**Research about Zero-carbon Energy on Reduction of Carbon Emissions for Commercial Vehicles under "Dual-Carbon" Target**

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**Abstracts: Driven by the "dual-carbon" target, it’s best time for great development for zero-carbon energy, which is a huge role in promoting the emission reduction of commercial vehicles. Based on zero-carbon (Green Electricity, Green Hydrogen and Green Ammonia), this paper carries out the research about carbon emissions prediction between zero-carbon energy and diesel in light-duty trucks and different penetration projects of zero-carbon energy from 2020 to 2060, and the changes in the quantity of light-duty trucks (including stock, increment, scrap and total amount). The calculation results show that CO2 emissions from Diesel is the largest, and shows a gradual upward trend in general, and reaches peak value in 2055 (1.793 billion tons). Based on different penetration projects for Green Electricity trucks, CO2 emissions of peaking is in 2035. As penetration increases, CO2 emissions gradually declines. Reduction of CO2 emissions of Project\_1 is 19.94% will stabilizes after 2055, however CO2 emissions of Project\_4 stabilizes after 2040 and 15 years earlier than Project\_4’s, and CO2 emissions is nearly zero. The change rule of CO2 emissions from "Diesel + Green Hydrogen" and "Diesel + Green Ammonia" is similar, and CO2 emissions from "Diesel + Green Ammonia" is higher than that of "Diesel + Green Hydrogen". The permeability of Project\_4 changes greatly, and the results is a large reduction. Based on 2020’s data, and as gray ammonia is fuel, the results show that the current overall emission level can be reduced only when the CO2 emissions level for the production of ash ammonia reduces less than 30% of the current level.**

**Key words: "dual-carbon" target; light-duty trucks; zero-carbon energy; green electricity; green [hydrogen](C:/Users/ZJTIE/AppData/Local/youdao/dict/Application/10.0.3.0/resultui/html/index.html" \l "/javascript:;); green ammonia; carbon emissions**

**0 introduction**

Since 21st century, the main problem that human society face is energy supply and environmental protection. Statistics data shows that since 1960s, the global temperature has risen year by year. By the end of 2020, the global temperature has risen more than 1℃, compared to the average temperature from 1850 to 1900. If it doesn’t control, temperature will rises 2℃ by 2050, and then major climate disaster is likely to occur[1].

In order to coping climate change, the Paris Agreement was signed by 175 countries in Apr. 2016 and implemented in Nov. 2016. The Paris Agreement is the third international legal document to combat climate change after the United Nations Framework Convention on Climate Change and the Kyoto Protocol, and has established the overall pattern of global climate governance after 2020. The Chinese government has set an independent action target in 2030 as follows: CO2 emissions will peak in 2030, and CO2 emissions per unit of GDP will be reduced by 60%-65% compared with 2005’s level[2].

In Sept. 2020, at the general debate of the 75th session of the United Nations General Assembly, Chinese leaders solemnly announced that 'China will increase its nationally determined contributions, and adopt more effective policies and measures, strive to peak its carbon emissions before 2030, and strive to achieve carbon neutrality before 2060.' The announcement of this important "Dual-Carbon" target has defined the time node for China's response to climate change and green and low-carbon development[3].

The "dual-carbon" target is a huge chance for the automotive industry and puts forward to specific requirements for green, low-carbon and sustainable development. In Dec. 2020, the China Association of Automobile Manufacturers released the 'Energy Saving and New Energy Vehicle Technology Roadmap 2.0'[4]. Among them, low-carbon is one of the three focuses of future automotive development. In May 2024, The State Council issued the 2024-2025 Energy Conservation and Carbon Reduction Action Plan, and proposed to "orderly promote new energy medium and heavy duty trucks and develop zero-emission freight fleets." In May 2024, The State Council issued the 2024-2025 Energy Conservation and Carbon Reduction Action Plan, proposed to "orderly promote new energy medium and heavy duty trucks and develop zero-emission freight trucks."

In order to achieve "dual-carbon" target, it develops non-fossil, green and renewable energy is the only way to achieve energy security, carbon emissions reduction and sustainable economic development.

**1 Research status**

Zero-carbon energy sources such as green electricity, green hydrogen (H2) and green ammonia (NH3) can be widely used. Green electricity mainly comes from hydro-power, solar energy, wind energy, nuclear energy, etc. Green hydrogen can be obtained by green electrolysis of water, and green ammonia is synthesized by green hydrogen and nitrogen.

In 2022, China electricity generation is 8.4 trillion kW·h, of which fire power accounts for 66% and reduces 5 percentage points to 2021 (71% in 2021). Zero-carbon energy accounts for 34%, of which 15% is hydro-power, 9% is wind power, 5% is nuclear power, and 5% is solar energy[5]. The rapid development of power generation of clean energy capacity is conducive to support sustainable economic development.

Light-duty trucks are generally used in urban and suburban areas, and so the trend of electric trucks is accelerating. According to statistics in 2023, the penetration rate of new energy light-duty trucks has reached 12.1%[6]. However, there is problem about battery capacity, insufficient range, inconvenient charging and other problems, it is impossible to completely replace fuel vehicles in the short term. The change from traditional fuel vehicles to burn zero-carbon energy (like green hydrogen and green ammonia) is also one of the development directions for light-duty trucks.

At present, there are three main applications of hydrogen as a fuel for commercial vehicles: hydrogen fuel cells, single hydrogen engines and hydrogen-doped combustion engines. Hydrogen fuel cells are efficient, noiseless, and produce water only. Compared with fuel cells, there is low development and use costs and a wide operating range for hydrogen engines. Due to the particularity of hydrogen, hydrogen engine development focuses on solving the problems of early ignition and knock. Wimmer's study found that with the delay of injection phase, the engine combustion heat release rate decreased and the cylinder pressure showed a downward trend[7]. Ye et al found that with the delay of hydrogen injection time, in-cylinder combustion detonation showed a strong tendency to change hydrogen supply[8]. In 2021, Cummins Corporation produced 6.7L medium-sized hydrogen fuel engine and 15.0L heavy-duty hydrogen fuel engine to further promote the development of hydrogen internal combustion engine and realize the practical application of hydrogen internal combustion engine[9]. BMW, Toyota and other companies have developed hydrogen engine cars, which shows that they have good power, economy and practicability[10].

At present, as a fuel hydrogen is the difficult to storage and transportation, which is difficult to solve in the short term and reduce the use cost. As a carrier of hydrogen, ammonia is easier to liquefy than hydrogen. Under normal pressure, ammonia can be liquefied at -33℃, while for hydrogen it needs to be lower than -253℃, which means that it’s better storage and transportation characteristics for ammonia than hydrogen[11,12]. Some domestic scholars believe that ammonia as a carrier of hydrogen, ammonia-hydrogen fusion fuel as a zero-carbon fuel for vehicle power is an important direction of future development, and commercial vehicles are a scenario for the future application of ammonia[13]. At present, ammonia is widely used in chemical industry, agriculture and other fields, in contrast, the mechanism of ammonia combustion is still being studied. Lesmana calculated the ignition delay and laminar flame velocity of NH3 at different temperatures and pressures under different mechanisms, and compared with existing experimental data in literature, and then found that Otomo mechanism could better predict the ignition delay time and flame velocity than other mechanisms[14]. Reiter and Kong[15,16] reported the research of ammonia-containing dual fuel system in compression-combustion engine. The results show that for the same engine performance, the energy substitution rate of ammonia can reach more than 95%. The fuel economy and emission of exhaust pollutants under different ammonia-diesel ratio were tested on compression combustion diesel engine. It was found that the fuel utilization efficiency was higher when ammonia provided 40%~60% of energy. In Feb. 2024, the world's first ammonia fuel container ship began construction in China, and the application of ammonia fuel began to accelerate, which is a milestone in leading the sustainable and green development of the shipping industry[17].

Since the "dual-carbon" target was proposed, China's new energy automobile industry has developed quickly. As passenger cars as is an example, and the sales quantity of new energy passenger cars in 2019 was 1.04 million, while the sales volume was 7.75 million in 2023, and the penetration rate reached 35.8% at the same time. It can be seen that the development speed of new energy vehicles. Except passenger cars, commercial vehicles are also an important part of China's automobile industry, with sales quantity is 4.03 million in 2023, and the quantity of commercial vehicles (light-duty trucks) is 20.93 million, while the total is still growing rapidly. At present, commercial vehicles still use traditional fossil fuels as the main fuel, and large-scale promotion of zero-carbon energy will help commercial vehicles to achieve low-carbon transformation and achieve the "Dual-Carbon" target. The National Development and Reform Commission and the Energy Administration issued the Medium and Long-Term Plan for the Development of Hydrogen Energy Industry 2021-2035, propose to promote the application of hydrogen fuel in commercial vehicles and gradually establish a complementary development model of hydrogen fuel and electric vehicles[18].

Today, there are few studies on carbon emissions of zero-carbon energy in commercial vehicles (carbon emissions, carbon peak time, etc.). Therefore, this paper carries out the carbon emissions prediction of commercial vehicles (light-duty trucks) in the service cycle, combined with zero-carbon energy penetration, and provides reference and data support for the promotion of zero-carbon energy in commercial vehicles and the research and formulation of policies, like prohibition time of fossil fuel vehicle.

**2. Life cycle analysis for fuel and vehicle**

**2.1 Fuel Properties**

Hydrogen energy is a twice energy with a wide range of sources and many application scenarios. It has the dual properties of raw material and fuel. At Ambient temperature and pressure, hydrogen is a highly combustible gas with high calorific value. It’s colorless, transparent, odorless, tasteless and insoluble in water[19].

Ammonia is a colorless toxic gas, and slightly less dense than air with a typical pungent odor. It’s easily soluble in water. As the world's second largest chemical, there is a mature production process and complete storage and transportation facilities of ammonia. According to the raw materials and carbon emissions used in the ammonia synthesis process, ammonia can be divided into gray ammonia, blue ammonia and green ammonia[20-22]. Gray ammonia is mainly synthesized from fossil energy sources such as coal, methane or petroleum. Blue ammonia is also synthesized using similar raw materials, but using advanced technologies (such as CCUS, carbon capture, utilization and storage technology) to reduce carbon emissions. Green ammonia can be synthesized by carbon-free energy, such as using green electrolysis of water to produce hydrogen, and then synthesized with nitrogen, the whole process is very low carbon emissions.

The main physical and chemical properties of diesel, methanol, hydrogen, and ammonia are shown in Table.1[23].

**Table 1. Main physical and chemical properties of fuel**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Property/Fuel** | **Diesel** | **Hydrogen** | **ammonia** | **Note** |
| Density (kg/m3) | 835 | 70.8 | 682.8 | Liquid state |
| Boiling point (℃) | 180-370 | -253.0 | -33.5 | 0.1MPa |
| Theoretical air-fuel ratio | 14.8 | 34.8 | 6.1 | / |
| Hydrogen mass content (%) | 15.3 | 17.8 | 100 |
| Octane number | / | 130 | 130 |
| Lower calorific value (MJ/kg) | 46.5 | 121.0 | 18.8 |
| Flame travel velocity (m/s) | 33 | 300 | 6 |

**2.2 Life cycle of Ammonia**

China has the second largest coal reserves in the world, and its coal chemical industry is relatively complete. This paper introduces the life cycle model of ammonia production-based coal as raw material.

The life cycle of ammonia fuel starts from the mining of raw coal, and then is sent to the ammonia plant through coal washing and road transportation, and then through the production of gas, transformation, decarburization, and other sections of ammonia synthesis, and finally to fuel of automobiles as the end. The ammonia life cycle process also requires the consumption of secondary energy sources such as diesel, gasoline, and electricity. Figure.1 shows the life cycle system model of ammonia fuel[24]. The mining, coal washing and transportation stages of raw coal are collectively called the raw material stage, the production stage of ammonia is the product stage, and the transportation and vehicle use stage of ammonia fuel is the use stage.

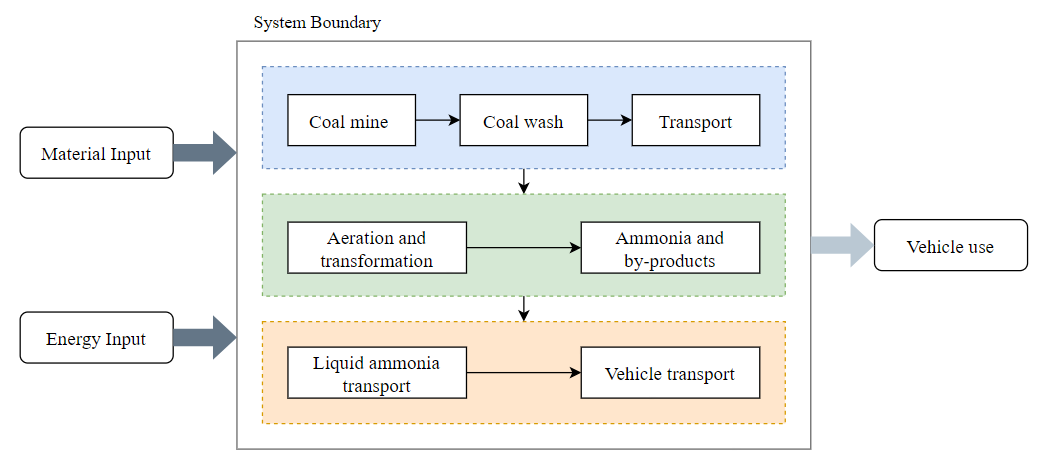


Figure 1. Life cycle system model of ammonia fuel

**2.3 Carbon emissions analysis in the production process**

As diesel is an example, emissions of diesel production include energy consumption emissions, hydrogen consumption emissions and burning emissions. Different regions and different production processes and methods will affect the carbon emissions results. This paper only studies carbon emissions in the production process. Table 2. lists the carbon emissions from the production of diesel, methanol and ammonia under different processes[26]. Green electricity comes from solar, wind, geothermal, etc., and the carbon emissions in the power generation process are almost zero (0.001kgCO2e/kg, in this paper). Green hydrogen comes from the hydrogen obtained by green electrolysis of water, and the carbon emissions are almost zero.

**Table 2. Carbon emissions from different fuel preparation processes**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fuel** | **Process** | **Technical route** | **Carbon Emissions**  **/kgCO2e/kg** | **Note** |
| Diesel | Manufacture | Atmospheric and vacuum distillation and coking (2020) | 0.64 | / |
| Green Electricity | From hydro-power, solar energy, wind energy, nuclear energy, etc. | 0.001 | / |
| Hydrogen | Natural gas reforming (2020) | 2.31 | / |
| Natural gas reforming (2035) | 1.62 |
| Coal electrolysis of water | 53.90 |
| Green electrolysis of water | 0.10 | Green Hydrogen |
| Ammonia | Coal gasification process in China (2020) | 5.94 | Gray Ammonia |
| Natural gas process in China (2020) | 2.91 |
| World Average Level (2020) | 2.90 |
| China Average Level (2020) | 5.02 |
| Green hydrogen is synthesized with N2 | 0.20 | Green Ammonia |

As can be seen from Table 2., the carbon emissions of diesel produced by atmospheric and vacuum distillation and coking in 2020 are 0.64kgCO2e/kg. The carbon emissions of hydrogen by natural gas reforming process are 2.31kgCO2e/kg, and the carbon emissions of hydrogen production using electrolytic water (coal power) are 53.90kgCO2e/kg, which indicates that the carbon emissions of hydrogen production are large and the cost is high. The carbon emissions of hydrogen production by electrolytic water (green electricity) are about 0.10kgCO2e/kg, which is mainly the emissions of electrolyte raw material preparation.

In China, the main methods of ammonia preparation are coal to ammonia and natural gas to ammonia. Compared with the global average level (2.90kgCO2e/kg), the carbon emissions level of coal to ammonia (5.94kgCO2e/kg) is 73.1% higher, indicating that the carbon emissions level of coal to ammonia still be further reduction. The carbon emissions level of ammonia produced from natural gas (2.91kgCO2e/kg) was basically consistent with the global average level. The carbon emissions of the preparation of green ammonia are about 0.20kgCO2e/kg, and the emissions are mainly from the preparation of raw materials such as electrolyte and catalyst, and the emissions of the production process.

**2.4 Carbon emissions during the whole life cycle of vehicles**

1) Calculation formula

According to the relevant principles of international standard ISO14040[25], the basic architecture of the whole life cycle of automobiles is defined, which mainly includes: ① fuel cycle, ② automobile production stage, ③ driving stage of the car(including maintenance), ④ automobile life scrap stage.

|  |  |
| --- | --- |
|  | (1) |

In Equation ⑴,  is the carbon emissions generated in the vehicle life cycle, kgCO2e; , , , and  are carbon emissions generated during raw material acquisition, vehicle production, driving (including maintenance) , scrap recycling respectively, kgCO2e.

2) Assumptions

The carbon emissions of the whole life cycle of a vehicle include three stages: manufacturing, use and recycling. compared with the carbon emissions generated in the use stage, the carbon emissions in the production and recycling stage are relative small. Therefore, it simplifies the study, the following assumptions are made:

1) Don’t consider the carbon emissions of cars in the manufacturing and recycling stages and carbon emissions from maintenance.

2) Only the carbon emissions in the use stage are studied. Based on the mandatory retirement mileage of 1 million km and the 10-year service life, and is calculated with an average annual operating mileage of 100,000km. This is the biggest prediction value.

3) the ratio of commercial vehicles of zero-carbon fuel increases from 0 to 100%.

4) The technical path is based on "Energy Saving and New Energy Vehicle Technology Roadmap 2.0" of China Mainland[4].

Therefore, the carbon emissions during vehicle driving is the emissions from the production of the fuel, and the emissions from the combustion in Equation ⑵.

|  |  |
| --- | --- |
|  | ⑵ |

In Equation ⑵,  is the carbon emissions from fuel production, kgCO2e,  is the carbon emissions from fuel combustion, kgCO2e.

|  |  |  |  |
| --- | --- | --- | --- |
|  | ⑶ |  | ⑶ |

In Equation ⑶,  is the carbon emission generated during the production of unit fuel, kgCO2/kg;  is the quantity of trucks;  is fuel average consumption per kilometer, kg/km;  is mileage, km.

|  |  |
| --- | --- |
|  | ⑷ |

In Equation ⑷,  is the average carbon emissions from combustion of unit km, kgCO2e/km.

For electrical vehicle,the carbon emissions from driving comes from the emissions from power generation process.

**3. Carbon emission prediction at the use stage**

**3.1 Time Range**

In this paper, 2020 is as the base year, and until is 2060 estimated (carbon neutral year), the span is 40 years. The change in carbon emissions is estimated at every 5 years as a time point.

**3.2 Permeability prediction**

Before 2020, the proportion of new energy commercial vehicles is relatively small. According to statistics in 2023, the penetration rate of new energy (electric) light-duty trucks has reached 12.1%[6]. Based on the technological progress of commercial vehicles, the development of zero-carbon energy, and the popularity of corresponding new energy commercial vehicles. In this paper, the penetration rate of zero-carbon energy vehicles is gradually increased, and the ratio of zero-carbon energy vehicles is set at 20% in 2030, and the zero-carbon energy penetration rate is finally achieved at 100% in 2050 (national plan), that is, the quantity of new diesel vehicles in 2050 and beyond is 0. In the European Union, the bill passed in 2023 completely bans the sale of fossil fuel vehicles by 2035, and only allows the sale of pure electric and carbon neutral (zero-carbon) fuel vehicles[28]. Therefore, 2035 is a key time point. In setting the penetration plan, this paper takes into account national plans and EU laws, and the penetration forecast plan (pure electric vehicles) is shown in Table 3a). Project setting is influenced by national policies, international environment and other factors. Hydrogen and ammonia vehicles, currently in a small range of commercial and development, assume a penetration rate of 1% in 2025, 5% in 2030, and is expected to achieve 100% penetration in 2050, Project\_1. Project\_1 is the penetration scheme developed in accordance with national planning, and Project\_4 is the penetration scheme developed in accordance with EU law. The permeability increases gradually from Project\_1 to Project\_4. Table 3b) lists.

**Table 3. Permeability prediction (unit: %)**

1. Electric Vehicle

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Project Year | 2020 | 2025 | 2030 | 2035 | 2040 |
| Project\_1 | 0 | 15 | 20 | **30** | 50 |
| Project\_2 | 0 | 20 | 35 | **50** | 70 |
| Project\_3 | 0 | 20 | 40 | **70** | 100 |
| Project\_4 | 0 | 25 | 50 | **100** | 100 |
| Project Year | 2045 | 2050 | 2055 | 2060 | |
| Project\_1 | 75 | 100 | 100 | 100 | |
| Project\_2 | 100 | 100 | 100 | 100 | |
| Project\_3 | 100 | 100 | 100 | 100 | |
| Project\_4 | 100 | 100 | 100 | 100 | |

1. Green Hydrogen Vehicle and Green Ammonia Vehicle

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Project Year | 2020 | 2025 | 2030 | 2035 | 2040 |
| Project\_1 | 0 | 1 | 5 | **15** | 40 |
| Project\_2 | 0 | 1 | 10 | **25** | 50 |
| Project\_3 | 0 | 1 | 15 | **30** | 60 |
| Project\_4 | 0 | 1 | 30 | **100** | 100 |
| Project Year | 2045 | 2050 | 2055 | 2060 | |
| Project\_1 | 70 | 100 | 100 | 100 | |
| Project\_2 | 80 | 100 | 100 | 100 | |
| Project\_3 | 100 | 100 | 100 | 100 | |
| Project\_4 | 100 | 100 | 100 | 100 | |

**3.3 Quantity estimation**

Based on the quantity of light-duty trucks in 2020 and the research report on the development trend of Chinese automobiles, the quantity is predicted to be 2060. In 2020, there are 20.93 million trucks in China mainland. According economics development forecast and better logistics system, there would be 159.41 million total stocks in 2060[26]. Table 4. lists quantity forecast of light-duty trucks of Project\_1.

**Table 4.** Quantity forecast of light-duty trucks of Project\_1 (Unit: thousand)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Type\Year** | | **2020** | **2025** | **2030** | **2035** | **2040** |
| Diesel | Stock | 2,093 | 2,093 | 1,687 | 3,016 | 2,784 |
| Increment | 0 | 1,687 | 3,016 | 2,784 | 2,881 |
| Gross | 2,093 | 3,780 | 4,703 | 5,800 | 5,665 |
| Scrap | 0 | 0 | 2,093 | 1,687 | 3,016 |
| Carbon neutral fuel | Stock | 0 | 0 | 298 | 754 | 1,193 |
| Increment | 0 | 298 | 754 | 1,193 | 2,881 |
| Gross | 0 | 298 | 1,052 | 1,947 | 4,074 |
| Scrap | 0 | 0 | 0 | 298 | 754 |
| Total Stock | | 2,093 | 4,078 | 5,755 | 7,747 | 9,739 |
| **Type\Year** | | **2045** | **2050** | **2055** | **2060** | |
| Diesel | Stock | 2,881 | 1,791 | 0 | 0 | |
| Increment | 1,791 | 0 | 0 | 0 | |
| Gross | 4,672 | 1,791 | 0 | 0 | |
| Scrap | 2,784 | 2,881 | 1,791 | 0 | |
| Carbon neutral fuel | Stock | 2,881 | 4,178 | 7,755 | 8,067 | |
| Increment | 4,178 | 7,755 | 8,067 | 7,874 | |
| Gross | 7,060 | 11,933 | 15,822 | 15,941 | |
| Scrap | 1,193 | 2,881 | 4,178 | 7,755 | |
| Total Stock | | 11,732 | 13,724 | 15,822 | 15,941 | |

**3.4 Key parameters**

According to Table1., Diesel, Green Electricity, Green Hydrogen and Green Ammonia were chosen selected for research. With reference to the overall emissions reduction targets of the "Energy-saving and New Energy Vehicle Technology Roadmap 2.0" of China Mainland[4], the carbon emissions and consumption of diesel production in 2025, 2030, 2035,2050 and 2060 are set to be reduced by 8%, 10%, 15%, 30% and 40% respectively, compared with 2020’s level. In other years, it deals by difference processing. The production emissions of Green Electricity, Green Hydrogen and Green Ammonia are small and remain unchanged. Consumption is average fuel consumption of light-duty trucks.

The data for the calculation of carbon emissions in the use stage are shown in Table 5.

**Table 5.** Key parameters of carbon emissions in the use stage

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Type | **Parameters** | | |
| **Carbon emissions in production**  **(kgCO2e/kg)** | **Consumption**  **(kg/100km)** | **Carbon emissions in burning**  **(kgCO2e/km）** |
| 2020 | Diesel | 0.64 | 10.02 | 0.31 |
| 2035 | 0.54 | 8.52 | 0.26 |
| 2050 | 0.45 | 7.02 | 0.22 |
| 2060 | 0.38 | 6.00 | 0.19 |
| 2020 | Green Electricity | 0.013 | 0.129 | 0 |
| 2035 | 0.011 | 0.094 |
| 2050 | 0.009 | 0.063 |
| 2060 | 0.008 | 0.048 |
| 2020 | Green Hydrogen | 0.10 | 3.84 | 0 |
| 2035 | 0.10 | 3.27 |
| 2050 | 0.10 | 2.70 |
| 2060 | 0.10 | 2.31 |
| 2020 | Green Ammonia | 0.20 | 24.8 | 0 |
| 2035 | 0.20 | 21.1 |
| 2050 | 0.20 | 17.4 |
| 2060 | 0.20 | 14.9 |

**5.7 Analysis of calculation results**

.⑴ Carbon emissions forecast (2020－2060)

The CO2 emissions of light-duty trucks from different fuels during the service phase in 2020-2060 are shown in Figure 2. "Diesel + Green Electricity" indicates that different trucks using Diesel and Green Electricity.

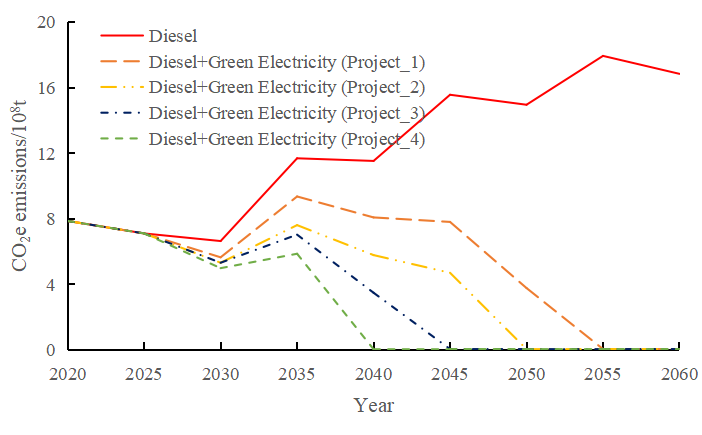


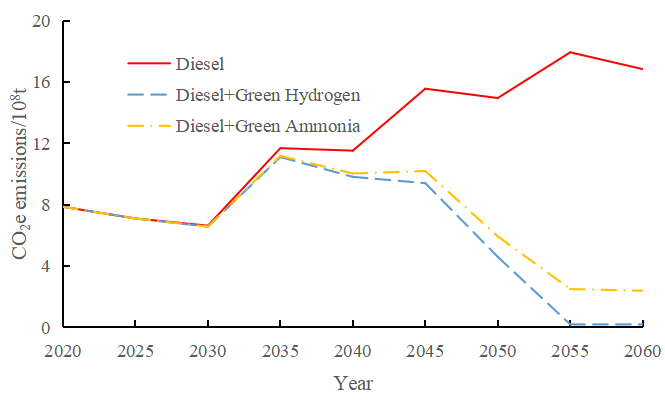
Figure 2. Comparison of CO2 emissions from 2020 to 2060

As can be seen from Figure 2. according to Table 3a), CO2 emissions from burning single diesel are the largest, and is a gradual upward trend in general, and reaching a peak in 2055 (1.793 billion tons). CO2 emissions from Project\_1 to Project\_4 is from diesel + green electricity. It can be seen that the penetration rate of pure electric vehicles increases, CO2 emissions gradually decline. The peak emissions will appear in 2035, and is 936 million tons for Project\_1 and 586 million tons for Project\_4, which decreases by 19.94% and 49.85% respectively compared with Diesel. CO2 emissions of Project\_1 will stabilize after 2055, and Project\_4 will stabilize after 2040, and 15 years earlier than scenario 1. CO2 emissions of Project\_1 and Project\_4 is 0.037 billion tons in 2060, compared with 1.684 billion tons when diesel is used, which is close to zero emissions. Project\_ 2 and Project\_3 is between Project\_1 and Project\_4.

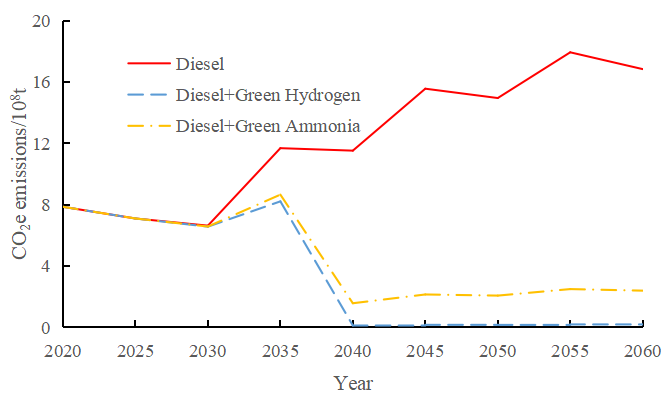
Figure 3. shows the comparison of CO2 emissions calculated according to Table 3b). "Diesel + Green Hydrogen" and "Diesel + Green Ammonia" means CO2 emissions generated by Diesel and Green Hydrogen or Diesel and Green Ammonia respectively.

As can be seen from Figure 3a), based on Project\_1, CO2 emissions from "Diesel + Green Hydrogen" and "Diesel + Green Ammonia" are similar, and is peak in 2035 of 1.111 billion tons and 1.118 billion tons respectively, and then gradually decreasing, and the emissions are stable in 2055 of 0.19 million tons and 240 million tons respectively. Compared with Diesel, and CO2 emissions "Diesel + Green Hydrogen" is close to zero emissions.

As can be seen from Figure 3b), based on Project\_4, CO2 emissions of "Diesel + Green Hydrogen" and "Diesel + Green Ammonia" will be peak in 2035, and is 822 million tons and 866 million tons respectively. It then drops sharply and basically stabilizes after 2040, and CO2 emissions from "Diesel + Green Hydrogen" is about 17 million tons, and emissions from "Diesel + Green Ammonia" is fluctuating slightly and about 214 million tons. The permeability of Project\_4 changes greatly, and is a large reduction.



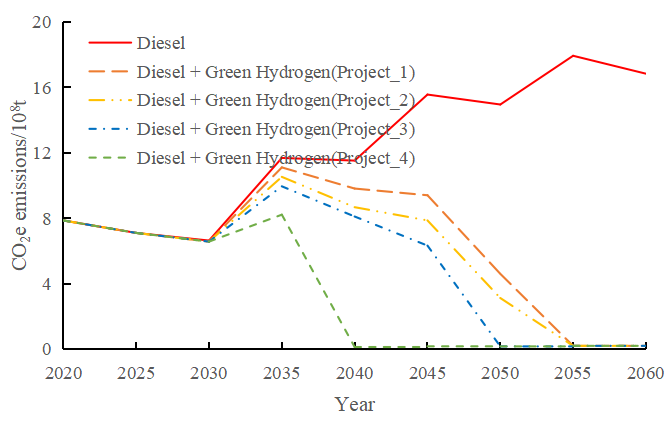
1. Project\_1



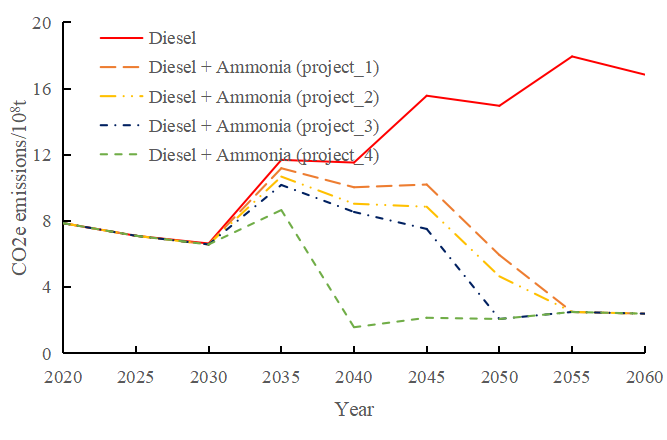
1. Project\_4

Figure 3. Comparison of CO2 emissions from 2020 to 2060

Figure 4 shows the carbon emissions from "Diesel + Green Hydrogen" and "Diesel + Green Ammonia" under four permeability schemes respectively. The results show that with the gradual increase of permeability, the carbon emissions of "Diesel + Green Hydrogen" and "Diesel + Green Ammonia" decrease gradually. For "Diesel + Green Hydrogen" ,carbon emissions of Project\_1 and Project\_2 stabilizes in 2055, while Project\_3’s can stabilize in 2045. Project\_4’s declines very quickly.

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1. "Diesel + Green Hydrogen" and Diesel

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1. "Diesel + Green Ammonia" and Diesel

Figure 4. Comparison of CO2 emissions from 2020 to 2060

1. **Carbon emission prediction from gray ammonia**

Despite the rapid development of zero-carbon energy, it is difficult to replace traditional energy in the short term. Overall emissions decreases by reducing the carbon emissions of ammonia and hydrogen production. In terms of storage and transport, ammonia is currently a better fuel. Based on 2020’s data, it is assumed that the production emissions in 2035 and 2050 are 65% and 30% of the 2020’s average level, i.e. 3.26kgCO2e/kg and 1.51kgCO2e/kg. The comparison results are shown in Figure 5.

As can be seen from Figure 5., under the conditions of 2020, the choice of Green Ammonia as fuel can significantly reduce carbon emissions. When the permeability is 0, CO2 emissions is 1.067 billion tons, and when the permeability is raised to 100%, CO2 emissions is 141 million tons, is a reduction of 86.8%. At this stage, the extraordinary development of Green Ammonia industry has an immediate and obvious effect on reducing the carbon emissions of commercial vehicles. Under the current conditions, the use of Gray Ammonia as fuel will greatly increase the overall emissions, because CO2 emissions in production process is so high. Only the carbon emissions level of the production of Gray Ammonia will be lower to 30% of the current level, to maintain the current overall emissions level. To use Gray Ammonia to reduce carbon emissions, carbon emissions in the production process must decrease greatly reduced, and it is possible to achieve.

Based on the comparison of zero carbon fuel as Green Hydrogen vs Green Ammonia, the difference of CO2 emissions is only 13.2% (1-86.8%), this means that under the hydrogen is convenient and economic conditions, hydrogen will be the best as an alternative zero carbon fuel for heave duty trucks, but consideration of the current cost of hydrogen storage and transport, the ammonia is an excellent alternative zero carbon fuel instead of hydrogen.

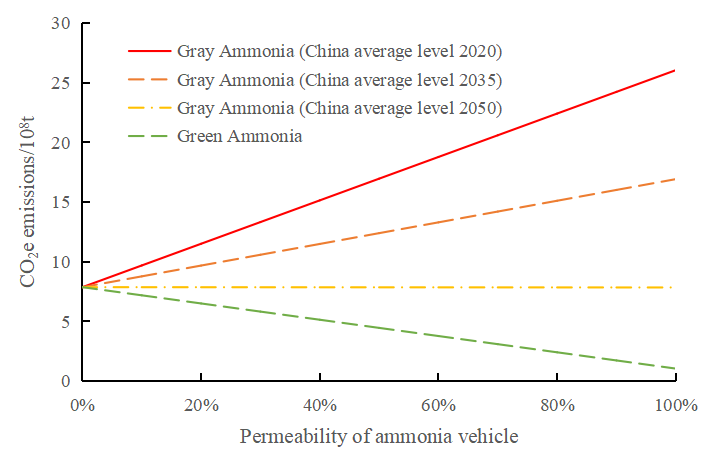


Figure 5. Comparison of CO2 emissions in 2020

**4 Conclusion**

With the implementation of the "dual carbon" goal, zero-carbon energy has been rapidly developed, and is a significant role in the emissions reduction of commercial vehicles. Based on the predicted penetration rate of zero-carbon energy vehicles and the changes in the quantity of light-duty trucks (including stock, increment, scrap and total), this paper carries out the carbon emissions prediction (2020-2060) for the use stage of zero-carbon energy on light-duty trucks. The conclusions are as follows:

⑴ CO2 emissions from burning Diesel are the largest, and it shows a gradual upward trend in general and reaching a peak in 2055 (1.793 billion tons). Based on different penetration projects for green electric vehicles, carbon emissions gradually decreases as the permeability increases. The peak emission of "Diesel + Green Electricity" will appear in 2035, with 936 million tons for Project\_1 and 586 million tons for Project\_4, which will decrease by 19.94% and 49.85% respectively compared with Diesel. CO2 emissions of Project\_1 will stabilize after 2055, and Project\_4’s stabilize after 2040, 15 years earlier than Project\_1. CO2 emissions of Project\_1 and Project\_1 is 0.037 billion tons in 2060, compared with 1.684 billion tons when diesel is used, which is close to zero emissions. CO2 emissions of Project\_2 and Project\_3 are between Project\_1 and Project\_4.

⑵ The changes law of CO2 emissions of "Diesel + Green Hydrogen" and "Diesel + Green Ammonia" are similar. Under Project\_1, emissions peak is in 2035, and then gradually decreases, and stabilize in 2055, and for Project\_4, in 2040.

⑶ it’s useful to accelerate the penetration rate of zero-carbon energy vehicles will help to achieve early carbon emission decline and stability.

⑷ Using gray ammonia as a fuel based on the 2020 data, the results show that the current overall emissions level can be maintained and reduced only if the carbon emission level of ash ammonia preparation is reduced to 30% or less of the current level. It can be seen that only when the CO2 emissions level of ash ammonia preparation is greatly reduced, ash ammonia as a carbon reduction fuel is meaningful.

⑸ In this paper, as 5 years is the base calculation analysis. In fact, for light-duty trucks it is fully possible to achieve a carbon peak in 2030, and achieve stable carbon emissions before 2050, and close to zero emission.

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**CONFLICT OF INTEREST STATEMENT**

Authors have no conflict of interest relevant to this article.

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