



The approach to air pollution control and the utilization of marine renewable energy in the UK

Yang Wu

College of Humanities and Foreign Languages, Xi'an University of Posts and Telecommunications, Xi'an 710121, China, email: stellaw84@126.com

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ABSTRACT

In the process of industrialization and urbanization, the urban smog in the UK is becoming increasingly severe. Smog has caused a certain degree of harm to people's life safety, animal and plant health and the appearance of buildings. In view of the characteristics of the mixed air pollution state, the British government began to carry out comprehensive governance. A series of measures, such as increasing the use of new energy, formulating long-term environmental protection plans, making environmental data public and information transparent, and strengthening public participation in air quality supervision, have all laid a solid foundation for the UK's environmental governance. It is worth mentioning that the UK's use of marine renewable energy plays an important role in environmental protection, such as the development of tidal energy and the use of offshore wind energy resources, which are in a leading position in the world. Through a series of governance measures, the UK's air pollution control has achieved significant results.

Keywords: Britain; Air pollution; Marine renewable energy; Governance

1. Introduction

Since the Industrial Revolution, the problem of smog pollution in Britain has become more and more serious, in the process of industrialization and urbanization, the environment is threatened, the air pollution has become a major environmental problem in British cities, severe air pollution has made local people suffer a lot. After a long process of smog control, the pollutant emissions have fallen dramatically. Especially the utilization of marine renewable energy plays an important role in environmental protection. The development and utilization of tidal energy and offshore wind energy have promoted ecological protection in the UK. The utilization of these clean energy sources effectively reduces the carbon emissions. The UK's environmental protection measures have also set an example worldwide.

2. Harmfulness caused by air pollution in the UK

2.1. Harmful to people's health and life

Air pollution is, in the first place, a serious threat to the lives and health of local residents. Pollution has increased rapidly since the Industrial Revolution. In the week after the heavy smog in early December 1873, 520 people died of tuberculosis, 764 died of respiratory disease and 1,112 died of respiratory disease. According to statistics, the smog in London from February 1st to 7th, 1880 caused 1557 deaths from respiratory diseases; On January 9th, 1892, the smog killed more than 1,317 people. In the smog of 1880, 1891 and 1892 in London, deaths from bronchitis were 130%, 160% and 90% higher than usual, respectively. In 1868, Manchester health officials discovered that the factory's middle-aged workforce was vulnerable to bronchitis and emphysema caused by the smog. Sulfur dioxide

(SO₂) is a major air pollutant, and its emissions in the UK showed an increasing trend during the 19th and 20th centuries (Fig. 1). It is estimated that a quarter of all deaths in Victorian Britain were caused by air pollution. In addition, thick smog blocks out a lot of sunlight in the city, and the gloomy weather can also cause the cartilaginous bone disease and mental illness among the city residents.

2.2. Damage to buildings, plants and animals

In addition to the harmful to human life and health, pollutants also cause serious corrosion and damage to buildings. London's St Paul's Cathedral, St Peter's Cathedral and New Exchange House in the strand were all affected by the smog, and the Houses of Parliament showed signs of falling stone before they were finished. High levels of air pollution can cause death or genetic mutations in animals. The first black sample of peppered moth was caught in Manchester in 1848, others were found in London later, light moths were almost extinct in smoggy areas in the 1870s, and butterflies were blackening. Animal deaths caused by smog were a regular occurrence in the 19th and 20th centuries. At a London fair in 1873, two cows died at dawn in the exhibition hall, and by 9 a.m., the reception area was full of sick animals who were tested as suffocating, their lungs filled with black blood. In addition, many plants find it difficult to grow in urban areas with heavy air pollution. The smog caused the green plants to become dull and even drop their leaves. After the great smog of London in 1894, the flowers of some plants were found to have shrunk and even turned black. Robert Angus Smith planted 20 camellia plants two miles downwind of Manchester city centre to test the effects of sulphur in the air and found the flowers to be dull or dead. After suffering serious damage from smog, people began to realize that smog is a harbinger of social disorder, environmental imbalance and biological degradation. How to control urban smog has become a major concern of British society.

3. Control methods of air pollution in UK

3.1. Utilization of marine renewable energy

Reducing emissions is one of the most effective methods for air pollution prevention and control, the utilization

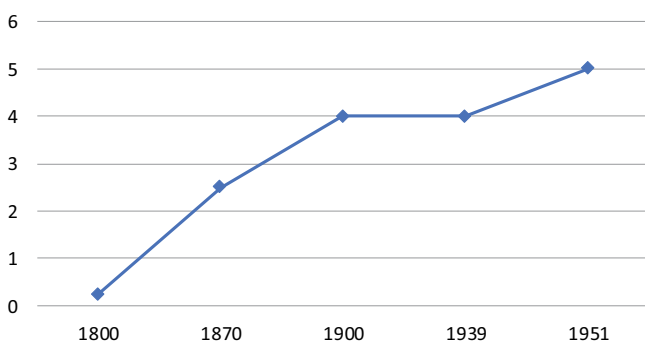


Fig. 1. Sulfur dioxide emission trend chart in the UK from 1800–1951 (unit: million tons). Data mapping according to Blaine William Clapp, *Environmental History of Britain since the Industrial Revolution*, 2021, p. 49.

of tidal power is expected to play an important role in promoting zero emissions in the UK. As a renewable energy, tidal energy has large reserves and low operating costs. Tidal energy converts the potential energy formed by the rising tide and ebbing tide of seawater into electric energy or other forms of energy. Tidal energy is easy to predict in terms of production and time, and is the most guaranteed marine energy now and in the near future. With the importance of environmental protection, more and more people are seeing the potential of this renewable energy source. The UK tidal energy technology is relatively mature, and the UK has the world's leading wave energy and tidal energy development technology. In Europe, the UK has the most marine energy infrastructure, with 13 locations, which contribute to the development and transformation of marine energy technology. Researchers from the University of Manchester said: "The wind and solar energy on the sea are intermittent, but we can determine when the tide will rise and fall. The utilization of tidal energy plays an important role in environmental protection". In 2021, four commercial scale tidal energy projects in the UK were successfully tendered, two of which were from Orbital Marine and the other from Simec Atlantis. It is estimated that by 2027, these projects will increase the power generation of tidal energy in Britain by nearly five times.

The development of the UK offshore wind energy industry is relatively mature and has entered a stage of large-scale commercial application. The UK has vast sea areas and high-quality wind energy resources. Starting from 2008, the UK ranked first in Europe with an installed capacity of 598 MW, and reaching 883 MW in 2009. In 2010, the UK put into operation the world's largest offshore wind power plant, with an investment of £780 million and a maximum production capacity of 300 MW, which is sufficient for over 200,000 households to use. In the past 10 y, the power generation of offshore wind power has gone from only 4% of British households to 33% of British households. Ecological protection has been deeply integrated into the development of marine energy in the UK.

3.2. Low carbon development, green upgrading

In order to reduce the concentration of harmful particulate matter in the air, the UK is a representative country in the use of new energy. In terms of energy restructuring, one important point is that the shift from coal to oil and gas. With the development of North Sea oil and gas fields in Britain in the 1960s, oil and natural gas became a new energy source to replace coal. According to the UK's National Grid, wind, solar, nuclear and imported electricity via undersea cables accounted for 48.5% of the UK's electricity consumption in 2019. As shown in Table 1, 48.5% of electricity is generated from zero-carbon sources, 43% is generated from fossil fuels and biomass provides the remaining 8.5% in UK in 2019. For the first time, zero-carbon energy has overtaken fossil fuels as the biggest source of electricity generation in UK, nearly half of the UK's electricity needs are generated from zero-carbon sources [1].

In addition to the use of oil and gas resources, wind energy, water energy, solar energy and other renewable clean energy also gradually into people's life. The city of

London uses wind and solar power to replace some of the electricity supplied by the National Grid, adjust the distribution of energy supply and distribution, and achieve emission reduction targets through the green energy plans. The UK government has pledged to reduce its carbon emissions by at least 100% from 1990 levels by 2020, making it a net zero emitter [2]. London is now the center of the global low-carbon economy, phasing out energy-intensive industries and promoting clean energy, which plays a positive role in national ecological and environmental protection. As shown in Table 2, the utilization rate of renewable energy in the UK is increasing year by year, increase from 25% in 2015 to 36% in 2019.

In 2019, coal's share of power generation fell to 1.9%, and the UK set a new record for continuous zero-coal generation, with 18 consecutive days from May to June, the longest continuous zero-coal generation since records began in 1882. By the end of the winter in 2019, the UK had just four coal plants left. In addition, nuclear power accounted for 17% of the UK's electricity consumption in 2019, up from 20% in 1990, and gas generation accounted for 38% of total electricity consumption in 2019, up from just 0.1% in 1990. John Pettigrew, chief executive of UK National Grid, said: At National Grid, we play an important role in accelerating progress towards a cleaner future and we are committed to delivering a secure energy system for all. A growing number of offshore wind projects in UK helped the country generate more offshore wind power than onshore for the first time in the third quarter of 2019, according to government figures. In December 2019, National Grid unveiled plans to invest almost 10 billion pounds in UK gas companies and electricity networks over the next 5 y, of which almost 1 billion pounds was earmarked for the transition to a net-zero power system, including investment in new equipment and technology. An additional 85 million pounds will be available to help people switch from gas to electric heat pumps and hydrogen

boilers. National Grid estimates that more than 23 million households will have new low-carbon heating by 2050. As a global center for green finance, the UK has established the world's first green investment bank, which raised \$26 billion in 2019 alone dollar funds. Solar capacity in the UK is growing steadily, Chris Hewett, chief executive of the Solar Trade Association, said: They paint a picture of a stagnant market, when in fact the UK solar market has stabled and recovered after several difficult years. The UK's cumulative generating capacity reached 13.35 GW at the end of 2019, with the majority of installed capacity coming from solar plants of between 5 MW and 50 MW (4.39 GW). Solar accounted for 28% of the renewable energy mix in 2020. In 2020, 43% of the UK's electricity came from renewable sources, including wind, solar and biogas, up from 37% in 2019. According to statistics, 13% of the UK's electricity comes from offshore wind and 11.1% from onshore turbines, resulting in a record 75.7 TWh of wind capacity in 2020, accounted for 24.1%. In 2020, offshore wind power production was particularly strong, growing by 29% compared with last year. The UK's total energy production and consumption figures for 2020 confirm the sharp decline in fossil fuel production and the growing share of renewables. Overall energy demand, including petroleum fuels for transportation, has fallen to 1950s levels due to COVID-19 restrictions, with total consumption falling by 13% year-on-year. In electricity generation, the share of coal power in UK has fallen to 1.8%, compared with 35.7% for gas peak-scaling plants. Renewable energy has outpaced fossil fuels, with electricity generation from renewables increasing from 6.9% since 2010 to its current all-time high. Table 3 shows the new energy generation in the third quarter in 2019 in UK, wind accounts for 20%, biomass 12% and solar 6%, wind power is a big part of it. The UK's record on renewable energy in recent years is clear for all to see.

The unique geographical advantage of the sea and the humid climate conditions make Britain an early adopters of wind energy in the world. In 2000, Britain's first offshore wind farm was built at Leicester, with a capacity of 4,000 kW, Britain began the large-scale development of offshore wind farms [3]. Since 2003, the UK has carried out several rounds of offshore wind farms. In 2008, it became the world's largest offshore wind power producer with 598 MW of installed capacity, nearly half the world. The installed capacity of offshore wind power increased by 20% in 2009, accounted for 56.2% of new global installed capacity in 2010. In 2020, 29 gigawatts of wind power were installed.

In addition to wind power, the development of nuclear power also represents the use of new energy in the UK. Britain was one of the first countries in the world to develop nuclear power, at the end of 2010, Britain still had

Table 1
Proportion of electricity generated by various energy sources in 2019 (UK)

Year	2019
Zero-carbon sources ratio, %	48.5
Fossil fuels sources ratio, %	43
Biomass sources ratio, %	8.5

Data source: UK's National Grid

Table 2
U.K. Renewable energy utilization ratio chart from 2015 to 2019

Year	Renewable energy utilization ratio, %
2015	25
2016	27
2017	30
2018	32
2019	36

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Table 3
List of new energy generation in the third quarter in 2019 (UK)

Wind energy	20%
Biomass	12%
Solar energy	6%
Total	38%

Data source: www.decc.gov.uk

19 nuclear reactors. Nuclear power supplied 15.7% of the UK's electricity in 2010. In the early days, Britain vigorously developed nuclear power to ensure the security of energy supply. Since the 1990s, more attention has been paid to the development of nuclear power due to its significant effect of reducing greenhouse gas emissions. In 2006, with the release of the UK's Energy Review 2006, The British government officially switched its support to new nuclear power stations, some power companies are getting involved in planning new nuclear plants. In total, the UK is expected to build about 19 million kW of new nuclear power plants by 2023 [4]. After a hundred years of smog, London has taken ecological environment construction as an important goal of urban development. Under the policy of the state, make extensive use of the advantages of new energy, especially the use of wind power to generate electricity instead of conventional thermal power, and using small renewable energy installations, it not only reduces energy consumption, but also improves the air quality.

Biogas was developed relatively early in Britain, where there are more than 30 reclaimed bogs [5]. Landfills and recycling are not the only purposes; another purpose is to extract biogas from the fermented waste for burning. In UK, biogas digesters have a half-life of two to four years, and half of the biogas will be discharged within two to four years. In the 1970s, the Coal Mine Administration gained experience generating electricity from methane from coal mines, and in 1980 designed a biogas scheme for the Everley waste collection site near The Purfleet Paper Mill in Essex, a network of pipes, like a drainage system, captures 55% of the methane, the flow of 3,000 m³/h supplies a third of the paper mill's fuel [6]. In 1990, there were 36 private power stations running on biogas from the landfill, by 1992, the production of these biogas had tripled [7]. In the energy transition, the UK has been advocating the use of new energy.

In 2019, Bioplex and Controllis company have developed a self-sustaining onsite power generation solution that combines solar and biogas to reduce or eliminate electricity costs. Not only does it help protect the environment, but it also reduces the cost of treating farm waste. Bioplex company has pioneered a high-throughput system that converts grass and energy crops, as well as a variety of animal and food waste, into natural fertilizer and biogas [8]. The recycled fertilizer is reused on farms, and biogas can be used to generate electricity. The Bioplex system uses mud, farmyard and stable manure to collect pasture deposits and crop waste. It can control parasites, pathogens, weeds and odors while minimizing excess fluid production. The Bioplex system produces biogas 20% more efficiently and eliminates fuel generation and harmful substances, the system produces biogas in 30 min to produce clean, renewable energy on demand [9]. The Controllis company offers ultra-efficient, highly reliable hybrid solutions: a 12 kW DC generator set, solar photovoltaic power array, battery pack and 75 kW AC power inverter [10]. On-site power is used to provide power to farms and can be used to provide power to other local sites. Solar arrays aid in energy production, and when biogas is not being produced, dedicated batteries provide electricity, making it a reliable, cost-effective way to

generate electricity locally. This invention can be described as an outstanding representative of the application of new energy.

3.3. Green travel, energy-saving home

In view of the pollution characteristics of mobile pollution sources and household individual emission sources in British cities during this period, the British government took a series of targeted measures. In the process of controlling mobile pollution sources, not only vigorously develop public transport and the promotion of new energy vehicles, but also strictly control the travel of private cars and carry out comprehensive reform of buses and taxis [11]. At the same time, promoting the use of unleaded gasoline as a fuel, as well as install dust filters on cars, and charge private cars congestion fees. In 2010, the UK set up 1 billion pounds Green Energy Fund to transform its transport system to use clean energy and improve the efficiency of low-carbon energy [12]. According to the experience of air pollution control in UK, after industrial upgrading, the major energy consumers during this period are no longer industrial enterprises, but households and motor vehicles, etc. Since the 2000s, London has targeted this issue with its Green Families Program, the government regularly offers energy efficiency upgrades to the families in London, carry out energy saving consultation activities for family members to publicize energy saving ideas [13]. Meanwhile, the government provides certain financial subsidies to cities, and increases efforts to promote the upgrading of lighting and electrical systems inside buildings, and encourage the public to replace energy-saving air conditioners and other electrical systems. It not only reduces the use of fossil fuels such as coal, but also reduces the emission of particulate matter. In addition, with the progress of science and technology, the British government also increased the level of scientific research monitoring during this period, the use of the internet and other new technologies to strengthen the transparency of air quality data, in order to carry out the national environmental protection work better and better.

As of 2019, the UK was the third largest market in Europe for ultra-low emission vehicles (ULEV), more than 240,000 electric and hybrid vehicles are registered, of which nearly 230,000 are ultra-low-emission vehicles [14]. According to the Department for Transport of UK, greenhouse gas emissions from cars are expected to fall by 52% between 2018 and 2050, and will become one of the most significant modes of transportation sector decline [15]. In 2020, The UK announced "The Green Industrial Revolution" to promote the "net zero goal" by 2050; transport is high on the list of 10 major initiatives, including the development of zero-emission electric cars, the promotion of public transport, cycling and walking, and the promotion of green air navigation, etc. In 2018, rail transport accounted for about 1.4% of the UK's total transport emissions [16]. By 2021, more than 70% of passenger rail transit vehicles have been electrified, and pure diesel trains will gradually be replaced in the future. Table 4 briefly summarizes the carbon emission status of major transport modes in UK and the long-term planning targets for 2050.

Table 4
Emission status by transport modes and long-term planning goals in UK

Transport modes	1990 (y) Emissions/ten thousand tons	2019 (y) Emissions/ten thousand tons	Growth rates (%)	Target in 2050/ten thousand tons
Cars	72.3	67.7	−6	32.5
Bus	5.3	3.1	−42	2.33
Heavy trucks	20.5	19.5	−5	14.4
Civil aviation	1.5	1.4	−5	1.4
Shipping	8.5	6.1	−29	3.75

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957887/2019_Final_greenhouse_gas_emissions_statistical_release.pdf

3.4. Joint control, develop planning

In view of environmental pollution, the British government has carried out comprehensive air pollution control through all-round cooperation. Joint governance between local departments and between local and national levels is a feature of air pollution control in the UK. The Clean Air: London Air Quality Strategy was preceded by an update to the London Air Pollution Emissions Database, which listed eight major air pollutants and six minor pollutants, and predicted London's air quality and pollution levels in 2014 and 2015 [17]. Based on monitoring data and forecast results, combined with economic and social development forecast models, the planning team proposed more predictable treatment measures to ensure that long-term targets for air pollution control are achieved on schedule. Environmental governance issues need to form a linear model of "prediction-track-evaluation", rather than stay in the current pollution control. Therefore, Britain's future-oriented governance model plays a positive role in China's environmental governance today.

At the end of 2020, the UK announced a 10-point plan for a Green Industrial Revolution, with the aim of promoting economic recovery and deep emission reduction in the post-COVID-19 era. An important part of this is to make London the world's green finance center through technological and financial innovation. It is worth noting that in the past 10 y of policy making, the British government has paid particular attention to political and economic considerations in addressing climate change, and consolidated its advantages by grasping the right to speak in climate governance [18]. This shows that the UK is committed to becoming a core leader in tackling climate change. The UK is not only committed to the rapid development of green transport at home, but will also use emissions cuts as an important way to shape its strategy to develop "Global Britain" after leaving Europe.

3.5. Science and technology to improve air quality monitoring

The improved air monitoring level provides a reliable data source for the effective control of urban smog. Before air monitoring, many smog events in England were simply based on sensory intuition. With the improvement of science and technology, the measurement of air quality in the UK is more detailed and precise. In the 20th century, the British were able to measure the concentration of smog

through scientific means, as well as the amount of dust in the air through a standard set of equipment that was widely used across the country. In December 1952, it was found that there were ten times as many pollutants in the air in London as in normal times, and the concentration of carbon dioxide was ten times higher than in 1850. Shocking concrete data strengthen the public awareness of anti-smog, comprehensive and systematic monitoring for the government's legislation provides sufficient scientific basis.

With the further development of science and technology, the number of monitoring agencies in Britain increased in 1960s, and the assessment content became more comprehensive. Since 1960, more than 1,200 monitoring stations of air pollution across the whole UK, centred on Warren Spring's Laboratory, have estimated and measured the amount of smog and sulfur dioxide in the air, providing the scientific basis for targeted environmental standards. In addition, British institutions of higher education, including Imperial College London, the University of Sheffield and University of Leeds, have also given full play to their advantages in environmental science and other aspects to strengthen pollution source monitoring and control of pollutant emissions from the perspective of professional knowledge, which undoubtedly provides sufficient theoretical support for local air pollution prevention and control.

4. Remarkable achievements and results in air pollution control

The promulgation of a series of important plans has played an important role in the environmental governance of UK. To achieve net zero emissions by 2050, the Transport Decarbonization Plan (2021) proposes the following several strategic initiatives. (1) Through the development of zero-emission public transport network, public transport or active transport will become the first choice of people's daily travel, and gradually reduce the use of cars. (2) Phase out the sale of non-zero-carbon vehicles by 2040 and develop road infrastructure [19]. (3) All forms of freight traffic will gradually adopt more advanced zero-emission technologies and data optimization solutions. (4) Reducing emissions from transport will be an important part of the UK's Green Industrial Revolution, and the use of green innovative technologies will drive the UK economy and create new jobs. (5) By 2050, every city in UK should have its own distinctive net zero transport network.

Table 5
Air quality observations in the UK in 2021

Pollutants	Results	Standard
Sulfur dioxide	All regions met the standards	European Union limit value
pm10	All regions met the standards	European Union limit value
pm2.5	All regions met the standards	European Union limit value

Author self-painted

In recent decades, the British government has made remarkable efforts to control the exhaust emissions caused by urban mobile pollution sources. London's road traffic has significantly reduced its soot emissions through the governance, soot emissions were reduced by 12%, concentrations of lead and other trace elements have declined by 60% overall [20]. As lead emissions from motor vehicles decreased, the concentration of lead in the air continued to decline, concentrations of trace elements such as zinc, arsenic, selenium and vanadium also declined. The number of smoggy days in London has fallen from 90 a year 100 years ago to less than 10 in the 21st century. From 1997 to 2018, the concentration of major pollutants in London decreased significantly, nitrogen oxide concentrations were reduced by 36%. The concentration of PM10 decreased by 22%, and sulfur dioxide concentration was reduced by 78%. According to the air quality limits set by the European Union, the British government conducted monitoring and assessment of air quality in 43 regions across the country in 2021, and reported the assessment results to the European Commission. It can be seen that the main air pollutants meet the EU limits, and the air quality has been significantly improved (Table 5).

5. Conclusion

In the process of industrialization and urbanization, while enjoying the achievements of industrial civilization, human beings have also suffered from ecological crisis and paid a heavy price for it, air pollution has caused great harm to human health and life. After hundreds of years of development and evolution, environmental issues have become an important issue faced by all countries in the world. Protecting the ecological environment that mankind depends on while developing economy has been widely concerned by the international community. Faced with the game between economic interests and environmental protection, as well as the reconstruction and transformation of people's cognitive attitudes to smog, Britain is finally starting to take governance measures of air protection. The British government has not only increased the use of new energy, formulated long-term environmental protection plans, but

also strengthen joint governance at all levels, open and transparent environmental data and enhance public participation in air quality supervision, a series of measures, especially the utilization of marine renewable energy have laid a solid foundation for environmental governance in the UK. Nowadays significant progress has been made in tackling air pollution in the UK, the number of days with good air quality increased, concentrations of major pollutants have decreased, its ultimately successful governance experience has set an example for the whole world. We believe that with our joint efforts, natural environment, social development and human civilization will advance hand in hand. The sky of the "Global Village" will be clearer in the future.

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