Life Cycle Environment Evaluation of Hydrogen Source System for Fuel Cell Vehicles

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Abstract. Fuel cell vehicles are regarded as the ultimate goal of new energy vehicles because of their high energy conversion efficiency and clean product emissions. This study is based on China's localized industrial and transportation data, combined with the "Life Cycle Assessment (LCA)" approach, and the use of the GREET model for the analysis of the WTW phase of the hydrogen energy system. Sensitivity analysis of hydrogen source system solutions by defining sensitivity factors. This study believes that the overall environmental benefits of natural gas reforming hydrogen production + high-pressure hydrogen gas + pipeline transportation plan are the best, and the relatively flexible and manoeuvrable ground high-pressure hydrogen trailer transportation method can be used as a supplementary solution for hydrogen energy transportation. When the ratio of coal to electricity is reduced below 40%, the environmental benefits of hydrogen production from electrolyzed water are expected to decrease to the same level as current level of hydrogen production from coal gasification.

1. Introduction

Since the 21st century, China's industrialization and urbanization process has been accelerating, the automobile industry and transportation industry have developed rapidly, and the ensuing energy security and environmental problems have become increasingly serious.

To cope with the current energy and environmental problems, China's automotive industry is constantly exploring alternatives to traditional fuel vehicles with cleaner and more efficient energy. Among them, new energy vehicles stand out because of their low emissions in the use of vehicles. Fuel cell vehicles are regarded as the ultimate goal of new energy vehicles because of their high efficiency, cleanliness, pollution-free and zero emission characteristics.

In the process of commercialization of fuel cell vehicles, one of the main bottlenecks is a hydrogen source system that can meet the requirements of large-scale application and environmental benefits of fuel cell vehicles. Because of zero emission of hydrogen energy in the use phase, the consumption and emission of fossil energy in the life cycle are generated in the upstream phase of the life cycle. Energy consumption and emission of hydrogen energy in the whole life cycle is the key to environmental benefit assessment.

2. Fuel cell vehicle hydrogen source system life cycle assessment (LCA) method

LCA is an evaluation of the whole life process of products from "Cradle" to "Grave". SETAC defines life cycle as [1]: LCA is an objective process for evaluating the environmental pressure of products, manufacturing processes and activities. It identifies and quantifies the energy and material utilization...
and the resulting environmental waste emissions, aiming at assessing the energy and material utilization and waste emissions to the environment and at seeking opportunities to improve environmental impacts.

3. Inventory analysis model for LCA of fuel cell vehicle

3.1. Energy consumption model

3.1.1. Unit process definition. In the whole life cycle of the fuel chain, each module is defined as a unit process with similar structure. Input is composed of raw materials and process fuels. The reactions in which raw materials participate are mostly chemical processes, which may cause pollution and emission. The way in which process fuels participate in the reactions is combustion of process fuels. Emissions and pollution will inevitably arise in the combustion process. Output is the main product and by-product. The main product can be used as raw material or process fuel for the next unit process. The by-product is the emission of carbon dioxide, nitrogen oxides and other gases.

Figure 2. Unit process.

For each unit process, energy efficiency is an important evaluation parameter when calculating energy consumption and total emissions. By definition, we get:

\[ \eta_x = \frac{E_{out,x}}{E_{in,x}} \]

\( \eta_x \) is the energy efficiency of the unit process; \( E_{out,x} \) is the output energy of the unit process; \( E_{in,x} \) is the input energy of the unit process.
Because the process of fuel exploitation, production, storage and transportation is very complex, it involves not only the production process, but also the product itself as process fuel. According to the use of raw materials and process fuels, they can be concretely divided into three categories:

1. All raw materials in the input process are consumed in the form of combustion, such as thermal power generation.

2. Among all the energy input, one part is the raw material for preparing fuel for chemical reaction, and the other part is the process fuel to provide heat or steam for the production process. For example, in the process of producing hydrogen from natural gas, natural gas is not only used as raw material, but also as process fuel.

3. One part of the energy input is used to prepare the main product fuel, but it does not involve the chemical reaction process. The other part is used as the process fuel. For example, the compression and liquefaction of hydrogen.

In the study of life cycle assessment, the second and third types of units involving process fuels are more common. At this time, the process fuel consumption of the unit process can be calculated by the following formula when the fuel per unit energy (1MJ) is produced [2]:

\[ E_{\text{process},x} = \frac{1}{\eta_x} - 1 \]  

(2)

### 3.1.2. WTP stage energy consumption model

In this paper, energy consumption refers to primary fossil energy consumption, mainly including coal, oil and natural gas. In this paper, i is used to refer to fossil energy.

For the unit process, the energy consumption is composed of the sum of direct energy consumption and indirect energy consumption. Direct energy consumption refers to the energy consumption of all inputs to the unit system during the unit process, including the consumption of raw materials and process fuels; indirect energy consumption refers to the energy consumption of process fuels in the upstream stage (i.e. WTP stage) production and transportation process. Therefore, the energy consumption of the unit process is:

\[ E_x = \sum_i E_{\text{in},x,i} + E_{\text{process},x} + E_{\text{upstream},x} \]  

(3)

\( E_x \) is the energy consumption of unit process (MJ/MJ); \( E_{\text{in},x,i} \) is the consumption of primary fossil energy i in raw material input for unit process to obtain unit product (MJ/MJ); \( E_{\text{process},x} \) is the consumption of process fuel in raw material input for unit process to obtain unit product (MJ/MJ); \( E_{\text{upstream},x} \) is the energy consumption of process fuel consumed in unit process x in the upstream stage (MJ/MJ).

Therefore, for the upstream stage of the fuel chain life cycle, there are:

\[ E_{\text{WTP}} = \sum_x E_x \]  

(4)

\( E_{\text{WTP}} \) is the total energy consumption (MJ) of the upstream life cycle (WTP) of the fuel chain(MJ);

And then,

\[ E_{\text{WTP}} = \sum_x \left( \sum_i E_{\text{in},x,i} + E_{\text{process},x} + E_{\text{upstream}} \right) \]  

(4)

\[ = \sum_x \sum_i E_{\text{in},x,i} + E_{\text{process}} + E_{\text{upstream}} \]  

(5)
\[ E_{\text{process}} = \sum_x \sum_z (E_{\text{process},x} \cdot \alpha_{x,z}) \]  

(6)

Based on the above formula, the life cycle energy intensity of the fuel chain WTP phase is:

\[ E_{\text{WTP}} = \sum_x \sum_z E_{\text{in},x,z} + \sum_x \sum_z (E_{\text{process},x} \cdot \alpha_{x,z}) + E_{\text{upstream}} \]  

(7)

It is not difficult to see from the above formula that in the process of solving the life cycle energy consumption intensity of WTP phase of fuel chain, because of the reference of process fuel to the upstream process of its own life cycle, it needs to be calculated iteratively by means of computer tools. In this calculation model, the maximum iteration step is set to 500, and the iteration precision is set to 0.3.

3.1.3. PTW stage energy consumption model. In the PTW stage, this paper only calculates the fuel consumption energy in the process of vehicle driving, and the functional unit is set as 1 km for vehicle driving [3]. At this stage, energy consumption is related to the physical properties of fuel and the fuel economy of vehicles:

\[ E_{\text{PTW}} = \rho \cdot LHV \cdot FE \cdot 100 \]  

(8)

\[ E_{\text{PTW}} \] is PTW stage energy consumption (MJ/km), \( \rho \) is the fuel density (kg/m) and \( LHV \) is the low calorific value (MJ/kg) of fuel. \( FE \) is the vehicle fuel economy index (L/100km).

It shows that fossil energy consumption at the downstream stage of terminal fuel life cycle (PTW) is related to fuel types and fuel economy.

3.2. Fuel life cycle emission model

3.2.1. Calculation of emission factor. In this paper, the emission factors of \( \text{CO}_2 \) and \( \text{SO}_2 \) can be calculated by the mass conservation formula of carbon and sulfur elements. The emission factors of other gases in specific equipment are calculated by using the data published in EPA document AP-42[4].

Greenhouse gas emissions are mainly generated by the combustion of fossil fuels. The emissions mainly include carbon dioxide, carbon monoxide, \( \text{CH}_4 \) and volatile organic compounds (VOC). According to the carbon conservation formula, the emission factor of \( \text{CO}_2 \) is calculated as follows:

\[ EF_{\text{CO}_2} = \left( \frac{1000 \rho_a}{LHV_a} CR_a (EF_{\text{CO}} CR_{\text{CO}} + EF_{\text{CH}_4} CR_{\text{CH}_4} + EF_{\text{VOC}} CR_{\text{VOC}}) \right) \frac{1}{CR_{\text{CO}_2}} \]  

(9)

\( EF_{\text{CO}_2} \) is the emission factor of \( \text{CO}_2 \) (g/MJ); \( \rho_a \) is the density of fuel a (kg/m); \( LHV_a \) is the low calorific value of fuel a (MJ/m); \( CR_a \) is the carbon content of fuel a (%); \( EF_{\text{CO}} \), \( EF_{\text{CH}_4} \), \( EF_{\text{VOC}} \) is the emission factor of \( \text{CO} \), \( \text{CH}_4 \), \( \text{VOC} \) (g/MJ); \( CR_{\text{CO}}, CR_{\text{CH}_4}, CR_{\text{VOC}} \) is the carbon content of \( \text{CO} \), \( \text{CH}_4 \), \( \text{VOC} \) (%) which is 43%, 75%, 85%, respectively; \( CR_{\text{CO}_2} \) is the carbon content of \( \text{CO}_2 \) which is generally 27.3%.

Similarly, assuming that all oxysulfide emissions in this paper are \( \text{SO}_2 \), the \( \text{SO}_2 \) emission factors can be obtained from the mass conservation formula of sulfur elements as follows:

\[ EF_{\text{SO}_2} = \frac{1000 \rho_a}{LHV_a} SR_a \frac{1}{SR_{\text{SO}_2}} \]  

(10)
\( EF_{SO2} \) is the emission factor of SO2 (g/MJ); \( SR_a \) is the sulfur content of fuel a (%); \( SR_{SO2} \) is the sulfur content of \( SO_2 \) which is generally 50%.

3.2.2. **Hydrogen fuel life cycle emission model.** For any unit process, the calculation of emissions consists of three parts: emissions from process fuel combustion, emissions from upstream stages of the process fuel life cycle, and non-combustion emissions from chemical reactions of the unit process itself, as shown below:

\[
EM_x = EM_{c,x} + EM_{uc,x} + EM_{upstream,x}
\]  

(11)

\( EM_x \) is the emissions of unit process (g/MJ); \( EM_{c,x} \) is the emission from process fuel combustion (g/MJ); \( EM_{nc,x} \) is the emission from the non-combustion process of the unit process (g/MJ); \( EM_{upstream,x} \) is the emissions from the upstream stage of the process fuel for the unit process (g/MJ). For the combustion process of process fuel, the fuel consumption device used is defined as t, and the emission related to the scope of this study is d, while the ratio of process fuel z to a certain technical means is \( \beta_{z,t} \) (\( \sum \beta = 1 \)), there are:

\[
EM_{c,x,d} = \sum_z \sum_t \beta_{z,t} EF_{z,t,d}(E_{process,x}\alpha_{x,t})
\]  

(12)

\( \beta_{z,t} \) is the ratio of t in process fuel z using energy consumption device (%); \( EF_{z,t,d} \) is the emission factor of d emitted from t of process fuel z using energy consumption device (g/MJ).

For emission products d in the upstream stage of life cycle, there are:

\[
EM_{WTP,d} = \sum_x \sum_z \sum_t \beta_{z,t} EF_{z,t,d}(E_{process,x}\alpha_{x,t}) + EM_{uc,d} + EM_{upstream,d}
\]  

(13)

It can be seen that the calculation of fuel life cycle emissions needs to involve the process of raw material extraction, production and storage and transportation in the upstream stage of process fuel, so it needs to be calculated iteratively to draw a conclusion.

For the emission calculation of the downstream stage of the terminal fuel life cycle (i.e. vehicle driving and using stage), the emission factor in GREET 2017 software is used as the benchmark to calculate the emission.

4. **Scheme comparison of hydrogen source system**

At the stage of hydrogen production, three schemes, coal gasification, methane steam reforming and electrolytic water, which are most widely used at present, are selected. In order to meet the requirement of hydrogen purity for fuel cell vehicles, pressure swing adsorption (PSA) method is used to purify hydrogen. It should be pointed out that, because the purity of hydrogen produced by electrolytic water is over 99.99%, this paper does not consider the emission and energy consumption caused by the purification process of hydrogen produced by electrolytic water. The hydrogen storage and transportation schemes include high-pressure gaseous hydrogen storage, low-temperature liquid hydrogen storage and corresponding transportation schemes, forming nine schemes as shown in Table 1. Based on the following nine plans, this paper will carry out the evaluation and analysis of the upstream stage of hydrogen source life cycle.
Table 1. Research scheme of hydrogen source system for fuel cell.

| Number | Hydrogen production scheme | Purification scheme | Hydrogen storage scheme | Transport scheme |
|--------|-----------------------------|---------------------|-------------------------|-----------------|
| 1      | Coal gasification           |                     | High pressure gaseous state | Tube trailer   |
| 2      |                              | Pressure swing adsorption (PSA) | Cryogenic liquid | Hydrogen pipeline |
| 3      | Steam reforming of methane   |                     | High pressure gaseous state | Tube trailer   |
| 4      |                              |                     | Cryogenic liquid | Hydrogen pipeline |
| 5      | Electrolysis water           | Emissions and energy consumption caused by purification are not considered | High pressure gaseous state | Tube trailer   |
| 6      |                              |                     | Cryogenic liquid | Liquid hydrogen tank car |
| 7      |                              |                     |                         |                 |
| 8      |                              |                     |                         |                 |
| 9      |                              |                     |                         |                 |

5. Evaluation of life cycle environmental benefits of hydrogen source system for fuel cell vehicle

5.1. Fuel life cycle emission model

5.1.1. Terminal fuel life cycle consumption of fossil energy. As a new type of clean energy, hydrogen energy does not produce carbon dioxide and other pollutants in the combustion process. At the same time, under the current energy structure, hydrogen energy is also a secondary energy based on the conversion of fossil energy. At the upstream stage of its life cycle, it needs to consume a large amount of fossil energy for conversion and as a source of energy. Combustion of process fuel. As the terminal energy of traditional vehicles, gasoline scheme serves as the benchmark scheme, which provides a reference for hydrogen energy scheme. The environmental benefits of nine hydrogen energy schemes are evaluated comprehensively from three dimensions: fossil energy consumption, greenhouse effect and environmental impact of pollutants [5].

As a new type of clean energy, hydrogen energy does not produce carbon dioxide and other pollutants in the combustion process. At the same time, under the current energy structure, hydrogen energy is also a secondary energy based on the conversion of fossil energy. In the upstream stage of its life cycle, a large amount of fossil energy is consumed for conversion and combustion as process fuel. As the terminal energy of traditional vehicles, gasoline scheme serves as the benchmark scheme, which provides a reference for hydrogen energy scheme. The environmental benefits of nine hydrogen energy schemes are evaluated comprehensively from three dimensions: fossil energy consumption, greenhouse effect and environmental impact of pollutants.

The relative variation and change rate of environmental benefit evaluation indicators of hydrogen energy schemes are reflected in Tables 2 and 3. The indicators of resource consumption and environmental impact decline of hydrogen energy schemes are marked in red. The relative consumption of fossil energy, greenhouse gas equivalent and environmental impact indicators of the nine hydrogen energy schemes are shown in figure 3, 4, 5.
Table 2. Variation of environmental benefit evaluation standard for nine hydrogen energy schemes relative to benchmark schemes.

| Evaluation                  | Scheme 1 | Scheme 2 | Scheme 3 | Scheme 4 | Scheme 5 | Scheme 6 | Scheme 7 | Scheme 8 | Scheme 9 |
|-----------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Fossil energy               | 0.05     | -0.26    | 0.89     | -0.64    | -0.95    | 0.19     | 2.77     | 2.45     | 3.64     |
| Greenhouse effect           | 85.08    | 61.04    | 180.88   | -61.24   | -85.13   | 32.93    | 418.97   | 394.60   | 518.50   |
| Photochemical smog potential| -5.12    | -5.14    | -5.13    | -5.13    | -5.15    | -5.13    | -5.09    | -5.11    | -5.10    |
| Acidification potential     | 0.08     | 0.03     | 0.33     | -0.02    | -0.07    | 0.23     | 1.54     | 1.49     | 1.81     |
| Human toxicity potential    | 0.08     | 0.03     | 0.39     | -0.05    | -0.10    | 0.26     | 1.81     | 1.76     | 2.14     |
| Aerosol potential           | 0.02     | 0.02     | 0.03     | -0.01    | -0.01    | 0.01     | 0.08     | 0.08     | 0.10     |

Table 3. Nine hydrogen energy schemes relative standard scheme environmental benefit evaluation standard change rate.

| Evaluation                  | Scheme 1 | Scheme 2 | Scheme 3 | Scheme 4 | Scheme 5 | Scheme 6 | Scheme 7 | Scheme 8 | Scheme 9 |
|-----------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Fossil energy               | 1%       | -6%      | 22%      | -16%     | -23%     | 5%       | 68%      | 60%      | 89%      |
| Greenhouse effect           | 29%      | 21%      | 63%      | -21%     | -29%     | 11%      | 145%     | 136%     | 179%     |
| Photochemical smog potential| -99%     | -99%     | -99%     | -99%     | -100%    | -99%     | -98%     | -99%     | -99%     |
| Acidification potential     | 26%      | 10%      | 106%     | -6%      | -23%     | 74%      | 496%     | 480%     | 583%     |
| Human toxicity potential    | 21%      | 8%       | 102%     | -13%     | -26%     | 68%      | 476%     | 463%     | 562%     |
| Aerosol potential           | 95%      | 95%      | 143%     | -48%     | -48%     | 48%      | 380%     | 380%     | 475%     |
**Figure 3.** Relative consumption of hydrogen. Energy fossil energy.

**Figure 4.** Relative emissions of hydrogen Greenhouse gases.

**Figure 5.** Relative value of hydrogen energy environmental impact index
According to the simulation results, we can get the following conclusions: The impact of hydrogen energy system scheme on natural environment and human is mainly human toxicity and acidification, while gasoline is mainly photochemical smog pollution.

6. Life cycle sensitivity analysis of hydrogen source system

6.1. Sensitivity analysis and definition of sensitivity factor

Sensitivity analysis refers to finding out the sensitive factors which have important influence on the research results from many uncertain factors, and exploring the analysis method of the influence degree of the changes on the research results under specific conditions.

To quantitatively analyze the sensitivity of hydrogen source system schemes to variables, the sensitivity factor is defined as shown in the following formula. The mathematical meaning of sensitivity factor is that when a certain factor is taken as the percentage of independent variable change unit, the index of life cycle quantitative analysis will increase or decrease accordingly. Sensitivity factor is the ratio of the analysis index to the percentage of independent variable change range, which represents the sensitivity of function value to this factor.

\[
    r = \frac{\Delta \text{spec}}{\Delta e/e}
\]

\(\text{spec and } \Delta \text{spec}\) Represent the quantitative indicators and their changes in the life cycle analysis of terminal energy, such as inventory materials, normalized indicators, etc; \(e\) and \(\Delta e\) represent the influencing factors and their changes in the terminal energy life cycle assessment respectively. When \(r > 0\), the influencing factors were positively correlated with the quantitative indicators; When \(r < 0\), the influencing factors were negatively correlated with the quantitative indicators.

6.2. Improvement of power structure

6.2.1. Sensitivity analysis of terminal energy life cycle. According to the data analysis of hydrogen energy and petroleum life cycle, the fossil energy consumption, greenhouse gas and pollutant emissions caused by the electric power stage are significantly higher than those of other schemes. This section will re-evaluate the hydrogen energy schemes and petroleum schemes based on the improved electric power structure data [6].

| Scene | Coal (%) | Natural gas (%) | Oils (%) | Hydropower (%) | Nuclear power (%) | Wind power (%) | Others (%) |
|-------|----------|-----------------|---------|----------------|-------------------|---------------|-----------|
| 2015  | 71.34    | 2.29            | 0.06    | 19.44          | 2.94              | 3.19          | 0.75      |
| Scene 1 | 60.00    | 3.19            | 0.08    | 27.12          | 4.10              | 4.45          | 1.05      |
| Scene 2 | 50.00    | 3.99            | 0.10    | 33.90          | 5.13              | 5.56          | 1.31      |
| Scene 3 | 40.00    | 4.79            | 0.13    | 40.68          | 6.15              | 6.68          | 1.57      |
| Scene 4 | 30.00    | 5.59            | 0.15    | 47.46          | 7.18              | 7.79          | 1.83      |
| Scene 5 | 20.00    | 6.39            | 0.17    | 54.24          | 8.20              | 8.90          | 2.09      |
| Scene 6 | 10.00    | 7.19            | 0.19    | 61.03          | 9.23              | 10.01         | 2.35      |
| Scene 7 | 0.00     | 7.99            | 0.21    | 67.81          | 10.25             | 11.13         | 2.62      |

On this basis, sensitivity analysis and sensitivity factor calculation are carried out under the optimization of coal electricity proportion. According to the life cycle inventory analysis of hydrogen energy, the comprehensive environmental benefit of hydrogen energy production link is poor, especially for the hydrogen production scheme of electrolytic water. Therefore, nine schemes of hydrogen source system are divided into three groups according to storage and transportation mode, so that each group only keeps different hydrogen production schemes, and the other schemes are the same. Among them, scheme 1-3 is hydrogen production from coal gasification, scheme 4-6 is
hydrogen production from natural gas reforming and scheme 7-9 is hydrogen production from electrolytic water. Next, a comparative analysis of comprehensive environmental benefits is made from fossil energy consumption, greenhouse gas emissions and human toxicity (HTP) environmental impact, as shown in Figure 16-18.

Figure 6. The consumption of fossil fuels for end energy (hydrogen and gasoline) varies with power structure.
(a) Three schemes for hydrogen production (high pressure hydrogen + trailer transportation)
(b) Three schemes for hydrogen production (high pressure hydrogen + pipeline transportation)
(c) Three schemes for hydrogen production (liquid hydrogen)
(d) Gasoline scheme

Figure 7. Greenhouse gas emissions from terminal energy (hydrogen and gasoline) vary with power structure.
As shown in the figure, it is intuitively concluded that the life cycle environmental impact of the electrolyzed water hydrogen production scheme is more sensitive to the change of the power structure; according to further calculation, the sensitivity factors of the hydrogen energy scheme and the gasoline scheme with the change of the power structure are listed in Table 5 to verify.

According to the simulation results, the following conclusions can be drawn:

1. After the decrease of coal-to-electricity ratio, the fossil energy consumption, greenhouse gas emissions and human toxicity of hydrogen energy schemes are all reduced. Among them, the electrolytic water hydrogen production scheme (scheme 7-9) has the highest sensitivity, and the sensitivity factor is 1.5-9.0 times that of other hydrogen energy schemes, while the environmental benefits of gasoline schemes are almost unaffected.

2. For the same scheme, the environmental impact sensitivity factor represented by human toxicity (HTP) is greater than that of fossil energy consumption and greenhouse gas emissions, indicating that
the decline of coal-fired power structure has a greater impact on human toxicity potential, and the impact of pollutant emissions on human health will show a relatively more significant decline;

(3) For the evaluation criteria of fossil energy consumption and greenhouse gas emissions, the intersection point between the scheme of hydrogen production by electrolytic water (scheme 3, 6, 9) and other schemes is between 20% and 40% of the coal-electricity ratio, indicating that when the coal-electricity ratio drops to about 40-20%, the consumption of fossil fuels and the level of greenhouse gas emissions from electrolyzed water production are comparable to those of other hydrogen production schemes.

Table 5. Sensitivity factors of hydrogen energy options and gasoline options with changes in power structure

| Scheme | Scheme 1 | Scheme 2 | Scheme 3 | Scheme 4 | Scheme 5 | Scheme 6 | Scheme 7 | Scheme 8 | Scheme 9 | Gasoline |
|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|
| Fossil energy | 0.09 | 0.10 | 0.20 | 0.07 | 0.08 | 0.20 | 0.74 | 0.81 | 0.81 | 0.03 |
| Greenhouse gases | 0.11 | 0.12 | 0.24 | 0.13 | 0.15 | 0.32 | 0.84 | 0.90 | 0.90 | 0.05 |
| Human toxicity | 0.34 | 0.39 | 0.59 | 0.31 | 0.37 | 0.63 | 0.90 | 0.95 | 0.96 | 0.11 |

7. Conclusion

In this study, the life cycle assessment (LCA) theory and method are used to establish the system boundary and inventory analysis model for the life cycle assessment of terminal energy. Based on the gasoline scheme as the benchmark scheme, the comparative assessment of the environmental benefits of the hydrogen source system of fuel cell vehicles in the whole life cycle is carried out. The main indicators include: fossil energy consumption, temperature. Room gas emissions and pollutant emissions. Taking 2015 as the base year and 1 km vehicle driving as the functional unit, this paper selected a set of nine hydrogen source system schemes which accord with the current energy structure and industrial level of China.

(1) From the perspective of environmental benefit evaluation, the comprehensive environmental benefit of the scheme of hydrogen production from natural gas reforming + high pressure hydrogen + pipeline transportation is the best. Compared with the benchmark scheme of gasoline, the fossil energy consumption of this scheme is reduced by 23%, the potential of greenhouse effect is reduced by 29%, and the potential of natural environment and human toxicity is also significantly reduced. Based on the current level of energy, transportation and industry in China, it is suggested that this scheme be used as an ideal route for fuel cell vehicles to promote the whole life cycle of hydrogen source system in the early and middle stages, and the relatively flexible and flexible ground high-pressure hydrogen trailer transportation mode can be used as a supplementary scheme for hydrogen energy transportation.

(2) In the index of the next generation of fuel cell vehicle technology requirements, the simulation of the target fuel cell vehicle power and economic performance index in this paper, the establishment of the tandem type hybrid power system of fuel cell vehicles for 0.1 under the condition of dynamic and economic performance evaluation results in the mixed degree, get the target of fuel cell. The fuel economy of the vehicle is 1.43kg/100km, provide a reference for obtaining hydrogen downstream data life cycle stage.

(3) In the proportion of coal continued to decline, gradually increase the proportion of clean energy scenarios for hydrogen and gasoline benchmark scheme for sensitivity analysis. With the decline of the proportion of coal, hydrogen for fossil energy consumption, greenhouse gas emissions and human toxicity were decreased, the sensitive degree of water electrolysis for the highest sensitivity factor is 1.5-9.0 times of other hydrogen program. In spite of the energy and industrial level at the present stage,
the application of water electrolysis solution will aggravate the deterioration of environment and energy, but when the proportion of coal fell to the current level is below 40%, the comprehensive environmental benefit of water electrolysis is expected to coal gasification, natural gas reforming at the same level. At the appointed time, electrolysis water hydrogen production plan can be used as a supplementary plan for large-scale hydrogen supply demand.

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