for energy consumption, emissions, waste from color TV sets manufacturing

Fuels/MJ	Coal (electricity)	701,791
Atmospheric emissions/kg	CO_2	4,48,363.048
	SO_2	2710.29
	NO_x	2995.288
	Dust	4190.5
Solid waste		28,028.048

Table 14
Inventory results for energy consumption, emissions, waste from transport of color TV sets

Fuels	Gasoline	96,004.125 kg	41,40,082 MJ
Atmospheric emissions/kg	CO_2		1275
	NO_x		21
	CO		64.5
	HC		7.5

Table 15
Inventory results for energy consumption, emissions, waste from use of color TV sets

Fuels/MJ	Coal (electricity)	2,41,15,968
Atmospheric emissions/kg	CO_2	28,80,000
	NO_x	14,400
	SO_x	23,040
	Dust	1,44,000

Table 16
Inventory results for energy consumption, emissions, waste from discarding color TV sets

Solid waste/kg	Glass	1,53,000
	Steel	36,000
	Copper	24,000
	Aluminum	6000
	Plastics	15,750

Table 17
Inventory results for energy consumption, emissions, waste from part plastic waste energy utilization

Waterborne waste/kg	CO_2	19,045.34
	SO_2	69.196
	NO_x	450.786
Solid waste/kg	Ash residue	4173.75
	Carbon	3118.442

The contribution in this impact category is measured in MJ. Distribution of energy source in the different unit processes are shown in Table 19.

It shows that process 5 is the largest energy consuming process, which consumes 57.30% energy in total. Followed by process 1 (21.36%), process 2 (9.84%), process 4 (9.84%) and process 3 (1.67%). The use of energy derived from coal (electricity) is 2,79,58,827 MJ, accounted for 66.43% in the total energy consumption (4,20,87,421 MJ). Followed by gasoline (19.67%), coal (8.61%), diesel oil (3.79%), heavy oil (0.85%), fuel oil (0.29%), light oil (0.20%) and natural gas (0.16%).

The result of distribution of energy resource categories in the different processes of a color TV set is presented in Fig. 2, which shows that process 1 consumes most energy resource categories, process 5 consumes most coal for electricity production and process 2 and process 3 consume half gasoline, respectively.

5. Environmental impacts

For life cycle assessment to be able to support decisions with respect to product solutions, the data obtained in the inventory must be interpreted to show which of the environmental

Table 18
The net calorific value of different energy

Energy	Net Calorific Value
Coal	20,934 kJ/kg
Crude oil	41,868 kJ/kg
Fuel oil	41,868 kJ/kg
Gasoline	43,124 kJ/kg
Diesel oil	43,124 kJ/kg
Heavy oil	41,868 kJ/kg
Light oil	41,868 kJ/kg
Natural gas	35,588 kJ/m^3
Electricity	11,840 kJ/kWh

Table 19
Distribution of energy source in the different unit processes of color TV sets (Unit: MJ)

Energy Source		Coal(Electricity)	Fuel Oil	Coal	Diesel Oil	Heavy Oil	Natural Gas	Light Oil	Gasoline
Process 1	Steel	3,89,033	1,21,320	13,67,640	0	0	0	0	0
	Aluminum	7,89,346	0	23,362	3331	59,787	65,766	0	0
	Copper	3,72,000	0	1,51,200	0	0	0	0	0
	Glass	13,98,515	0	13,95,825	15,92,483	0	0	0	0
	PE	0	0	97,640	0	0	0	0	0
	PVC	0	0	5,87,402	0	0	0	0	0
	PS	1,92,174	0	0	0	2,99,775	0	82,229	0
	Total	31,41,068	1,21,320	36,23,069	15,95,814	3,59,562	65,766	82,899	0
Process 2		0	0	0	0	0	0	0	41,40,082
Process 3		7,01,791	0	0	0	0	0	0	0
Process 4		0	0	0	0	0	0	0	4,140,082
Process 5		2,41,15,968	0	0	0	0	0	0	0
Process 6		0	0	0	0	0	0	0	0
Process 7		0	0	0	0	0	0	0	0
Total		2,79,58,827	1,21,320	36,23,069	15,95,814	3,59,562	65,766	82,899	82,80,164

exchanges are significant, and how great their contributions are compared to each other, so as to help to examine and evaluate the environmental impacts.

In the *EDIP* method [14] the interpretation of the inventory is done by 3 steps:

(1) Characterization—how much do the emissions contribute to the various types of environmental impacts?
(2) Normalization—how great are the potentials for impacts on the environment relative to the impacts from the society's activities as a whole?
(3) Weighting—which of the environmental impacts are the most important?

In the characterization step, it is determined how much the emissions associated with the product contribute to the various types of environmental impacts (e.g. global warming, acidification, etc.). For example, all emissions that contribute to global warming are expressed in CO_2-equivalents. The characterization is based on properties of the emitted species, and characterization factors available in the literature are globally valid.

$$\mathrm{EP}(j) = Q_i \cdot \mathrm{EF}(j)_i \tag{1}$$

where EP(j) is the environmental impact potential for impact category j, Q_i is the amount of emitted substance i, and $\mathrm{EF}(j)_i$ is an equivalency factor for compound i's contribution to environmental impact category j.

In the normalization step, contributions from the product to each type of environmental impact is divided by the expected lifetime of the product and the yearly contribution to each impact from an average person in 1 year.

$$\mathrm{NP}(j) = \frac{\mathrm{EP}(j)}{T \cdot \mathrm{ER}(j)} \tag{2}$$

where NP(j) is the normalized environmental impact potential for impact category j, T is the expected lifetime of the product in years, ER(j) is the normalization reference for impact category j and thus, as a result of the normalization, all environmental impacts from the product are expressed as a fraction of an average person yearly contribution to the impact, and the unit is milliperson equivalents, mPE. The normalization references show how much an average person contributes to each kind of environmental impact.

Some environmental impacts may be considered more important than others, and the purpose of the weighting step is to weight the results obtained in the normalization step in accordance with the users concern with the studied environmental impacts. The rating of concern with environmental impacts is of course subjective, several individual sets of weighting factors can be established, based on different means.

$$\mathrm{WP}(j) = \mathrm{WF}(j) \cdot \mathrm{NP}(j) \tag{3}$$

where WP(j) is the weighted environmental potential for impact category j and WF(j) a weighting factor for environmental impacts category j.

Politically determined environmental targets have been selected as basis for weighting by the *EDIP* method, and year 2000 has been chosen as the common target year. The result of the weighting is a "weighted environmental impact potential", with the unit milliperson equivalents, targeted, $\mathrm{mPE}_{\mathrm{T2000}}$.

The weighting factors indicate how important various environmental impacts are considered in China. A weighting factor of 1 indicates that status in 1990 will be maintained in year 2000 according to the national plants. Weighting factors smaller than 1

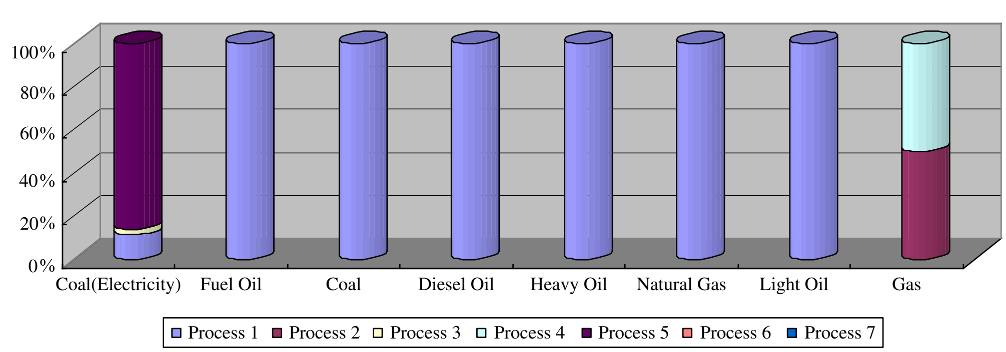

Fig. 2. Distribution of energy resources in the different processes of a color TV set.

Table 20
Categories of environmental impacts

Environmental impacts	Global warming (GW)	Global
	Acidification (AC)	Regional
	Nutrient enrichment (NE)	Regional
	Photochemical ozone formation (PO)	Regional
	Bulk waste (BW)	Local
	Slag and ashes (SA)	Local

indicate how much the environmental impact will grow between 1990 and 2000 whereas weighing factors larger than 1 indicate how much the environmental impact will be reduced between 1990 and 2000. The normalization references and weighting factor are specific for different countries.

The normalization reference $ER(j)_{90}$ for impact category j based on emissions in 1990 can be determined by the following equation:

$$ER(j)_{90} = \frac{EP(j)_{90}}{Pop_{90}} \quad (4)$$

where $EP(j)_{90}$ is determined by characterization of the total mass of emissions for the area in question in 1990. Pop_{90} is the total population for the area in question in 1990. $Q(j)_{i90}$ contributing to the specific impact category (j) through multiplication by an equivalency factor $EF(j)$ is specific for each emitted substance (i).

$$EP(j)_{90} = \sum EP(j)_{90} = \sum \left(Q(j)_{i,90} \cdot EF(j)_i \right) \quad (5)$$

For the global environmental impacts (global warming and stratospheric ozone formation), the normalization references are globally valid and extracted directly from literature [14]. For the regional and local impacts, the normalization references are calculated based on Chinese data [15].

The general Chinese targets for environmental emissions have been selected as basis for weighting in this study, and year 2000 has been chosen as the target year. The weighting factor $WF(j)$ for the environmental impact category (j) is thus defined as the normalization reference ($ER(j)_{90}$) divided by society's target contribution in the year 2000 based on political reduction plans, $ER(j)_{T2000}$.

$$WF(j) = \frac{ER(j)_{90}}{ER(j)_{T2000}} \quad (6)$$

The 2000 target reduction plans for all impact categories in China are generally concerned with single substances or groups of substances and not with the environmental impacts as such. Due to relatively low level of industrialization in China and the significant growth in all sectors in recent years, the Chinese targets aiming at limiting the growth of pollution (growth plans) are considered as useful indicators of the Chinese environmental concern. The determination of weighting factors has been based on general Chinese reduction targets and the present factors are valid for the whole country [15].

Chinese normalization references "$EP(j)_{90}$" and weighting factors "$WF(j)$" have been reported by Nielsen and Yang [15], and the weighted environmental potential in China can be calculated by the following equation:

$$WP(j) = \frac{EP(j)_{90}}{T \cdot ER(j)_{90}} \cdot WF(j) \quad (7)$$

5.1. Characterization

The emissions of the system have been grouped into impacts (characterization step) based on the method of Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences [8]. This method leads to a single score. In this paper, 6 impact categories were considered: global warming, acidification, nutrient enrichment, photochemical ozone formation, bulk waste, and soot and ashes. The impact categories considered are shown in Table 20.

5.1.1. Global warming

This impact category refers to the change in earth's climate due to the build-up of chemicals that trap heat from the sunlight. Substances such as CO_2, CH_4, NO_x, CFC-11, CFC-12, CFC-13, CCl_4, $CHCl_3$ and CO all contribute to global warming of the environment [15].

Table 21 shows the results of global warming characterizations of the different processes in color TV set life cycle. The values are expressed in grams of equivalent CO_2 per kg. The emissions related to global warming in the LCI analyzed are CO_2, CH_4, NO_x and CO, which have the corresponding global warming potentials of 1, 25, 320 and 2 respectively [8].

The total influence of CH_4 and CO on the global warming effect is very small in comparison to the contribution of NO_x, accounted for 61.13%. Followed by CO_2 (38.60%), this is because, despite having a lower characterization factor 1, the amount of CO_2 emitted is much higher than the other gases.

The global warming emissions of different processes in color TV set life cycle are presented in Fig. 3, which shows that process 5 emits highest amount of emissions (68.29%), followed by process 1 (20.54%), process 3 (10.65%), process 7 (0.46%), process 2 (0.03%) and process 4 (0.03%). Process 6 doesn't emit any global warming emissions.

Table 21
The emissions related to global warming and global warming characterizations

Process		CO_2/kg	CH_4/kg	NO_x/kg	CO/kg	kg CO_2-eq
Process 1	Steel	3,41,659.46	648.288	808.297	3960	6,24,441.7
	Aluminum	94,266	0	488.13	0	2,50,467.6
	Copper	64,778.919	0	251.415	38.88	1,45,309.479
	Glass	1,67,282.856	0	1130.67	41.31	5,29,179.876
	PE	1,9225.5	39	0.516	0	20,365.62
	PVC	91,230.248	136.5	1.806	10.815	95,242.298
	PS	84,313.636	0	278.386	0	1,73,397.156
	Total	8,62,756.619	823.788	2959.22	4051.005	18,38,403.729
Process 2		1275	0	21	64.5	8124
Process 3		4,48,386.048	0	2995.288	0	14,06,878.208
Process 4		1275	0	21	64.5	8124
Process 5		28,80,000	0	14,400	0	74,88,000
Process 6		0	0	0	0	0
Process 7		19,045.34	0	450.786	0	1,63,296.86
Total		42,12,738.007	823.788	20,847.294	4180.005	1,09,12,826.8

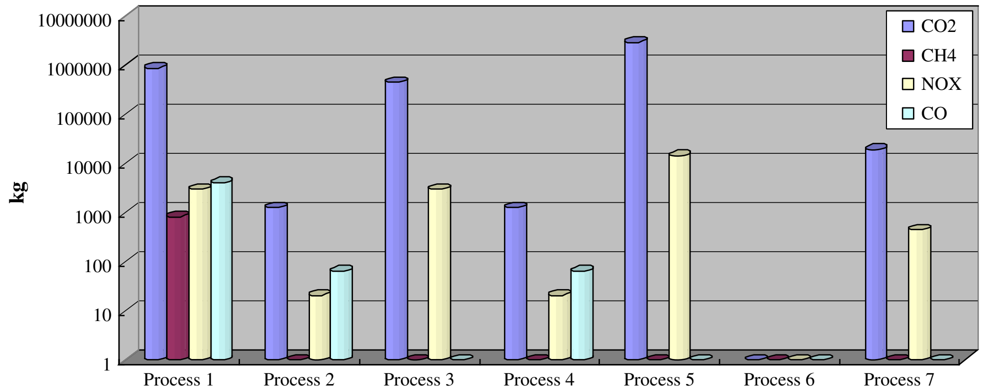

Fig. 3. The global warming emissions of different processes in color TV set life cycle.

Production of steel emits 39.87% of global warming emissions, followed by glass (19.35%), aluminum (10.88%), PVC (10.50%), PS (9.72%), copper (7.47%) and PE (2.21%).

5.1.2. Acidification

Substances such as SO_x, NO_x, NH_3, H_3PO_4, HF, H_2S, HCl and organic acids all contribute to acidification of the environment. In the Chinese inventory the main contributions of SO_x, NO_x and NH_3 are addressed [15]. Acidification includes the processes that increase the acidity of water and soil systems by releasing SO_2 or equivalents.

Table 22 shows the results of acidification characterizations of the different processes in color TV set life cycle. The values are expressed in grams of equivalent SO_2 per kg. The emissions related to the acidification in the LCI analyzed are SO_2, and NO_x, which have the corresponding characterization factors of 1.0 and 0.7, respectively [8].

The total influence of SO_2 on the acidification effect, accounted for 69.22%, is bigger than the contribution of NO_x. Because, both of the characterization factor and emitted amount of SO_2 are bigger than NO_x.

The acidification emissions of different processes in color TV set life cycle is presented in Fig. 4, which shows that process 5 emits most amount of atmospheric emissions (69.77%), followed by process 1 (18.55%), process 3 (10.63%), process 7 (0.97%), process 2 (0.04%) and process 4 (0.04%). Process 6 doesn't emit acidification emissions.

During process 1, production of glass emits 32.48% of acidification emissions, followed by steel (30.30%), aluminum (13.97%), PS (7.93%), PVC (7.84%), copper (6.20%) and PE (1.29%).

Table 22
The emissions related to acidification and acidification characterizations

Process		SO_2/kg	NO_x/kg	kg SO_2-eq
Process 1	Steel	2207.676	808.297	2773.484
	Aluminum	902.328	488.13	1244.019
	Copper	365.351	251.415	541.342
	Glass	2102.954	1130.67	2894.423
	PE	127.59	0.516	127.951
	PVC	778.89	1.806	780.154
	PS	510.873	278.386	705.743
	Total	6995.662	2959.22	9067.116
Process 2		0	21	14.7
Process 3		2710.29	2995.288	4806.992
Process 4		0	21	14.7
Process 5		23040	14,400	33120
Process 6		0	0	0
Process 7		69.196	450.786	384.746
Total		32815.148	20,847.294	47,408.254

5.1.3. Nutrient enrichment

The main sources of nutrient enrichment are N and P emitted to water and NO_x and NH_3 emitted into the atmosphere [15].

The characterization factor for this impact category is a product of nutrient factor and a transport factor. The nutrient factor captures the relative strength of influence on algae growth in aquatic ecosystems. The transport factor accounts for the probability that the release arrives in the aquatic environment in which it is a limiting nutrient. The contribution in this impact category is measured in terms of nitrogen equivalents released per kilogram of emission. Table 23 shows the results of nutrient enrichment characterizations of the different processes in color TV set life cycle. The values are expressed in grams of equivalent NO_3^- per kg. The emissions related to the nutrient enrichment in the LCI analyzed are NO_x, COD and N which have the corresponding characterization factors of 1.35, 0.23 and 4.43, respectively [8].

The total influence of NO_x on the nutrient enrichment effect, accounted for 99.50%, is bigger than the contribution of N (0.07%) and COD (0.43%).

The nutrient enrichment emissions of different processes in color TV set life cycle is presented in Fig. 5, which shows that process 5 emits most amount of nutrient enrichment emissions (68.70%), followed by process 1 (14.66%), process 3 (14.29%), process 7 (2.15%), process 2 (0.10%) and process 4 (0.10%). Process 6 doesn't emit nutrient enrichment emissions.

During process 1, production of glass emits 39.27% of nutrient enrichment emissions, followed by steel (27.53%), aluminum (15.88%), PS (9.06%), copper (8.18%), PVC (0.06%) and PE (0.02%).

5.1.4. Photochemical ozone formation

Nonmethane volatile organic compounds (NMVOC), CO and CH_4 are considered as the main contributors to photochemical ozone formation in China [15]. Table 24 shows the results of photochemical ozone formation characterizations of the different processes in color TV set life cycle. The values are expressed in grams of equivalent C_2H_4 per kg. The emissions related to the photochemical ozone formation in the LCI analyzed are CO and CH_4, which have the corresponding characterization factors of 0.03 and 0.007, respectively [8].

The total influence of CO on the photochemical ozone formation effect, accounted for 95.60%, is bigger than the contribution of CH_4 (4.40%).

The photochemical ozone formation emissions of different processes in color TV set life cycle is presented in Fig. 6, which shows that process 1 emits most amount of photochemical ozone formation emissions (97.42%), followed by process 2 (1.29%) and process 4 (1.29%).

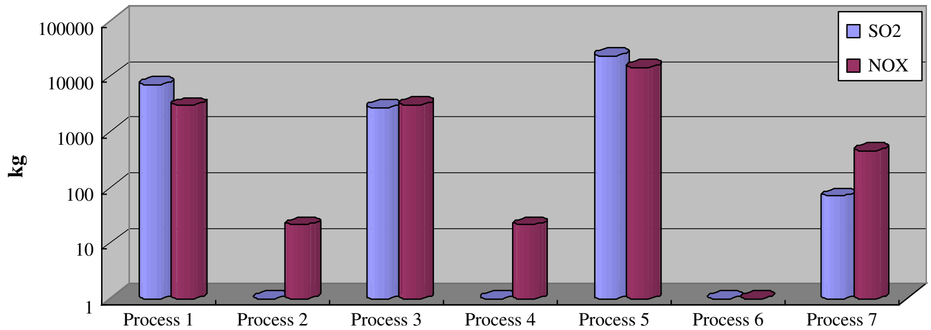

Fig. 4. The acidification emissions of different processes in color TV set life cycle.

During process 1, production of steel emits 94.53% of photochemical ozone formation emissions, followed by PVC (3.02%), glass (0.85%), copper (0.80%) and PE (0.80%).

5.1.5. Bulk waste

Table 25 shows the results of bulk waste characterizations of the different processes in color TV set life cycle.

Process 6 emits the highest amount of solid waste (47.99%). Followed process 1 (44.79%), process 3 (5.73%) and process 7 (1.49%). Other 3 processes don't emit any amount of solid waste.

During process 1, steel production emits 84.53% of solid waste, followed by aluminum (7.46%), PVC (5.67%), glass (0.84%), PE (0.67%), copper (0.47%) and PS (0.36%).

5.1.6. Soot and ashes

Table 26 shows the results of soot and ashes characterizations of the different processes in color TV set life cycle.

Process 1 emits 77.70% soot and ashes. Followed by process 5 (21.67%) and process 3 (0.63%).

During process 1, copper production emits 96.44% of soot and ashes, followed by glass (1.66%), aluminum (0.91%), steel (0.76%) and PS (0.22%).

5.1.7. The percentage of each emission during different processes

The emissions related to different environmental impacts of different processes in color TV set life cycle are CO_2, CH_4, NO_x, CO, SO_2, COD, N, solid waste and soot and ashes. The respective percentages of each emission in different processes are presented as follows:

- Process 5 emits the highest amount of CO_2, accounted for 68.36%. Followed by process 1 (20.48%), process 3 (10.64%), process 7 (0.45%), process 2 (0.03%) and process 4 (0.03%). Process 6 doesn't emit any CO_2.
- Process 1 emits 100% of CH_4.
- Process 5 emits the highest amount of NO_x, accounted for 69.07%. Followed by process 3 (14.37%), process 1 (14.19%), process 7 (2.16%), process 2 (0.10%) and process 4 (0.10%). Process 6 doesn't emit any amount of NO_x.
- Process 1 emits the highest amount of CO (96.91%), followed by process 2 (1.54%) and process 4 (1.54%).
- Process 5 emits the highest amount of SO_2, accounted for 70.21%. Followed process of 1 (21.32%), process 3 (8.26%) and process 7 (0.21%).
- Process 1 emits 100% amount of COD.
- Process 1 emits 100% amount of N.
- Process 6 emits the highest amount of solid waste (47.99%). Followed process 1 (44.79%), process 3 (5.73%) and process 7 (1.49%). Other 3 processes don't emit any amount of solid waste.
- Process 1 emits 77.70% soot and ashes. Followed by process 5 (21.67%) and process 3 (0.63%).

The relevant emissions related to different environmental impacts of different material productions during process 1 are CO_2, CH_4, NO_x, CO, SO_2, COD, N, solid waste and soot and ashes. The respective percentages of each emission in different material production processes are presented as follows:

- Production of steel emits 39.60% of CO_2, followed by glass (19.39%), aluminum (10.93%), PVC (10.57%), PS (9.77%), copper (7.51%) and PE (2.23%).
- Production of steel emits 78.70% of CH_4, followed by PVC (16.57%) and PE (4.73%).

Table 23
The emissions related to nutrient enrichment and nutrient enrichment characterizations

Process		NO_x/kg	COD/kg	N/kg	kg NO_3^--eq
Process 1	Steel	808.297	10.152	27.72	1216.336
	Aluminum	488.13	0	0	658.976
	Copper	251.415	0	0	339.410
	Glass	1130.67	76.194	0	1543.929
	PE	0.516	0	0	0.697
	PVC	1.806	0	0	2.438
	PS	278.386	0	0	375.821
	Total	2959.22	86.346	27.72	4137.606
Process 2		21	0	0	28.35
Process 3		2995.288	0	0	4043.639
Process 4		21	0	0	28.35
Process 5		14,400	0	0	19,440
Process 6		0	0	0	0
Process 7		450.786	0	0	608.561
Total		20,847.294	86.346	27.72	28,286.506

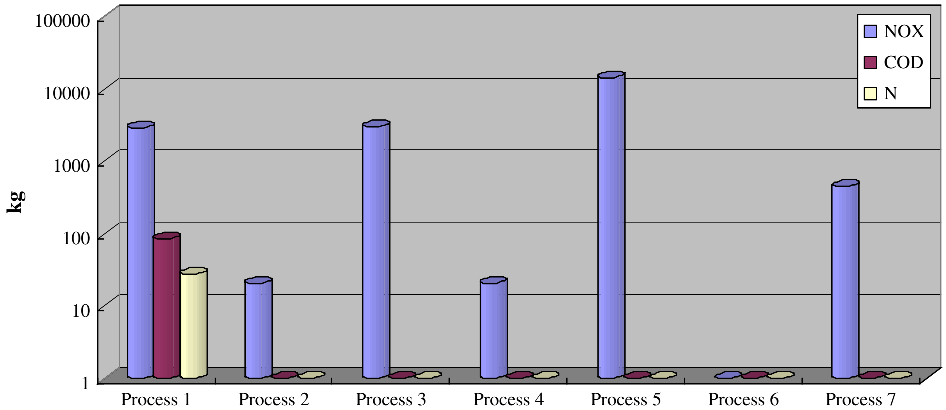

Fig. 5. The nutrient enrichment emissions of different processes in color TV set life cycle.

- Production of glass emits 38.21% of NO_x, followed by steel (27.31%), aluminum (16.50%), PS (9.41%), copper (8.50%), PVC (0.06%) and PE (0.02%).
- Production of steel emits 97.75% of CO, followed by glass (1.02%), copper (0.96%) and PVC (0.27%). Other material production processes don't emit any amount of CO to environment.
- Production of steel emits 31.55% of SO_2, followed by glass (30.06%), aluminum (12.90%), PVC (11.13%), PS (7.30%), copper (5.22%), and PE (1.82%).
- Production of steel and glass emit 11.76% and 88.24% of COD, respectively.
- 100% of N is emitted by steel production.
- Steel production emits 84.53% of solid waste, followed by aluminum (7.46%), PVC (5.67%), glass (0.84%), PE (0.67%), copper (0.47%) and PS (0.36%).
- Copper production emits 96.44% of soot and ashes, followed by glass (1.66%), aluminum (0.91%), steel (0.76%) and PS (0.22%).

5.2. Normalization and weighting

Table 27 summarizes the results from the categorization of the impacts, for the chosen functional unit.

Weighting factors are applied in order to scale the seriousness of the results, measured in indicator points. The normalization references and weighting factors used for the purpose of this study are shown in Table 28.

Table 24
The emissions related to photochemical ozone formation and photochemical ozone formation characterizations

Process		CO/kg	CH_4/kg	kg C_2H_4-eq
Process 1	Steel	3960	648.288	123.338
	Aluminum	0	0	0
	Copper	38.88	0	1.166
	Glass	41.31	0	1.239
	PE	0	39.0	0.273
	PVC	10.82	136.5	1.28
	PS	0	0	0
	Total	4051.01	823.788	127.297
Process 2		64.5	0	1.935
Process 3		0	0	0
Process 4		64.5	0	1.935
Process 5		0	0	0
Process 6		0	0	0
Process 7		0	0	0
Total		4180.01	823.788	131.167

5.3. The weighted environmental potentials of 10,000 color TV sets

According to Eq. (7), the weighted environmental potentials have been calculated and presented in Table 29.

Fig. 7 shows that soot and ashes is by far the category affected mostly during the color TV set life cycle, accounts for 86.07% of the total environmental impact. Bulk waste contributes by 4.62% to the total impact, followed by global warming (3.98%), acidification (3.67%), nutrient enrichment (1.27%) and photochemical ozone formation (0.39%).

Soot and ashes, CO_2, CH_4, NO_x, CO, SO_2, COD, N and solid waste are emissions related to different environmental impacts, the weighted environmental potentials of different emissions are presented as follows:

(1) For Global warming: NO_x (63.644×10^3 $mPET_{2000}$) > CO_2 (40.190×10^3 $mPET_{2000}$) > CH_4 (0.196×10^3 $mPET_{2000}$) > CO (0.080×10^3 $mPET_{2000}$).
(2) For Acidification: SO_2 (66.541×10^3 $mPET_{2000}$) > NO_x (29.591×10^3 $mPET_{2000}$).
(3) For Nutrient enrichment: NO_x (33.137×10^3 $mPET_{2000}$) > N (0.145×10^3 $mPET_{2000}$) > COD (0.023×10^3 $mPET_{2000}$).
(4) For Photochemical ozone formation: CO (9.839×10^3 $mPET_{2000}$) > CH_4 (0.452×10^3 $mPET_{2000}$).
(5) For Bulk waste: 120.835×10^3 $mPET_{2000}$.
(6) For soot and ashes: 2252.443×10^3 $mPET_{2000}$.

The respective percentages of different emissions' weighted environmental potentials are soot and ashes (86.07%), solid waste (4.62%), NO_x (4.83%), SO_2 (2.54%), CO_2 (1.54%), CO (0.38%), CH_4 (0.02%), N (0.006%), COD (0.0009%).

5.4. The environmental impact loading of 10,000 color TV sets

At the final step, the weighted environmental potentials are added up to give an environmental impact loading (*EIL*), which can be defined as follows:

$$\mathrm{EIL} = \sum_j \mathrm{WP}(j) = \sum_j \frac{\mathrm{EP}(j)_{90}}{T \cdot \mathrm{ER}(j)_{90}} \cdot \mathrm{WF}(j) \qquad (8)$$

The EIL of 10,000 color TV sets is calculated to be 2617.119×10^3 $mPET_{2000}$, in which that the value of 1 point is representative for 1/1000th of the yearly environmental load of 1 average Chinese inhabitant.

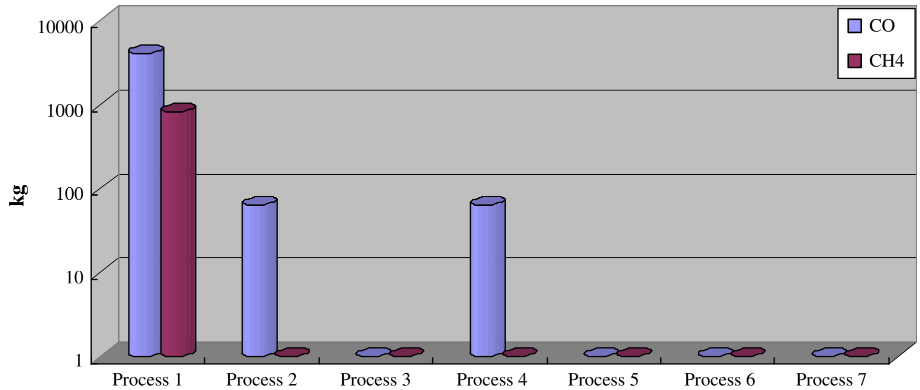

Fig. 6. The photochemical ozone formation emissions of different processes in color TV set life cycle.

Table 25
The solid waste related to bulk waste

Process		kg
Process 1	Steel	1,85,220
	Aluminum	16,338
	Copper	1032
	Glass	1839.06
	PE	1467.81
	PVC	12,425.175
	PS	793.636
	Total	2,19,115.681
Process 2		0
Process 3		28,028.048
Process 4		0
Process 5		0
Process 6		2,34,750
Process 7		7292.192
Total		4,89,185.921

Table 26
The emissions related to soot and ashes

Process		kg
Process 1	Steel	3942.973
	Aluminum	4713.3
	Copper	4,98,093.146
	Glass	8568
	PE	0
	PVC	0
	PS	1147.5
	Total	5,16,464.919
Process 2		0
Process 3		4190.5
Process 4		0
Process 5		1,44,000
Process 6		0
Process 7		0
Total		6,64,655.419

Table 27
The results from the categorization of the environmental impacts

Impact category	Equivalent mass	Unit
Global warming	1,09,12,826.8	kg CO_2-eq
Acidification	47,408.254	kg SO_2-eq
Nutrient enrichment	28,286.506	kg NO_3^--eq
Photochemical ozone formation	131.167	kg C_2H_4-eq
Bulk waste	4,89,185.921	kg
Soot and ashes	6,64,655.419	kg

Table 28
The normalization references and weighting factors for different environmental impact categories

Impact category	Normalization reference [8]	Weighting factor [15]
Global warming	8700 kg CO_2-eq/(person·a)	0.83
Acidification	36 kg SO_2-eq/(person·a)	0.73
Nutrient enrichment	62 kg NO_3^--eq/(person·a)	0.73
Photochemical ozone formation	0.65 kg C_2H_4-eq/(person·a)	0.51
Bulk waste	251 kg/(person·a)	0.62
Soot and ashes	18 kg/(person·a)	0.61

5.5. *The weighted environmental potential percentages of different processes*

To different environmental impact categories, the weighted environmental potential percentages of different processes are shown as follows

(1) For Global warming, is process 5 (71.44%) > process 1 (17.54%) > process 3 (13.42%) > process 7 (1.56%) > process 2 (0.08%) = process 4 (0.08%) > process 6 (0%).
(2) For Acidification, is process 5 (69.86%) > process 1 (19.13%) > process 3 (10.14%) > process 7 (0.81%) > process 2 (0.03%) = process 4 (0.03%) > process 6 (0%).
(3) For Nutrient enrichment, is process 5 (68.73%) > process 1 (14.63%) > process 3 (14.30%) > process 7 (2.15%) > process 2 (0.10%) = process 4 (0.10%) > process 6 (0%).
(4) For Photochemical ozone formation, is process 1 (97.05%) > process 2 (1.48%) = process 4 (1.48%) = process 3 (0%) = process 5 (0%) = process 6 (0%) = process 7 (0%).
(5) For Bulk waste, is process 6 (47.99%) > process 1 (44.79%) = process 3 (5.73%) = process 7 (1.49%) = process 2 (0%) = process 4 (0%) = process 5 (0%).

Table 29
The weighted environmental potentials for different environmental impact categories

Impact category	Weighted environmental potential ($\times 10^3$ $mPET_{2000}$)
Global warming	104.111
Acidification	96.133
Nutrient enrichment	33.305
Photochemical ozone formation	10.292
Bulk waste	120.835
Soot and ashes	2252.443

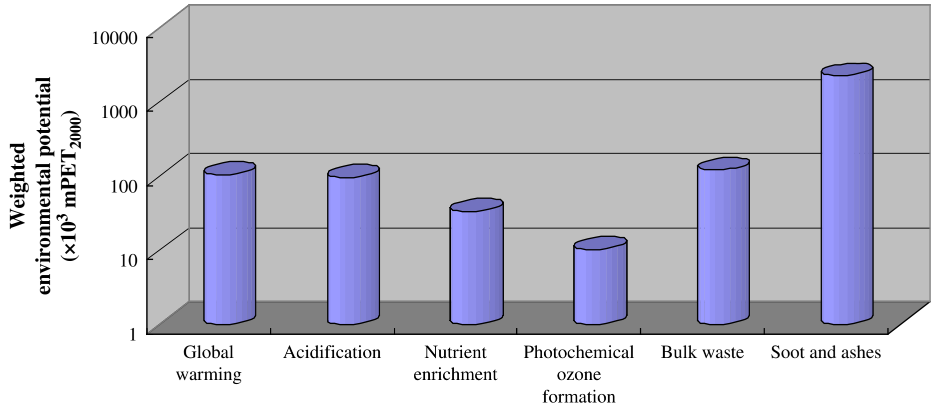

Fig. 7. The weighted environmental potentials of 10,000 color TV sets.

(6) For Soot and ashes, is process 1 (77.70%) > process 5 (21.67%) > process 3 (0.63%) > process 2 (0%) = process 4 (0%) = process 6 (0%) = process 7 (0%).

For the total environmental impact loading percentages of different processes, is process 1 (70.89%) > process 5 (24.82%) > process 6 (2.22%) > process 3 (1.87%) > process 7 (0.19%) > process 2 (0.01%) = process 4 (0.01%) (Fig. 8).

5.6. *The weighted environmental potential percentages of different material productions*

In process 1, the weighted environmental potential percentages of different material productions are shown as follows:

(1) For Global warming, is Steel (33.97%) > Glass (28.78%) > Aluminum (13.63%) > PS (9.43%) > Copper (7.90%) > PVC (5.18%) > PE (1.11%).
(2) For Acidification, is Glass (31.92%) > Steel (30.59%) > Aluminum (13.72%) > PS (7.78%) > PVC (8.60%) > Copper (7.78%) > PE (1.41%).
(3) For Nutrient enrichment, is Glass (37.32%) > Steel (29.39%) > Aluminum (15.93%) > PS (9.07%) > Copper (8.21%) > PVC (0.06%) > PE (0.02%).
(4) For Photochemical ozone formation, is Steel (96.91%) > PVC (1.00%) > Glass (0.97%) > Copper (0.91%) > PE (0.21%) > Aluminum (0%) = PS (0%).
(5) For Bulk waste, is Steel (84.53%) > Aluminum (7.46%) > PVC (5.67%) > Glass (0.84%) > PE (0.67%) > Copper (0.47%) > PS (0.36%).
(6) For Soot and ashes, is Copper (96.44%) > Glass (1.66%) > Aluminum (0.91%) > Steel (0.76%) > PS (0.22%) > PE (0%) = PVC (0%).

For the total environmental impact loading percentages of different material productions during process 1, is Copper (91.16%) > Steel (4.41%) > Glass (2.28%) > Aluminum (1.39%) > PS (0.41%) > PE (0.05%) > PVC (0.31%) (Fig. 9).

6. Discussion

- The material composition inventories, manufacturing materials inventories and environmental impact type inventories in

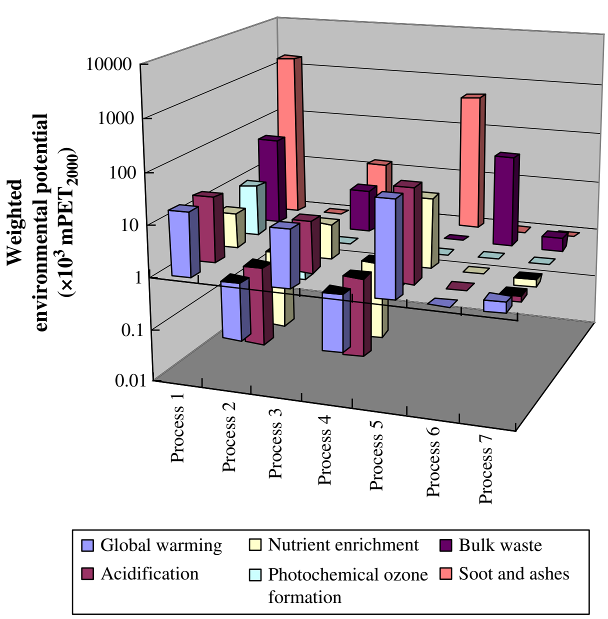

Fig. 8. The weighted environmental potentials of different processes.

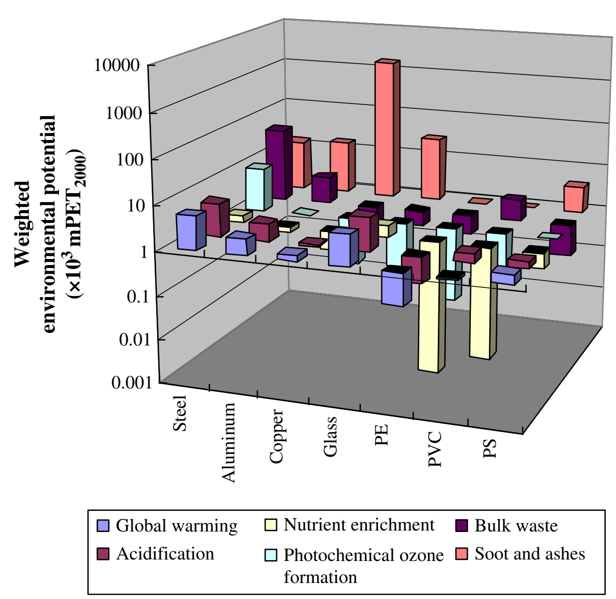

Fig. 9. The weighted environmental potentials of different material productions during process 1.

this paper are not complete enough, however, they are still valuable for providing us with a rough estimate of the energy consumption and environmental impacts of a color TV set in China.

- The normalization references and weighting factors used in this paper should be considered as rough estimates and a little bit old, especially, the weighting factors presented in this paper are based on target emissions in 2000 which is actually not "the future" when this paper comes out. However, they are still useful to conduct us to research the life cycle of a color TV set in China because these normalization references and weighting factors haven't changed greatly for a number of years anyway, and an updated version can be determined more easily based on the results presented here.
- The density of fumes in copper production is much lower than the density of air because of a much higher temperature for fumes, so actually 384,000 Nm^3 fumes' mass is much lower than 496,512 kg. It means that the environmental impact potential of soot and ashes due to emitting of fumes will be lower than that in this paper and the *EIL* of color TV set will decrease accordingly.
- It will reduce 1722.656 kg dust, 34,453.125 kg CO_2, 172.266 kg NO_x and 275.625 kg SO_x released into the environment if electricity from the process of partial plastic waste energy utilization can be utilized instead of 34,453.125 kWh of electricity generated from coal.

7. Conclusions

The present study shows the results of an LCA performed upon 10,000 color TV sets. Production and transportation of color TV set manufacturing materials and manufacturing (includes welding, assembling and testing), transport, use and disposal of color TV sets, and partial plastic waste energy utilization are checked. Several conclusions were drawn from this study.

(1) Contribution of energy consumption from process 5, its contribution to the total energy consumption by 57.30%; Coal (Electricity) supplies 66.43% of energy consumption; process 1 consumes most energy resource categories.
(2) Process 1 has the biggest environmental impact loading during different processes of color TV set life cycle, accounted for 70.89% of the environmental impact loading of color TV set, during which copper production's contribution to the environmental impact of process 1 loading by 91.16%.
(3) The environmental impact loading of 10,000 color TV sets is calculated to be 2617.119×10^3 $mPET_{2000}$; Soot and ashes is the emission category affected mostly during the color TV set life cycle, accounts for 86.07% of the total environmental impact; 77.70% of soot and ashes is emitted by process 1, during which copper production's contribution to process 1's soot and ashes by 96.44%.
(4) The total environmental impact loading percentages of different processes, are process 1 (70.89%) > process 5 (24.82%) > process 6 (2.22%) > process 3 (1.87%) > process 7 (0.19%) > process 2 (0.01%) = process 4 (0.01%); The total environmental impact loading percentages of different material productions during process 1 are Copper (91.16%) > Steel (4.41%) > Glass (2.28%) > Aluminum (1.39%) > PS (0.41%) > PE (0.05%) > PVC (0.31%).

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