The Chinese Energy System for LCA calculations

B. De Benedetti[1], G.L. Baldo[2], M. Marino[1], B. Liu[3], I. Boustead[4], W.T. Dove[4]
[1]Materials Science Dept., Politecnico di Torino, Italy E-mail: debene@polito.it
[2]Life Cycle Engineering, Italy. E-mail gibald@tin.it
[3]Tsinghua University, Beijing (China)
[4]Boustead Consulting Ltd., UK, E-mail: info@boustead-consulting.co.uk

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ABSTRACT

The calculation of energy and raw materials requirements in any Life Cycle Assessment (LCA) of extended product systems involves a quantitative assessment of the production efficiencies of the fuel producing industries involved in the system. During a recently completed INCO project financed by the European Community, aimed at evaluating the environmental characteristics of a Chinese car production system, it was necessary to calculate the performance of the Chinese energy system. This consists of four main phases: primary energy production, secondary energy production (e.g. electricity and steam), energy delivery and lastly energy use.

Since China does not exchange electricity with other countries, a super-grid system model has been created for the specific Chinese energy mix. The use of both official statistical data and a user-friendly LCA tool (the Boustead Model), permits an easy quantification of the relationship between Chinese electricity use and upstream primary fuel production and associated waste emissions.

To this effect we have determined the Eco-profile for the generation and delivery of 1 MJ of electricity in China.

INTRODUCTION

Since 1980 the energy requirements of Asia have grown substantially: at present, they constitute about 25% of the total world consumption [1]. In this context, China drives the growth and in the Asian power plant market it represents the most important country with 240 MW of power installed [2]. The Chinese Government forecasts that this will increase to approx. 255 MW of power installed before 2010 [3]. The interest to create a model of the electricity system is therefore high and a recently concluded project financed by the European Community (INCO Project) [4] gave the opportunity to create a super grid model representing the Chinese electricity system from an LCA point of view. This paper defines the environmental load for the generation and delivery of 1 MJ of electricity. The term Eco-profile is used to indicate that the system examined follows the production sequence "from cradle to gate", i.e. from raw materials extraction until the product (electricity) ready to be used by the final consumer.

THE MODEL OF THE ELECTRICITY GRID

China does not exchange electricity with other countries and most of the energy consumption is located in the eastern part of the country. It is therefore possible to represent the system with a unique simple model in which the four main phases (primary energy production, electricity generation, electricity distribution and lastly electricity use) are connected by physical flows and characterised by emissions to the environment.

Figure 1 presents the system considered with the percentages of the production technologies at present used in China (normally referred to as “mix of primary fuels”). This system refers to the 1996 practice and it is built using official data given by “China Energy Review” [5]: the total electricity output was 1.081,3 TWh (about $3{,}9\times10^{12}$MJ) and the electricity transmission network loss rate was 8,53% of the production.

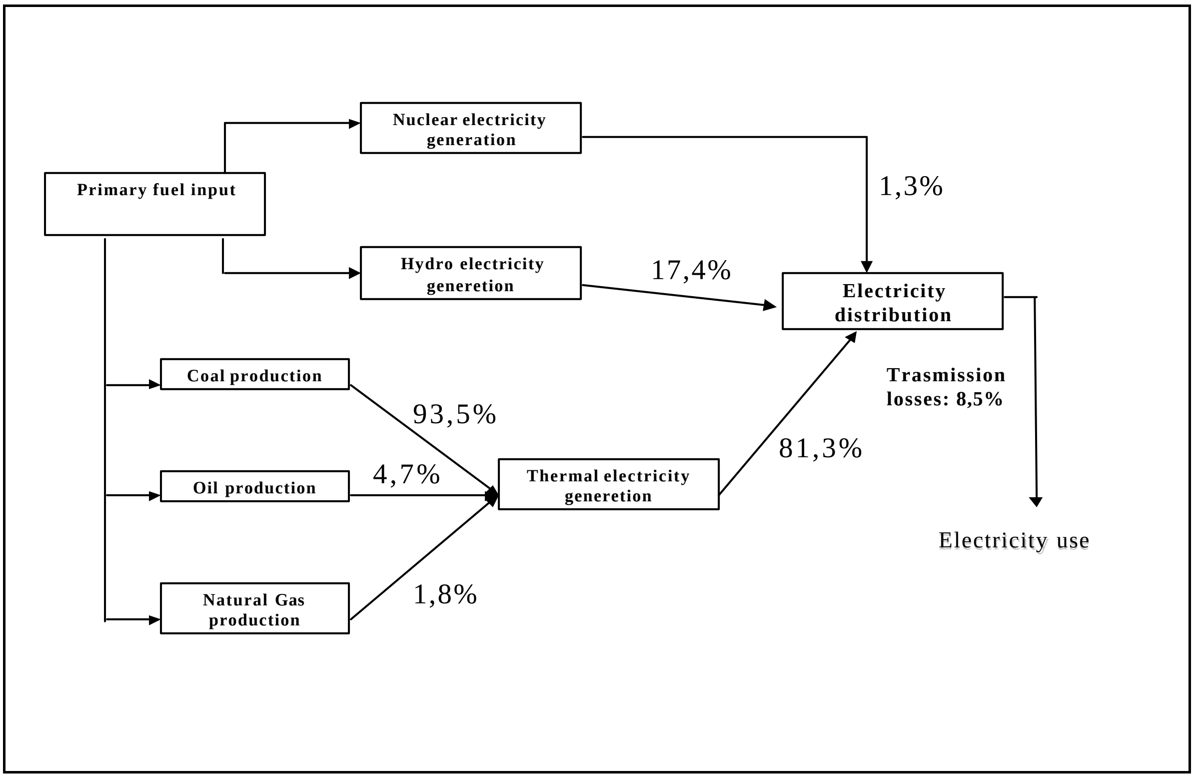

Figure 1. Energy flows for the production and delivery of electrical energy at the consumer in the Chinese system [5].

The Chinese energy system is coal dominated and for thermal electricity generation this primary fuel accounts for over 93 % of the primary input of energy.

To reproduce the real situation, a computer model was created in order to determine the quantity of energy necessary to generate one MJ of electricity available to the final consumer. The Boustead Model was the software tool used for the calculations.

Table 1 gives the situation about thermal power generation and the calorific values used for each fuel: in 1996 the thermal electricity generated was 879 TWh (about $3{,}16\times10^{12}$MJ) [5].

To calculate the overall efficiency (η_e) of the electricity supply industry with a LCA point of view, it is necessary to start with primary fuels in the earth calculating the efficiency with which each primary fuel is produced (η_p) and going through the generation efficiency (η_g), with the relationship: $\eta_e = \eta_p \times \eta_g$.

Table 1. Fuels used for the thermal power generation in 1996 and the considered calorific value [5].

Fuel	***Quantity***	***Calorific value***
Coal	470,4 Mt	19 MJ/kg
Fuel oil	10,47 Mt	43 MJ/kg
Manufactured gas	8.678,35 MNm^3	19,4 MJ/Nm^3

The production efficiency for coal is calculated examining the coal industry in 1996, from coal mining, to coal washing and coke making. The same was done for oil production and treatment and natural gas extraction and delivery. In all cases transport operations were considered.

The precise efficiencies of hydro power and nuclear power are not known and average values of 80% and 35% respectively have been used. In the case of hydro power, the electricity consumed by the plants is 0,51% of the production, while, in the case of nuclear power, it is 6% of the production.

RESULTS

It is useful to give the results using an energy table (Table 2). The energy requirements expressed in Table 2 refer to the total energy consumption when the production processes are traced back through all operations to the extraction of raw materials from the earth. Within the table, the overall energy requirements are analysed into a number of groups. The first breakdown is by fuel producing industry. The electricity supply industry is separately identified because, of all the fuel supply industries, it exhibits the lowest production efficiency. In this case, it means that for every MJ required by the consumer, a further 2,50 MJ have to be used by the electricity supply industry, giving an overall efficiency, η_e, of less than 29%.

The "*energy use*" column represents the energy that is received by the final operator who consumes energy. This is independent of country and is directly related to the technology that is used in the various processing operations because this governs the demand for energy.

The "*transport energy*" column refers to the energy associated with fuels consumed directly by the transport operations as well as any energy associated with the production of non-fuel bearing materials, such as steel, that are taken into the transport process.

The "*feedstock energy*" represents the energy of the fuel bearing materials that are taken into the system but used as materials rather than fuels.

Finally, the "*production energy*" column represents the energy that is used by the fuel producing industries in extracting the primary fuel from the earth, processing it and delivering it to the ultimate consumer. This will also include the energy associated with the production of any non-fuel materials (such as steel) that are taken into the fuel production process. In this case, only the electricity supply industry is involved, but the same table can be used to present results of any LCA study. In fact, the importance of this breakdown is that "*energy use*" and "*feedstock energy*" are dependent on the technology used by the process operators. In contrast, the *production energy* depends upon the country in which the processes are carried out.

Table 2. Gross energy in MJ to generate 1 MJ of electricity available to the consumer in China.

Fuel type	Production energy	Energy Use	Transport energy	Feedstock energy	Total energy
Electricity/MJ	2,45	1	0,05	-	3,5
Oil fuels/MJ	-	-	-	-	-
Other fuels/MJ	-	-	-	-	-
Total/MJ	2,45	1	0,05	-	**3,5**

One aim of an LCA is to reveal opportunities for the conservation of energy resources [6]: a second format for presenting energy data in terms of the primary fuel inputs is shown in Table 3.

Table 3. Gross energy inputs as primary fuels to generate 1 MJ of electricity in China.

Primary fuel	MJ per MJ of electricty	%
Coal	2,96	84,7%
Oil	0,24	6,8%
Gas	0,01	0,3%
Hydro	0,24	6,8%
Nuclear	0,05	1,4%
TOTAL	**3,5**	100%

Since Chinese electricity is predominantly derived from burning fossil fuels, the air emissions associated with each MJ of electricity delivered to the consumer correspond to a 100 year Global Warming Potential (GWP_{100}) of about 515 g $CO_{2\ equivalents}$.

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