Analysis on energy saving and emission reduction of clean energy technology in ports

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Abstract. This paper discusses the application of clean energy technology in ports. Using Ningbo port Co. Ltd. Beitun second container terminal branch as an example, we analyze the effect of energy saving and emission reduction of CO₂ and SO₂ by clean energy alternative to fuel oil, and conclude that the application of clean energy technology in the container terminal is mature, and can achieve effect of energy-saving and emission reduction of CO₂ and SO₂. This paper can provide as a reference for the promotion and application of clean energy in ports.

1. Introduction
Clean energy refers to the energy which does not produce harmful substances emissions, including renewable and non-renewable energy. Renewable energy is the energy that can be recovered after consumption and does not produce or produce little pollutants, such as solar energy, wind energy, geothermal energy, bioenergy and ocean energy, etc. Non-renewable energy is used to minimize the pollution of the ecological environment during production and consumption, including low-pollution fossil fuels such as natural gas, and fossil fuels treated with clean energy technologies such as clean coal, clean oil, etc. [1]. The research and utilization of clean energy technology has been developed by the United Nations Framework Convention on Climate Change (UNFCCC) and has become an important way in the world to reduce greenhouse gas emissions such as CO₂. At the same time, clean energy technologies can reduce the application of fossil energy and emissions of air pollutants, so as to improve energy application efficiency. Therefore, clean energy is considered to be essentially a technology system for energy use. The Chinese government has vigorously promoted clean energy technologies, hoping to reduce carbon and pollutant emissions.

2. Application of clean energy in ports
After the 20th century, China's economy has been in a high-speed development stage, at the same time resulting in energy shortages, environmental pollution, climate change and other issues. Therefore, the development and utilization of clean energy has aroused great concerns of government departments. Ministry of Transport of the People's Republic of China in June 2014 issued 'on the promotion of port transformation and upgrading of the views of guidance' [2]. The document encourages port enterprises to use liquefied natural gas (LNG), wind energy, solar energy, increases the use of clean energy in the port to promote the port transformation and upgrading to achieve the sustainable development of the port. The document facilitates the use of clean energy in ports, especially for container terminals as the main practitioner.
The use of clean energy can be summarized as three kinds. First, the application of renewable energy, ground source heat pump and solar water heater alternative fuel or coal-fired boiler heating, wind and solar lighting and other alternative shore electricity, to reduce energy consumption and pollutant emissions. Second, the application of LNG, mainly to replace transport vehicles fuel, reduce pollutant emissions. Third, the application of onshore power, mainly to replace diesel generator power generation, thus reduce fuel consumption and pollutant emissions.

The use of clean energy will increase business costs. Now clean energy is mainly used in large-scale ports which face higher environmental requirements, including Shenzhen Yantian Port, Ningbo Zhoushan Port, Shanghai Port, Qingdao Port and so on. The clean energy technology is not yet widely used in China.

3. Energy saving and emission reduction analysis
Using Ningbo port Co. Ltd. Beilun second container terminal branch (NBSCT) as an example, we analyze the effect of energy saving and emission reduction by the use of clean energy.

3.1. Terminal background
The terminal is one of the best container terminals for super-sized container ships over 10,000 twenty-feet equivalent unit (TEU) capacities. It is one of the most advanced terminal in energy saving and emissions reduction in China. It is the first container terminal company to power tire cranes with electricity instead of diesel fuel. It is also one of the first companies in the country to spread the use of LNG container trucks. The terminal was first evaluated as one of the 'China green port' in 2016. It has used solar energy, wind energy, geothermal energy, LNG, and onshore power. It is the most advanced company in application of green energy, energy-saving emission reduction effect is significant.

3.2. Analysis method

3.2.1. energy use compare method. It is the comparison of energy consumption and pollutant emissions before and after cleaning alternative fuel or onshore power.

3.2.2. standard coal equivalent coefficient method. The standard coal equivalent coefficient method is used to convert the physical quantity of energy by standard coal equivalent. So it is easy to compare energy consumption. Standard coal equivalent coefficient is illustrated in Table 1.

|                  | Diesel(t) | Electricity (10,000kWh) | LNG (t) | Solar energy (MkJ) |
|------------------|-----------|------------------------|---------|--------------------|
| tce<sup>a</sup>  | 1.4571    | 3.15                   | 1.862   | 29.3               |

<sup>a</sup> tce ( ton of standard coal equivalent ) is 1 ton of standard coal equivalent. It is conversion target based on the calorific value of standard coal to calculate the conversion of various energy.

<sup>b</sup>10,000kWh = 3.15tce. 3.15tce is the average calorific value of coal consumption of 10,000 kWh electricity in 2015 in China.

3.2.3. Emission factor calculation method. Emission factor calculation method is used to calculate emissions of CO₂, SO₂ after using fossil energy. Emissions of CO₂, SO₂ are illustrated in equation (1).

\[ E_{CO_2,SO_2} = EC \times EF \]  

\( E_{CO2,SO2} \) is emission of CO₂ (t) or SO₂(kg), \( EC \) is energy consumption (t, kWh). \( EF \) is emission factor of CO₂ (t/t, t/ kWh) or SO₂(kg/t, kg/ kWh). \( E_{CO2,SO2}, EC, EF \) are illustrated in Table 2.
Table 2. Emissions factor of CO$_2$, SO$_2$.

|                   | Diesel(t) [4] | LNG(t) [4] | Electricity(kWh) |
|-------------------|---------------|------------|------------------|
| EF$_{CO_2(t)}$    | 3.1605        | 2.8376     | 0.0008           |
| EF$_{SO_2(kg)}$   | 0.7           | —          | 0.0028           |

Most of China's power is generated by thermal power plants, and most of thermal power plants are coal-fired power plants. According to the data provided by the China Electricity Council, energy resource consumed per unit electricity generated by 6MW and above power plants in China is 315gce/kWh in 2015, we calculate that one kilowatt-hour of electricity emitted carbon dioxide 0.0008t.

3.3. Analysis of the energy saving and emission reduction

In NBSC, they mainly use air energy, solar and wind energy as the renewable energy, the following is the result.

3.3.1. Air Source Heat Pumps. Currently, NBSC has installed 5 air source heat pumps in the replacement of oil boilers to provide 35 tons hot water for the staff canteen and shower rooms each day, fuel oil was totally replaced [5]. As a result, it used 8.110.000 kWh electricity to replace 281.83 ton fuel oil, saving energy 377.92 tce, and reduced 823.73 ton CO$_2$ and 0.20 ton SO$_2$.

3.3.2. Solar water heater. NBSC replaced oil boilers with solar heaters in staff laundries, the solar collection area of which was 5.62 m$^2$[5]. As a result, in 2015, NBSC consumed 407.47 MKJ heat energy, replaced 20.25 tons fuel oil, saving 13.9 tce energy, and reduced 1296 tons CO$_2$ and 0.13 ton SO$_2$.

3.3.3. Wind and light hybrid street lights. NBSC installed 8 wind and light hybrid street lights, saving 4380 kWh of electricity annually [5], saving 1.38 tce energy, and reduced 3.51 tons CO$_2$ and 0.01 ton SO$_2$.

3.3.4. Use of LNG. Currently, NBSC has a total of 130 container trucks, including 110 LNG container trucks, accounted of 84.6% [5]. In 2015, NBSC consumed 2628.9 tons LNG, replaced 2542.65 tons diesel, increasing energy consumption 1190 tce, reducing 576.28 ton CO$_2$ and 17.80 ton SO$_2$. According to China's current calculation method, container trucks using LNG will increase the energy consumption more 32% than that of diesel. The calculation method does not exclude the current LNG leakage caused by engine technology, so 1 ton LNG equivalent to the amount of standard coal is high.

3.3.5. Onshore power. Onshore power is the technology of using the electricity supplied by shore municipal power grids for vessels at berth instead of power generated by auxiliary engines on board consuming diesel. During the 12th five-year period, the Ministry of Transport of the People's Republic of China issued a series of relevant documents, in order to guide the port to use shore electricity, to achieve emission reduction of vessels at berth. NBSC has installed onshore power facilities supplied with low voltage and normal frequency electricity, mainly used for domestic vessels, for which the power of whose auxiliary engines is no more than 120 kW[5]. In 2015, 343 ships stopped at the port, consuming 3.96*10,000 kWh, replacing 11.87 tons fuel oil, saving 12.47 tce energy, and reduced 4.97 ton CO$_2$ and 0.50 ton SO$_2$.

3.3.6. By the application of air source heat pumps, solar water heater, wind and light hybrid street lights, onshore power, NBSC reduced the energy consumption significantly. It reduced much CO$_2$ and SO$_2$. And while the use of LNG container trucks increased energy consumption, it significantly reduced CO$_2$ and SO$_2$. The results are shown in Table 3.
4. Conclusions and suggestions

By the case study on application of clean energy in NBSCT, air, solar, wind, light, electricity energy can be applied primarily to fuel replacement at ports, with significant CO\textsubscript{2} and SO\textsubscript{2} emission reductions.

The application of LNG in port will sufficiently reduce CO\textsubscript{2} and SO\textsubscript{2} emissions, but according to China's current calculation method it will also increase the overall energy consumption. Chinese government encourages the use of LNG to reduce air pollution. However, using current calculation methods to assess energy consumption, this may result in large energy consumption. Consequently, enterprises are not willing to use LNG. It is also required in China that energy consumer should record its consumption. Since container trucks in the port are owned and managed by third parties, the consumed LNG are beyond NBSCT’s coverage.

In accordance with the international practices, CO\textsubscript{2} emissions include direct emissions and indirect emissions. In this paper, direct emissions are derived from burning diesel and LNG, and indirect emissions are those caused by the generation of electricity.

References

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